TACTICAL PLANNING OF THE GASTROINTESTINAL AND HEPATOLOGY DEPARTMENT OF MEDISCH SPECTRUM TWENTE

DECREASING THE ACCESS TIME FOR PATIENTS BY IMPROVING THE MANAGEMENT OF RESOURCES

SASKIA BUSSCHER

EXAMINATION COMMITTEE
PROF. DR. IR. E.W. HANS
DR. IR. SCHUTTEN
DR. IR. I.M.H. VLIEGEN
DRS. H.H. BLONK

TACTICAL PLANNING OF THE GASTROINTESTINAL AND HEPATOLOGY DEPARTMENT OF MEDISCH SPECTRUM TWENTE

Decreasing the access time for patients by improving the management of resources

Author
Saskia Busscher
Industrial Engineering and Management
Faculty of Behavioural, Management and Social sciences

External supervisor
Drs. H.H. Blonk
Medisch Spectrum Twente

Internal supervisors
prof. dr. ir. E.W. Hans
dr. ir. J.M.J. Schutten
dr. ir. I.M.H. Vliegen
University of Twente

Medisch Spectrum Twente

UNIVERSITY OF TWENTE.

SUMMARY

Introduction
The *Gastrointesintestinal and Hepatology Department* (GHD) of *Medisch Spectrum Twente* (MST) desires to reduce its access times in order to meet the nationally approved standards for the access times for non- acute health care, the *treeknormen*. The treeknormen prescribe that 80% of the patients should get an appointment or treatment within three weeks and the other 20% of the patients should see a doctor within a maximum of four weeks (RIVM, 2014). The GHD is far from meeting the treeknormen at this moment with access times as high as four months at the *Outpatient Clinic* (OC) and two months at the *Endoscopic Centre* (EC).

Research objective
The department desires to find out whether it is possible to use its resources, such as the available time of the medical staff, more efficiently, so that access times can be reduced. Therefore the main objective of this research is:

To develop and assess interventions that can lead to the decrease of access times at the Gastrointestinal and Hepatology Department of Medisch Spectrum Twente in order to meet the nationally approved treeknormen.

In order to decrease the access time, this research focuses on the following two sub problems:

1. *Imbalance in the distribution of program time over the EC- and OC programs*
2. *Empty slots in the schedule at the OC* with three main causes: nursing slots not being filled by planners, no-shows, and emergency programs not being fully booked

Research Approach
Sub problem 1 is addressed by developing a heuristic to determine a ratio according to which the available program hours should be divided over the two sections.

Sub problem 2 is addressed by first searching for interventions that might reduce access times of the OC. After the formulation of interventions, we use computer simulation to test these interventions. Afterwards, the following five different *Key Performance Indicators* (KPIs) were measured to draw conclusions about the influence of the interventions on the access times:

1. Mean access time in weeks
2. Percentage of patients receiving care in time according to internal- and external standards
3. Clinical throughput (number of appointments)
4. Percentage of idle time, split out in idle time caused by no-shows, and total idle time
5. Overtime

Results
Sub problem 1: We developed two formulas, each calculating the amount of program time needed for the coming three months for one of the two sections (OC and EC). These formulas determine the program time needed by measuring the amount of consultation and/or scopy hours within a certain time span following from one hour of consultations or scopies in the past. The amount of program hours needed for each section according to these calculations is supplemented with the influx of new patients for each section. The balance in the distribution of the program time is improved by dividing the available program hours over the EC and the OC according to a ratio. This ratio is calculated by

dividing formula 1 by formula 2. To keep the access times of both sections in balance, the ratio is important even if there is less or more program time available than the total needed program hours.

Sub problem 2: We tested the influence of five different interventions on the access times and conducted a sensitivity analysis to determine the influence of decreasing the number of no-shows. The content of the five interventions and the sensitivity analysis are described in Table i. All interventions yielded an improved access time for non-emergency patients and in line with that, a higher percentage of patients seen in time according to the internal and external standards. Other improvements and deteriorations with regard to the current situation are found in Table i.

Table i: The interventions tested on the model of the OC and the difference between the current situation and the experimental situations with regard to the measured KPIs

INTERVENTION	**RESULTS**
A. EQUALLY SPREADING PATIENTS OVER AVAILABLE DOCTORS AND NURSES IMPLYING SHIFTING TASKS FROM DOCTORS TO NURSES	- The clinical throughput increases - The percentage of total idle time of the nurses decreases
B. OVERBOOKING: SCHEDULING MORE PATIENTS INTO PROGRAMS THAN OFFICIALLY POSSIBLE WITH REGARD TO THE AVAILABLE PROGRAM TIME	- The clinical throughput increases - The percentages idle time due to no-shows decrease for the doctor and nurse programs - The percentage of total idle time of the nurses decreases - There is overtime for liver doctors and nurses
C. CARVE-OUT MODEL- SCHEDULING LESS EMERGENCY PROGRAMS	- The access times for emergency patients increase (above the standards) - The percentage of total idle time of emergency programs decreases
D. CARVE-OUT MODEL- FILLING EMERGENCY PROGRAMS GRADUALLY WITH NON-EMERGENCY PATIENTS WHEN THE DATE OF THE PROGRAM APPROACHES	- The access times for emergency patients increase (but remain within the standards) - The clinical throughput increases - The percentage of total idle time of emergency programs decreases
E. REDUCING THE VARIATION IN THE NUMBER OF PROGRAMS PER WEEKDAY	No extra improvements or deteriorations besides the lower access times for the non-emergency patients
SENSITIVITY ANALYSIS: MEASURING THE INFLUENCE OF DECREASING THE NUMBER OF NO-SHOWS	Small, but significant improvements for all measured KPIs

Conclusions & Recommendations

Sub problem 1: We recommend using the heuristic to determine a ratio according to which the available program hours should be divided over the two sections. We advise to build an Excel tool which automatically uses the heuristic to calculate the needed program time for each section.

Sub problem 2: We recommend to implement interventions A, D, and E in order to fill up more of the empty slots of the OC. We recommend to not implement intervention C because of the negative impact on the access times of emergency patients. There is a clear trade-off between the decrease of access time and the amount of overtime for intervention B. Therefore, the GHD first has to make a decision on whether having a certain amount of overtime is acceptable when this leads to lower access times for non-emergency patients, before deciding whether or not to introduce intervention B. Finally, before making a decision on the introduction of interventions to reduce the no-shows, we recommend the GHD to conduct further research on the costs and benefits of these interventions.

ABBREVIATIONS AND DEFINITIONS

ABBREVIATIONS

AIOS	Doctor in training
ANIOS	Doctor not in training
AD TEST	Anderson- Darling test
COLO	Colonoscopy
COLODDKS	Colonoscopy screening program
COLOPOL	Colonoscopy polypectomy
CP	Check-up patient
CPIBD	Check-up patient inflammatory bowel disease
CPL	Check-up patient liver
CPDOC	Check-up patient doctor
DTC	Diagnose treatment combination
DUODENO	Gastroscopy
EC	Endoscopic centre
ED	Emergency department
EPF	Electronic Patient File
ERCPPAP	Endoscopic retrograde cholangio pancreatography papillotomy
GASHE	Gastroscopy hemostasis
GASSORO	Gastroscopy probe on x-ray
GH	Gastrointestinal and hepatology
GHD	Gastrointestinal and hepatology department
GP	General practitioner
IBD	Inflammatory bowel disease
KS TEST	Kolmogorov- Smirnov test
KPI	Key performance indicator
MST	Medisch Spectrum Twente
NP	New patient
NP-EMERGENCY	New patient emergency
OC	Outpatient clinic
SIGMO	Sigmoidoscopy
STDEV	Standard deviation
TC	Telephonic consult
VCP/VPN	Nursing consult
WAC	Waiting list check-ups

DEFINITIONS

ACCESS TIME	The time span in weeks between the day the patient wants to make an appointment for a consult, diagnostics or a treatment/operation and the actual date of this appointment.
DATA MANAGER	The staff member responsible for setting up the schedule.
DEPARTMENT DOCTOR	The doctor responsible for evaluating the requests of new patients.
FAX REPORTS	Excel files containing data about referral dates, appointment dates, and the urgency of treatment of patients.
ISCHEMIA	An insufficient supply of blood to an organ (Medical Dictionary, n.d.). At the GHD, ischemic patients are patients with a restricted blood supply to the intestines.
MEDIFY	A program which allows patients to fill in a questionnaire at home and depending on the result of this questionnaire, the duration for a screening consult is determined.
STAKEHOLDER	Any groups or individuals who can affect or are affected by the achievement of the organization's objectives (Freeman, 2010).
TREEKNORMEN	The nationally approved standards for access times for non- acute health care (RIVM, 2014).
X-CARE	Data management system used at the GHD to create schedules for the scopy- and consultation programs with regard to the duration of the programs, and the patients and scheduled appointments within these programs.

TABLE OF CONTENTS

PREFACE

Here it is: my Master thesis! I have written this report over the course of the past months and I am very proud that it is finally finished. The period in which I wrote my thesis was a period in which I learned a lot. I found it very instructive and refreshing to be able to apply the theoretical knowledge I acquired during the courses of my Master studies in a practical setting, the gastrointestinal and hepatology department (GHD) of Medisch Spectrum Twente. It offered me insights in the practical workings of many of these theories in a hospital situation as well as an opportunity to gain detailed knowledge about the effects of interventions on tactical planning issues.

There are some persons without whom it would have been very hard to write my thesis. First of all, I would like to thank Ilona Blonk, as my external supervisor she was very helpful in helping me out when I encountered difficulties in for example finding the correct information. I also would like to thank Brigitte Holtschlag and Nicoline Mogendorff, team managers of the GHD, because they allowed me to execute this research at their department. Furthermore, I would like to thank Ingrid Vliegen, who was my internal supervisor during the first few months of my research. She really helped me in defining the focus of my research. I also would like to thank Erwin Hans and Marco Schutten, my two internal supervisors, Erwin taught me that it is sometimes better to take a step back, to be able to find a better focus and avoid tunnel vision. Furthermore, Marco really helped me during the end phase of my research and helped me to better structure my report. Finally, I would like to thank my boyfriend, family, and friends. They all really motivated me when I sometimes doubted myself.

I hope you enjoy reading my thesis!

Saskia Busscher
Enschede, November 2015

1. INTRODUCTION

In the Netherlands, there is pressure on health care organizations to organize their activities more effectively and efficiently (Hulshof, Kortbeek, Boucherie, Hans, & Bakker, 2012). The most important reason for this is that both demand and expenditures in health care have been rising steadily for years. This increase in demand was also clearly felt at the *Gastrointestinal and Hepatology Departments* (GHDs) in the Netherlands. For example, the number of outpatient treatments for chronic intestinal diseases underwent a strong growth in the past twenty years: from 0.4 to 21.2 treatments per 10 000 persons per year (van den Akker-Ploemacher, 2013).

The GHD of *Medical Spectrum Twente* (MST) also encounters problems with the number of patients in need of an appointment. The GHD faces large waiting lists and high access times. Access time is defined as the time span in calendar days between the day the patient wants to make an appointment for a consult, diagnostics, or a treatment/ operation and the actual date of this appointment (RIVM, 2014).

In Section 1.1, we elaborate on the context in which we execute this research. Then, in Section 1.2, we identify which problem(s) the organization of our research faces. Finally, in Section 1.3, we formulate our research objective and explain our research approach.

1.1 RESEARCH CONTEXT

In this section, a brief description of the MST, our organization of research, will be given (Section 1.1.1). After this, we elaborate on the GHD, which is the department we focus on in this research (Section 1.1.2).

1.1.1 Medisch Spectrum Twente

This research is carried out at MST, which is one of the largest non-academic hospitals in the Netherlands. MST has locations in Enschede, Oldenzaal, Losser, and Haaksbergen, with Enschede being the largest location. MST provides health care for the approximately 264, 000 residents in the region it serves and has a total capacity of 1070 beds. Location Enschede is planning to move to a new building that is still under construction at the moment of writing. Most of the clinical departments based in Enschede will move to this new location from the end of 2015 onwards (Medisch Spectrum Twente, n.d.). The GHD will also move to this new location.

1.1.2 The Gastrointestinal and Hepatology Department

The GHD is engaged with the diagnostics and treatment of diseases and disorders of the digestive organs such as the pancreas, gall bladder, bile ducts, liver, esophagus, stomach, and small and large intestines (Medisch Spectrum Twente, n.d.). The department is partly located in Enschede (location Ariënsplein) and partly in Oldenzaal. Since the move to the new location is scheduled for the end of 2015, we take into account the features of the GHD in the new situation. The GHD consists of three sections:

The endoscopic centre (EC)

At the EC, the scopies are executed. Scopies are procedures in which doctors or endoscopic nurses insert an endoscope (a flexible tube with an eyepiece or camera) into the mouth or rectum of a patient in order to see the inside of the esophagus, stomach, or intestines (Nederlandse Vereniging van Maag-Darm-Leverartsen, n.d.). The EC has a total capacity of eight treatment rooms. In

Enschede, four general rooms, one room with x-ray devices, and one room with echo graphic devices are located. In Oldenzaal, two general rooms are located.

The outpatient clinic (OC)

At the OC, the consults take place. This section is used for check-ups for patients with a chronic disease and for consults with new patients, amongst others. The anamnesis rooms are also located at the OC. These are used for screening programs, where patients who have to undergo some sort of sedation prior to a scopy receive information about the procedure. The OC has a total capacity of eleven consultation rooms and four anamnesis rooms. Eight consultation rooms and two anamnesis rooms are located in Enschede, and the remaining rooms are located in Oldenzaal.

The nursing ward

At the ward, patients with a *Gastrointestinal and Hepatology* (GH) related disease reside when they have to be hospitalized for one or more nights. This section has a capacity of 32 beds and is located in Enschede. The ward is shared with another specialty, so the exact number of beds belonging to the GHD cannot be given. Usually around twenty beds are used by the GHD.

1.2 Problem identification

This section describes why high access times are considered a problem at the GHD and why it is important to decrease them.

The OC is continually confronted with many new patients and at times patients are forced to wait for over four months to get a first consult. The EC has shorter waiting lists, but even at this section, waiting times for a scopy can get as high as two months. These high access times cause a range of problems. For example, because of the many phone calls (both from patients and General Practitioners (GPs) planners receive, their workload appears to be increasing when access times increase. The planners also have to filter out double requests sent by GPs, who hope sending more requests will increase the chance of their patients to get an appointment on short notice. Furthermore, it causes patients to look for care somewhere else, by going to different hospitals.

Since there are several factors causing pressure on the demand for GH related care at the moment, the initial thought that the access time problem would solve itself over time cannot be deemed realistic anymore. As mentioned earlier, the demand for outpatient treatments for patients with chronic intestine diseases has increased steeply in the past twenty years (van den Akker-Ploemacher, 2013). The influx of chronically ill patients leads to a higher demand for consultation hours, since these patients need regular check-ups. Next to that, a screening program to detect intestine cancer was introduced in the Netherlands for residents between 55 and 75 years old in January of 2014 (Rijksinstituut voor Volksgezondheid en Milieu, n.d.). This program caused a higher demand for scopies.

The GHD needs to bring down its access times in order to meet the nationally approved standards for access times for non- acute health care, the so-called *treeknormen*. The applicable treeknormen for the GHD are access time to the hospital or specialist, access time for diagnostics, and access time to the outpatient clinic. The treeknormen prescribe that 80% of the patients should get an appointment or treatment within three weeks and the other 20% of the patients should be treated within a maximum of four weeks (RIVM, 2014). Since the treeknormen are described in weeks, we use 'weeks' as a time unit for access times within this research. Therefore, *access times* are defined as: the time span in weeks between the day the patient applies for an appointment for a consult, diagnostics or a treatment/operation and the actual date of this appointment. If we compare the treeknormen with the actual access times at the GHD, we conclude the GHD is far from meeting the treeknormen at this moment.

The employees of the GHD are unsure whether the high access times are solely a result of inefficient use of resources, or if there is perhaps a shortage of capacity. To be able to make a feasible planning, there must be sufficient capacity available to fulfill the demand. In theory, it is possible that the GHD does use its resources in the most efficient way, and that the actual problem is the shortage of available capacity. Though this is a possibility, we should keep in mind that several researches state that high access times are usually not the result of a lack of capacity, but are more often caused by a mismatch between capacity and patient demand (Murray & Tantau, 2000; Bazzoli, Brewster, Liu, & Kuo, 2003; Silvester, Lendon, Bevan, Steyn, & Walley, 2004; Rouppe van der Voort, van Merode, & Berden, 2010).

1.3 Research objective and approach

From the problem identification described in the previous section, we formulate our research objective in Section 1.3.1. We then describe the research approach by formulating several research questions (Section 1.3.2), and by making a first demarcation of the scope of this research (Section 1.3.3).

1.3.1 Research objective

At the moment, the GHD is not complying with the treeknormen for the access times. The department desires to find out whether it is possible to use its resources, such as the available time of the medical staff, more efficiently, so that access times can be reduced. Therefore the main objective of this research is:

To develop and assess interventions that can lead to the decrease of access times at the Gastrointestinal and Hepatology Department of Medisch Spectrum Twente in order to meet the nationally approved treeknormen.

1.3.2 Research questions and corresponding chapters

Chapter 2: Context analysis

How can we describe the context of the GHD and what are the (main) problems of the GHD that need our attention?

In this chapter, a situational analysis of the GHD is performed. Since the employees at the GHD are uncertain whether the capacity of the department is sufficient to deal with the demand, we also perform calculations on the available and required capacity. Furthermore, we formulate *Key Performance Indicators* (KPIs), which are then used to measure the current performance at the GHD.

Chapter 3: Literature review

What information about decreasing access times for health care is available in the literature?

In this chapter, a literature review is performed in order to find out what interventions that could possibly lead to a decrease in access times for health care are mentioned in the relevant literature.

Chapter 4: Modelling the gastrointestinal and hepatology department

How can we model the GHD in such a way that we can assess interventions focusing on the decrease of access times?

In this chapter, we first determine what interventions we want to test on the model. Then, the focus of the remaining sections is on building a model that can be used to evaluate these interventions. We will also verify and validate the model we build.

Chapter 5: Experiments & Results

How can we set up our experiments and what are the results of executing these experiments?

In this chapter, we describe how we translate the interventions we want to test, into experiments to conduct on the model formulated in Chapter 5. After setting up these experiments, we run the experiments on our model and provide insight in the results.

Chapter 6: Conclusion & Recommendations

What is the conclusion of this research and what are the recommendations for the GHD?

In this chapter, we provide an overall conclusion of the research. Furthermore, we come up with recommendations for the GHD with regard to all of the interventions we researched on our model, as well as for general improvements in the planning of the GHD.

1.3.3 Demarcation of scope

Most problems with access times are experienced at the OC and EC and therefore the ward is excluded from this research. The OC and the EC are strongly interrelated because they generate demand for each other: a patient often is referred to the EC as a result of a consult at the OC (or vice versa). Sometimes, patients come from or go to the ward before or after receiving a scopy. However, the majority of procedures performed at the GHD are outpatient treatments. The ward is most used for patients with complications, infections, or planned admissions (patients receiving inpatient scopies). From now on, when we use the abbreviation GHD, we only mean the EC and the OC.

To further specify the scope of this research, we use the framework for health care planning and control developed by Hans, van Houdenhoven, and Hulshof (2011). The framework distinguishes four types and four levels of planning, as shown in Figure 1.1. The types of planning are ordered in managerial areas (Hans, et al., 2011). The levels of planning are hierarchically ordered in terms of the time horizon in which decisions are made.

Since the GHD desires to use its resources more efficiently, we conclude that the managerial area of our focus is resource capacity planning. As explained above, we cannot be sure at this moment whether there is a capacity problem. Therefore, we need more information before we can demarcate our scope with regard to the level of planning. Since calculations on the available and needed capacity are performed in Chapter 2, the scope of this research will be further demarcated at the end of that chapter. The blue hatched area of Figure 1.1 shows the temporary scope of our research.

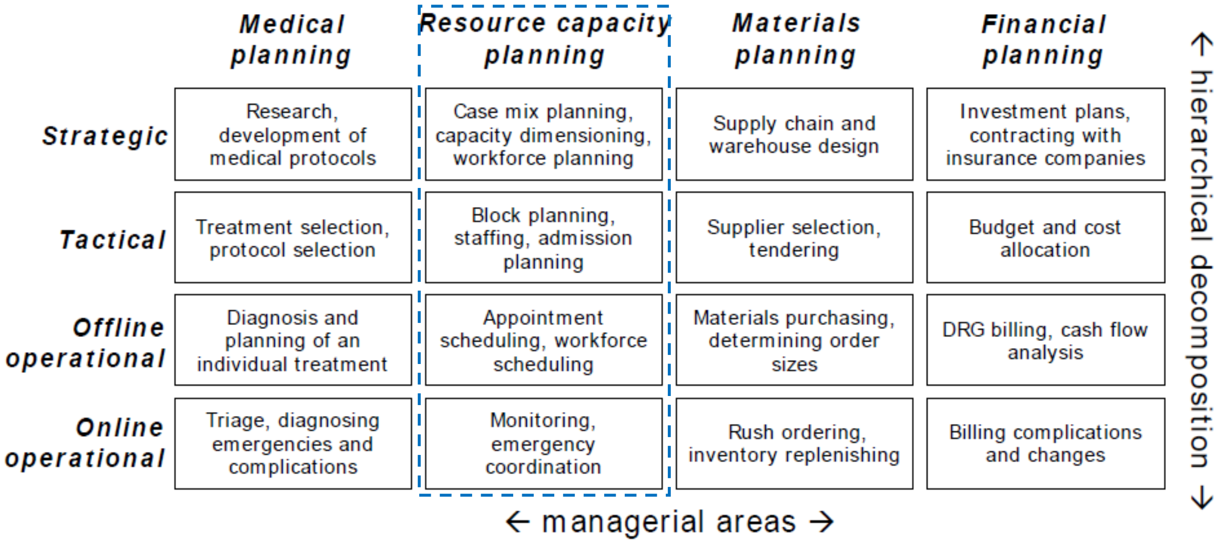


Figure 1.1 The (temporary) scope of this research blue hatched in the framework for health care planning and control (Hans, et al., 2011)

2 CONTEXT ANALYSIS

We start our context analysis with a description of the care path of a patient (Section 2.1). Section 2.2 explains the current process of planning. Then, Section 2.3 focuses on analysing the main problems and causes related to our research objective. Furthermore, we construct KPIs which are used to measure the current performance of the GHD (Section 2.4). In Section 2.5, we draw a conclusion of Chapter 2 and we further demarcate the scope of our research.

2.1 CARE PATH DESCRIPTION

In this section, the care path of (new) patients at the GHD is described and visually represented in Figure 2.1.

A patient is referred to the GHD (to the EC for a scopy or to the OC for a consult) by his or her GP or by a specialist of another discipline. The planner who receives the referral, hands it over to the department doctor. The *department doctor* is the doctor responsible for evaluating referrals of new patients. The 'function' department doctor rotates amongst the GH doctors per week. The department doctor reviews the referral, fills in his or her findings on the assessment form (shown in *Appendix A*) and then hands the form over to the planner again. Reviewing the referral also includes assigning an urgency code to the patient according to the time span within which treatment is needed. More information about these urgency codes is found in Section 2.2.4. After the assessment form has been filled, the planners schedule an appointment, taking in mind the urgency code, for the patient and contact the patient about the appointment date.

After a patient underwent a scopy or a consult, he or she has three options:

1. The patient is discharged as a patient of the GHD and is referred back to the GP or specialist of another discipline (end of treatment at GHD)
2. The patient is referred to/ has to come back at the EC
3. The patient is referred to/ has to come back at the OC

Occasionally, a patient admitted at the *Emergency Department* (ED) needs a scopy. In this case, this scopy is scheduled on spot by a nurse working at the EC and the planners are not involved here. After the scopy, the patient has the same three options as other patients treated at the GHD.

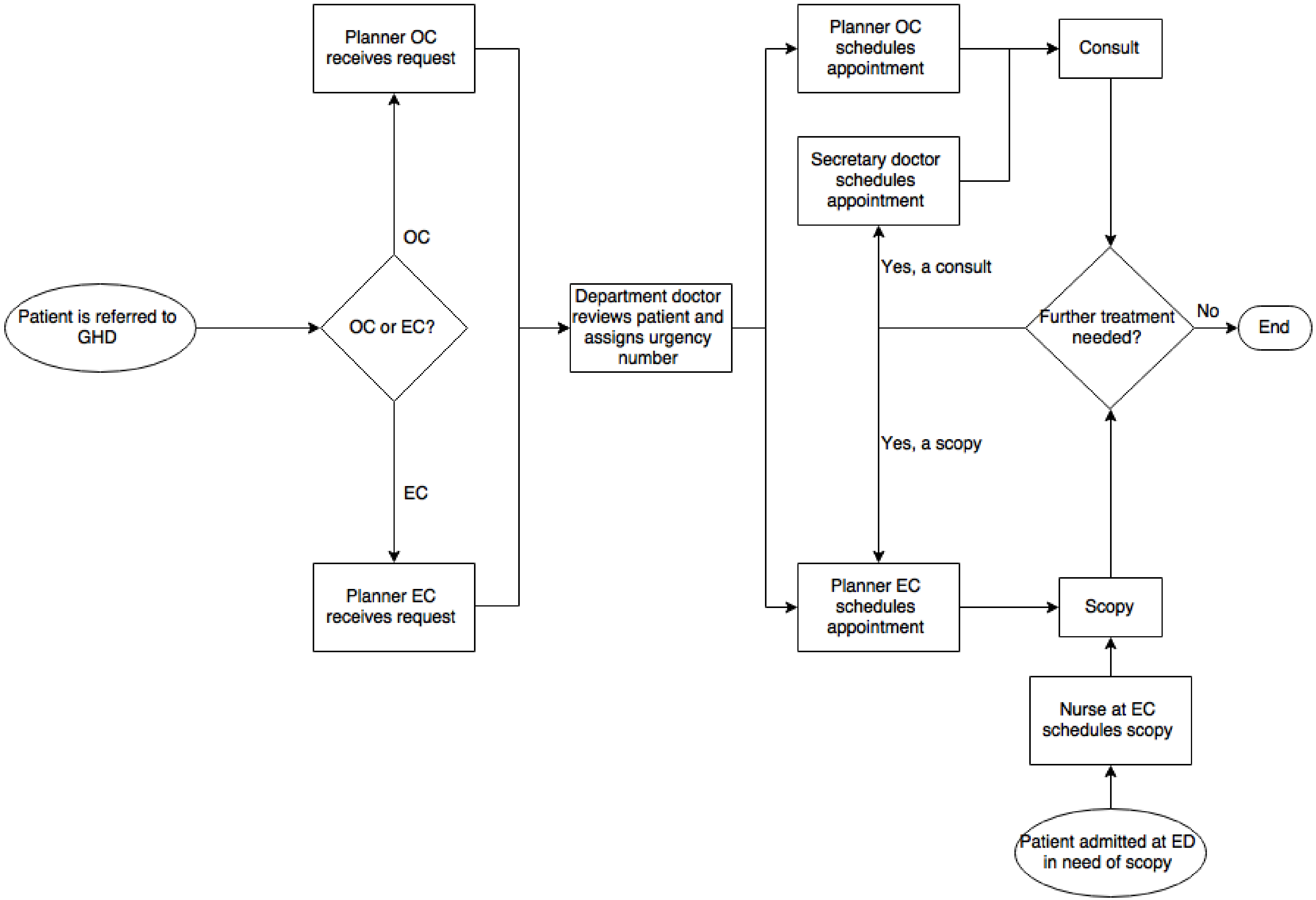


Figure 2.1 The care path of patients in need for GH related treatment

2.2 PLANNING & CONTROL OF RESOURCES AND PATIENTS

In this section, we elaborate on the three steps of the planning process. In Section 2.2.1 we focus on setting up the schedule, where the available time of doctors is distributed over the EC and the OC (step 1). Section 2.2.2 then focuses on the specification of the programs where the type of scopies and consults to be executed in the programs are determined (step 2). The final step (step 3) of the planning process is 'appointment scheduling' where slots for appointments are assigned to patients (Section 2.2.3). Furthermore, we also explain the meaning of the urgency codes used by department doctors to review a referral of a patient (Section 2.2.4).

2.2.1 Step 1: Setting up the schedule

The process of planning starts with gathering information to set up the schedule. The schedule is divided into morning and afternoon programs, each with a specific purpose. There are fixed elements, such as non-clinical days, education, and conferences, but also scopy- and consultation programs need to be scheduled. The *data manager*, the staff member responsible for setting up the schedule, schedules the fixed elements first.

Second, the scopy programs are scheduled. The morning programs start at 8:45 (with an exception on Thursday, they then start at 9:00) and end at 12:30. Afternoon programs start at 13:30 and end at 16:30 (with an exception on Thursday, they then end at 16:15).

Third, the consultation programs are scheduled. The morning programs start at 8:45 (with an exception on Thursday, they then start at 9:00) and end at 12:30. Afternoon programs start at 13:30 and end at 17:00. The data manager also includes three emergency consultation programs per week which are used to schedule patients who need a consult within one or two weeks. Note that it is not always possible to schedule three emergency programs due to this being the last step of setting up the schedule. This results in weeks with less than three emergency programs.

The data manager uses the so called 'min-max' file to determine the number of scopy- and consultation programs she needs to schedule per week. This file contains a minimum and a maximum number of scopy and consultation programs for each week, depending of the type of week (holidays are for example taken into account). These minima and maxima are calculated by rounding the average number of programs executed in the first eleven months of 2014 and subtract (minima) or add (maxima) two or three programs to this average. In *Appendix B*, the content of this min-max file is represented.

Figure 2.2 displays a schedule of an arbitrary week. In the schedule, different colors and abbreviations are used to indicate the types of programs. For example, green elements are used for scopy programs, and yellow elements are used for consultation programs.

Week 3 - 2015	Ma 12			Di 13			Wo 14			Do 15			Vr 16			Za 17			Zo 18		
Naam	VM	NM	AV	VM	NM	AV	VM	NM	AV	VM	NM	AV	VM	NM	AV	VM	NM	AV	VM	NM	AV
[redacted]	CA-	MSB	IW	OK	MSB		PE	SE1	VWa	OV	Afd	BL	NKD	NKD							
	SE2	PO		MM	SE1	BL	NKD	NKD	BL	OVV	SE2		PE	SE1	VWa						
	NKD	NKD	BL	PIB	SVP		C	C	C	V	V	V	V	V	V						
	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V						
	NKD	NKD	BL	OZ	OPL		SE1	PE		OVV	SE1	VWa	PE	SVP				AWw			AWw
	Afd	Afd	BL	Afd	PM		Afd	Afd		AVI	POn		Afd	Afd							
	PL	VID	VWa	SVP	PF		PT	NKD	BL	V	V	V	PO	NKD							
	PL	SE1		SE1	Afd	VWa	NKD	NKD	BL	V	V	V	SE1	SVS							
	gp	gp		gp	gp		gp	gp	BL	gp	gp		gp	gp		gp	gp		gp	gp	
	gp	gp		gp	gp		gp	gp		gp	gp		gp	gp		gp	gp		gp	gp	
	PL	PS		CNa	CNa	CNa	CNa	CNa	CNa	VaV	SGA		SVP	SGA				VWw			VWw
	SA	PI		CW-	CW-		SA	PE		VaV	PS		CW-	CW-							
	SE			SE				SE					SE								
	Vv	Vv	Vv		SE		SE				SE										
		SE						SE		SE											
	PO	SE		PO	PO		SE														
	BV	BV	BV	CNa	CNa	CNa	CNa	CNa	CNa	AVI	Afd		Afd	Afd							
	Afd	Afd		Afd	Afd		Afd	Afd		Adm	PE		PS	PE							
	Ava	Ava		Ava	Ava		Ava	Ava		Ava	Ava		Ava	Ava							
	Afd	Afd		Afd	Afd		OND	OND		AVI	Afd		Afd	Afd							
	AOA	AOA		AOA	AOA		Afd	Afd		AOA	AOA		AOA	AOA							
	ml	ml		ml	ml		ml	ml		ml	ml		ml	ml							
													SE	SE1							

Figure 2.2 The schedule of the GHD of an arbitrary week of 2015 (Medspace, n.d.)

2.2.2 Step 2: Program specification

Once the program is set up, the program needs to be further specified in terms of which type of scopies (for example colonoscopies or gastroscopies) or consults (for example telephonic consults) are to be executed. The programs are specified by taking in mind the capabilities of the doctors with regard to the types of scopies and consults they are able to execute. The data management system X-care is used for this specification. *X-care* is a system used at the GHD to create schedules for the scopy- and consultation program with regard to the duration of the programs, and the patients and scheduled appointments within these programs.

At the EC, programs are specified by the planners who specify the programs per treatment room. This implies, the planners cannot take into account different durations for scopies for different doctors and therefore the planners use standardized time slots. The planners assign a doctor or endoscopic nurse to a room and specify the programs further if there are any restrictions in the capabilities of the doctor or nurse. They for example fill in only colonoscopies for endoscopic nurses. The slots for staff members with no (or little) restrictions are left open until the next step. In contrast to the OC, there are no emergency programs scheduled per week at the EC. Instead, the planners schedule slots with code U2. This code is used for patients who need a scopy within one or two weeks. The intention is to schedule two hours per day for this code, though this is not always possible.

For patients in need of a scopy within 72 or 24 hours, the planners have to schedule a radiographic/emergency shift every afternoon which is a combination of a radiographic- and an emergency program. During this program, 2.5 hours are left open to be able to deal with emergencies. Emergency cases occurring in the morning usually wait until the afternoon or are handled by doctors during their lunch break (12:30). Since not all doctors are capable of working with the x-ray devices, only five doctors are scheduled for the radiographic/ emergency shifts.

At the OC, the programs are specified by the secretaries of the doctors who specify the programs per doctor. This means, they can take into account different durations for consults for different doctors and therefore they use individually specified time slots. This could for example lead to doctor A having fifteen minutes to see a new patient while doctor B only has ten minutes for this type of appointment. The secretaries themselves decide what type of consults take place. Usually, they fill the program with check-up patients and reserve an hour at the end of the program for telephonic consults. They also have to reserve a slot for one new patient per GH doctor per program. For an assistant doctor they need to reserve two slots for new patients per program.

2.2.3 Step 3: Appointment scheduling

Finally, the programs are filled with actual patients. For both sections, scheduling a patient depends on the urgency code the patient has. More information about the urgency codes is presented in Section 2.2.4.

At the EC, the planners schedule most of the appointments and no precedence is given to either new or existing patients. Existing patients are patients who are on the waiting lists, such as patients in need of a check-up scopy every three or five years. The planners schedule emergency patients who need an appointment within one or two weeks into the U2 slots and fill remaining slots (with exception of the emergency shift in the afternoon) with non-emergency patients. If a patient needs an appointment within 72 or 24 hours, this patient is scheduled into the emergency shift on spot by a nurse working a shift at the scopy department. The planners of the EC are not involved in scheduling these patients.

At the OC, patients in need of a check-up are scheduled first and then new patients are scheduled. As explained in Section 2.1, check-up patients are scheduled by the secretaries of the doctors. When the secretaries experience a shortage of slots for check-up patients, they sometimes use the slots meant for new patients. If there still remain slots for new patients, the planner of the OC fills these slots with non-emergency patients. Patients who need an appointment within one or two weeks are also scheduled by the planner, but are scheduled into the emergency programs.

2.2.4 Urgency codes

The OC and EC both use a system with urgency codes to determine the time span within which a patient needs a scopy or a consult. The urgency codes used at the OC are the numbers 1 until 5. At the EC, the same codes are used, but here the codes are supplemented with codes s and d. Although the theoretical meanings of the codes are clear for all employees, in practice it is not always possible to comply with the time-spans due to the waiting lists. Table 2.1 shows the urgency codes and the accompanying time spans within which the patient should get an appointment.

Table 2.1 Urgency codes used at the GHD to prioritize patients with regard to the time-span within which they need an appointment (Scheurink-Engbers, 2015)

URGENCY CODE	TIME SPAN WITHIN WHICH AN APPOINTMENT IS NEEDED
D (ONLY USED AT THE EC)	24 hours
S (ONLY USED AT THE EC)	72 hours
1	One week
2	Two weeks
3	Three weeks
4	Six weeks
5	Three months

2.3 PROBLEM ANALYSIS

In order to describe the access time problem in a structured way and in order to find all the possible sub problems related to the high access times, we construct a problem bundle by using literature, observations, and conversations with staff members at the OC and EC. The problem bundle is presented in *Appendix C* and distinguishes three sub problems: imbalance in the distribution of program time over the EC and the OC programs (Section 2.3.1), empty slots in the schedule (Section 2.3.2), and capacity shortage (Section 2.3.3). Finally, in Section 2.3.4, we conclude with an overview of which sub problems are addressed in this research.

2.3.1 Sub problem 1: Imbalance in the distribution of program time over the endoscopic centre and the outpatient clinic

Since the number of programs the data manager schedules is not based on demand, this possibly leads to an imbalance. As abovementioned, the 'min-max' file (represented in *Appendix* B) is used to determine the number of scopy- and consultation programs which need to be scheduled. This file contains a minimum and maximum number of scopy- and consultation programs to schedule each week and these numbers are based on the rounded average of the number of programs executed in the first eleven months of 2014.

The waiting lists of the EC are shorter than the waiting lists of the OC, because EC programs have a higher priority to be scheduled. This higher priority is caused by the perception that executing scopies is financially more attractive than executing consults. Furthermore, scheduling half programs at the EC is not beneficial, whereas this is not perceived as a problem at the OC. At the EC, multiple staff members are involved in the execution of one scopy program, when one of them leaves early, this results in 'left over' staff members with no tasks.

2.3.2 Sub problem 2: Empty slots in the schedule

This sub problem has a direct influence on the access times since the empty slots could have been filled with patients from the waiting lists. We distinguish four causes for empty slots in the schedule:

1. **Slots are not filled by the planners**
   Sometimes slots are not filled by the planners because no suitable patients can be found in time. One of the reasons for this, is the lack of screening consults. A screening consult sometimes is required before a patient can undergo a scopy and an imbalance between scopies and screening consults could therefore lead to empty slots at the EC. The GHD came up with two solutions to increase the number of screening consults:
   - Increase the number of screening nurses supervised by one doctor. A doctor supervises three screening nurses simultaneously at the moment, but if this number increases to four, more patients can be screened at the same time.
   - Decreasing the duration of screening consults with the introduction of Medify and hereby making it possible to screen more patients within one screening program. *Medify* is a program which allows patients to fill in a questionnaire at home and depending on the results of this questionnaire, the duration for a screening consult is determined.
2. **Late cancellations**
   When an appointment is not cancelled timely, the planners are not always able to fill the empty slot caused by the cancellation again. Usually, planners or secretaries schedule an appointment without using or asking the patients' preferences. Since patients generally do not have influence on their appointment date, they might cancel their appointment because the time

and/or date is not suitable. According to the secretaries, another reason to (not) cancel (timely) is illness.

3. **No-shows**
   Sometimes patients do not show up for their appointment. There are three causes for no-shows identified at the GHD:
   - Patients (claim they) are not informed about their appointment.
   - Patients forget their appointment
   - Patients do not show up 'on purpose', for example, because their complaints went away.
4. **Emergency programs not fully booked (OC)**
   The emergency programs at the OC are not always (completely) filled with patients. These programs are only used for new patients with urgency codes 1 or 2. Patients with other urgency codes are not scheduled in these programs even if the programs remain partly empty.

2.3.3 Sub problem 3: Capacity shortage

It is possible that the GHD deals with capacity shortage leading to high(er) access times due to an increased demand or a decreased capacity. The demand for GH related health care is increased due to the introduction of the screening program for intestine cancer in 2014 and the increase in the prevalence of chronic intestine diseases in the past few years. The capacity is decreased because of the amount of extra non GH related tasks of the doctors (for example educating at universities), staff members being unavailable due to illness, and the varying number of staff members due to a high turnover of A(N)IOS.

At the moment of writing, it is not clear if capacity shortage is an issue at the GHD and therefore this problem is dotted in the problem bundle. In order to provide some insight in whether or not capacity shortage is a problem at the GHD, we perform some (simple) calculations.

Data collection

We collect data of the years 2013 and 2014 from X-care and the fax reports. *Fax reports* are Excel files containing data about referral dates, appointment dates, and the urgency of treatment of patients. Although it is preferable to use the most recent data, we decide not to use data from 2015. There were two doctors unavailable during the first months of 2015 and therefore the GHD was not operating under normal circumstances during that period. Furthermore, there is no information available of the arrival rates of new patients before 2013.

Since the procedure for screening consults will change in the near future leading to more screening consults, we exclude the screening programs from our calculations. Furthermore, since there is no reliable information available for ischemic patients, we also exclude the ischemic programs. *Ischemia* is an insufficient supply of blood to an organ (Medical Dictionary, n.d.). At the GHD, ischemic patients are patients with a restricted blood supply to the intestines.

We take into account consultation and scopy types from which the total appointment duration of that type makes up more than 2% of the total appointment duration of all appointment types. We determine the included appointment types separately for 2013 and 2014. To avoid getting a biased view caused by excluding appointment types with a low frequency, we merged these rare appointment types into a 'remainder' group. Table 2.2 shows an overview of the different appointment types we use in our calculations.

Table 2.2 The appointment types used in the calculations for the capacity shortage problem of the GHD[1]

APPOINTMENT TYPES OUTPATIENT CLINIC	**APPOINTMENT TYPES ENDOSCOPIC CENTR**
CHECK-UP PATIENT (CP)	*COLONOSCOPY* (COLO)
CHECK-UP PATIENT INFLAMMATORY BOWEL DISEASE (CPIBD)	*COLONOSCOPY POLYPECTOMY* (COLOPOL)
CHECK-UP PATIENT LIVER (CPL) (2014)	*COLONOSCOPY SCREENING PROGRAM* (COLODDKS) (2014)
NEW PATIENT (NP)	*GASTROSCOPY* (DUODENO)
TELEPHONIC CONSULT (TC)	*ENDOSCOPIC RETROGRADE CHOLANGIO PANCREATOGRAPHY PAPILLOTOMY* (ERCPPAP) (2014)
NURSING CONSULT (VPN- 2013 AND VCP- 2014)	*GASTROSCOPY HEMOSTASIS* (GASHE) (2013)
REMAINDER	*GASTROSCOPY PROBE ON X-RAY* (GASSORO)
NEW PATIENT EMERGENCY (NP-EMERGENCY)	*SIGMOIDOSCOPY* (SIGMO)
	REMAINDER

Capacity

The capacity of the GHD is shown in Table 2.3 and is calculated by determining the amount of program time available per year. At the OC, we determine the program time per group of staff members with the same capabilities. For example, appointment type VCP is only executed by nurses and not by doctors. *Appendix D (D1)* shows an overview of the appointment types executed per group of staff members. As already described in Section 2.2.2, the planners of the EC schedule appointments per room instead of per doctor. Due to this way of registration it is not possible to determine which staff members are responsible for which programs at this section and therefore only the total amount of program time is presented for the EC.

Table 2.3 The available program time in hours (per group of staff members) per section of the GHD for the years 2013 and 2014 (5593 sessions, 2013-2014, X-care)

	OUTPATIENT CLINIC			**ENDOSCOPIC CENTRE**	
GROUPS	**2013**	**2014**	**GROUPS**	**2013**	**2014**
1. DOCTORS LIVER	-	1664.4	-		
2. DOCTORS GENERAL	4575.5	1802.7	-		
3. DOCTORS IBD	-	1272.8	-		
4. NURSES	1162.3	1256.8	-		
5. EMERGENCY PROGRAMS	521.7	436.5			
TOTAL	6259.4	6433.2	TOTAL	4380.8	4618.0

From Table 2.3, we conclude that the number of hours available for both the OC and the EC have increased (slightly) from 2013 to 2014. The table also shows there are more hours available for the OC than for the EC. Furthermore, at the OC, we see that the available program time shifted from more general doctors to more specialized doctors from 2013 to 2014. This shift might be caused by a change in registration or by the GHD focusing on offering more specialized consults for their patients.

Demand

Confidential

[1] If a year is added to an appointment type, this appointment type is only taken into account for that specific year.

Capacity shortage?
As explained above, it is not possible to determine the exact demand for health care at the GHD and therefore it is also not possible to determine with certainty whether there is enough capacity available at the GHD or not. However, we try to provide some insight with the capacity and demand as calculated in the paragraphs above. For the OC, we use the solver in Excel to calculate minimum utilization rates of the program time of the staff members. The utilization rates are calculated by distributing the available program time (capacity) over the demand for appointments taking in mind the restrictions caused by the different capabilities of the staff members. The exact way of calculating the utilization rates is found in *Appendix D* (D2).

The solver presents a feasible solution for the OC, with an overall utilization rate of 93.2% in 2013 and 87.4% in 2014. The utilization rates per staff member group are found in Table 2.5. In theory, the amount of capacity available at the OC was sufficient to deal with the demand of the past two years. However, as we check Table 2.5, we see that several groups of staff members have a relatively high utilization rate while the utilization rates of the emergency programs are relatively low. This especially is an issue in 2013 where all doctors have utilization rates of 100%, but also in 2014 there is a difference between the utilization rates of the 'normal' programs and the utilization rate of the emergency programs. These differences are caused by the 'carve-out' effect. Emergency programs can only be used for emergency patients, even if this results in empty slots, leading to low utilization rates for these programs (group 5) and higher utilization rates for the other programs (groups 1 until 4).

Table 2.5 The minimum utilization rates of the OC (per group of staff members) for the years 2013 and 2014 (Fax reports, X-care)

GROUPS	**UTILIZATION RATES**	
	2013	**2014**
1. DOCTORS LIVER	-	100%
2. DOCTORS GENERAL	100%	96.7%
3. DOCTORS IBD	-	58.6%
4. NURSES	93.1%	100%
5. EMERGENCY PROGRAMS	34.0%	48.0%
TOTAL	93.2%	87.4%

For the EC, we only know the available program time and the demand in hours. Since we cannot determine the amount of hours available per staff member group, we only need to divide the demand by the capacity. This results in minimum utilization rates of 89.0% in 2013 and 89.7% in 2014. These results imply that in theory the amount of capacity available at the EC was sufficient to deal with the demand of the past two years.

2.3.4 Problems addressed in the research

From the sub problems mentioned in Section 2.3.1 until Section 2.3.3 we include the following in our research:

1. **Imbalance in the distribution of program time over the EC- and the OC programs**
   Determining a new distribution of the program time over the two sections does not necessarily lead to the decrease of access times. However, since having increasing access times in one section is not desirable and since a smooth patient flow is preferable, redistributing the program time over the EC and OC might be profitable for the GHD.
2. **Empty slots in the schedule**

- *Slots are not filled by the planners:* Because it is more efficient to have no initial empty slots (or as little as possible) in the schedule, we include this part of the sub problem in our research.
- *No-shows:* Decreasing the impact of no-shows or the number of no-shows could lead to less empty slots in the schedule. We for example want to find out if overbooking is a good option to decrease the (negative) impact of no-shows.
- *Emergency programs not fully booked (OC):* As shown in Section 2.3.3, the (theoretical) utilization rate of emergency programs is very low. We address this part of the sub problem in our research to see if we could either decrease the amount of program time distributed to the emergency programs or if we could use more of the slots in these programs.

We exclude '*late cancellations*' (part of sub problem 2), because there is no reliable data available for this sub problem. The planners and secretaries sometimes have to cancel an entire (or large part of a) program because the doctor is unavailable. Occasionally, the patients are then registered as cancellations (and these slots of course are not filled again), blurring the data for this sub problem. Furthermore, the secretaries at the OC and the planners of the EC state that most of the canceled appointments are filled again.

Although we include '*slots are not filled by the planners*', we exclude the lack of screening programs from this part of the sub problem. This decision is made because of the two abovementioned solutions that are introduced in the near future. These solutions probably result in a higher capacity of the screening programs. Since we cannot precisely predict the influence of these solutions, we assume the lack of screening programs as a cause of empty slots will disappear or at least strongly decrease in the future. We suggest to check whether this problem is solved after introduction of the two solutions.

Furthermore, from the calculations on the capacity of the GHD we conclude that this problem does not need to be addressed in this research. We do however see that the calculated minimum utilization rates per staff member group for the OC are relatively high in 2013 and 2014 with exception of the utilization rate of the emergency programs. This enhances our formulation of sub problem 2 where we want to address the low utilization rate of these programs.

2.4 Analysis of current performance

We start with a stakeholder analysis (Section 2.4.1). Second, we identify KPIs for these different stakeholders (Section 2.4.2) and finally, in Section 2.4.3, we use these KPIs to determine the current performance of the GHD.

2.4.1 Stakeholder analysis

There are multiple stakeholder (groups) involved and interested in the access times of the GHD. *Stakeholders* are defined as "any groups or individuals who can affect or are affected by the achievement of the organization's objective" (Freeman, 2010). We distinguish five different stakeholder groups, each comprising of one or more stakeholders.

1. **Medical staff**
   - *GH doctors*: GH doctors are responsible for executing both scopies and consults.
   - *Doctors in training (AIOS)*: AIOS are doctors who are currently in education to become a GH doctor and they execute both scopies and consults.

- *Doctors not in training (ANIOS)*: ANIOS are doctors working at the GHD, though they are not specifically trained or in training to become a GH doctors. ANIOS execute consults.
- *GH specialized nurses (OC)*: GH specialized nurses perform check-ups of chronically ill patients who have to visit the GHD periodically.
- *Endoscopic nurses (EC)*: endoscopic nurses are trained to perform colonoscopies and therefore execute this type of scopies.
- *Nurses assisting scopies (EC)*: nurses assisting scopies assist a doctor during a scopy program. Every scopy program requires the assistance of two nurses.
- *Nurse recovery room (EC)*: the nurse of the recovery room takes care of patients brought there when the patients received some sort of sedation during their scopy.
- *Coordinator (EC)*: the coordinator at the EC prepares patients for their scopies and is responsible for scheduling emergency patients on spot. He or she might also assist during a scopy when this is necessary.

2. **Planners**
    - *Data manager*: the data manager collects the requests for congresses, holidays etcetera of all doctors, ANIOS, and AIOS in order to set up the schedule.
    - *Planners of the EC*: the planners of the EC schedule scopies for both new and existing (check-up) patients.
    - *Planner of the OC*: the planner of the OC schedule consults for new patients.
    - *Secretaries of the OC*: the secretaries of the OC schedule consults for existing (check-up) patients.
3. **Patients**
    Patients visit the GHD to receive either a (check-up) consult or a (check-up) scopy.
4. **Management of the hospital**
    - *Team managers*: the team managers are responsible for the daily activities and the guidance of staff members working at the GHD. There are two team managers at the GHD: one at the EC and one at the OC.
    - *Board of directors MST*: the board of directors is responsible for the entire hospital and has three primary roles: establishing policies, making significant and strategic decisions, and oversee the activities of the organization (Arnwine, 2002).
5. **Health insurance companies**
    Health insurances are insurances to prevent the risk of high medical expenses for patients. Since 2012, insurance companies can set up contracts with hospitals in which they capture requirements with regard to quality, prices, and the number of treatments a hospital should offer (Rijksoverheid, n.d.; Nederlandse Vereniging van Ziekenhuizen, n.d.; Schippers, 2015).

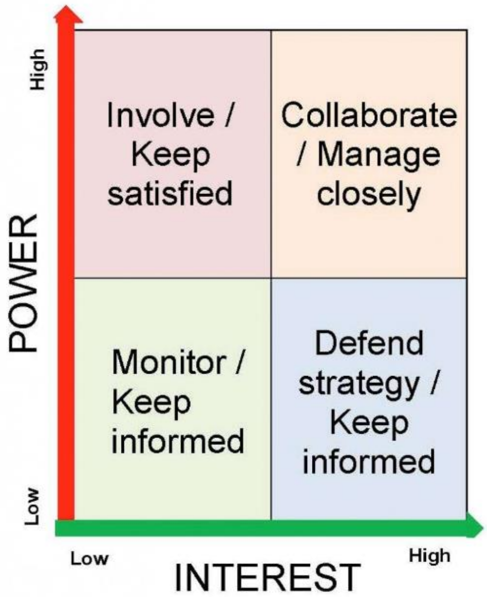
Understanding the power and interest of the stakeholders is very important to get support for projects (of change) and to determine the impact stakeholders have on these projects (Colak, 2014; Mind Tools, n.d.; Requirement Techniques, n.d.). In order to determine the position of the stakeholders, we place the five stakeholder groups in the power- interest grid. Figure 2.3 shows the original (and empty) grid on the left and the grid filled with our stakeholder groups on the right.

Both the management and the insurance companies have a high interest combined with a high power and therefore these two stakeholder groups are the most important to keep in mind when determining KPIs. Both the hospital and the health insurance companies want to attract patients by offering, amongst other things, low access times, which is causing their high interest.

The medical staff has less, but still some power (since they are executing the scopies and consults). Furthermore, they want good access to health care for their patients, resulting in a relatively high interest.

Patients have a high interest in low access times since this influences the speed with which they are helped with their medical issue(s), but they do not have any power. We should keep an eye on their preferences though; our project is not successful if this group is not content with the outcomes.

The planners have the lowest interest and almost no power in our project and are therefore the least important stakeholder group.



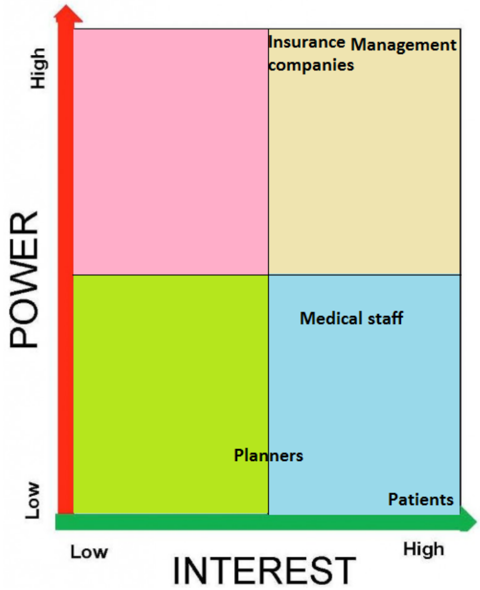


Figure 2.3 The original power-interest grid on the left and the grid filled with our stakeholder groups on the right (Colak, 2014)

2.4.2 Key performance indicators

Measuring and evaluating the performance of systems is important for continuous improvement (Sink, 1985). Measurements can be performed with the use of KPI. A hospital typically uses various KPIs to measure its performance and to identify the bottlenecks in their processes (Health Information and Quality Authority, n.d.).

According to Campbell, Braspenning, Hutchinson and Marshall (2002) there are three main questions we have to ask ourselves when developing KPIs for health care:

1. **Which stakeholders are involved?**
   Different stakeholders usually have a different view on what aspects of performance are important. Managers for example usually focus on efficiency while patients tend to focus more on the quality of care. As stated in Section 2.4.1, we have five stakeholder groups: management of the hospital, health insurance companies, medical staff, patients, and planners.
2. **On what aspects of health care do we focus?**
   Is the focus on processes and/or on outcomes of the provided health care? In our research, we focus on KPIs measuring processes of influence on our main problem (the high access times), and on our sub problems. Although maintaining a good quality (outcomes) of care is very important, our focus is not on this aspect of health care. We assume that the quality of health care is sufficient at the moment and we take precautions to maintain this quality, by for

example fixating the minimum duration of appointments when building a model in the following chapters.

3. **Are there restrictions because of the availability of information?**
   There is a limit in what hospitals register and therefore there is a limit to which KPIs can be used to measure the performance. Due to these restrictions, we exclude ischemic patients and check-up patients of the OC. Because check-up patients of the EC usually have very small access times and because we want to keep the access times of both sections (somehow) comparable we exclude the check-up patients of the EC as well. We also exclude data from before 2013 since there is no (reliable) information available from earlier years. Furthermore, for each KPI below, we explain whether we include it in our measurements or if we exclude it (due to other than above mentioned restrictions in the available information).

All stakeholder groups

The access time is important for all stakeholder groups and is the main focus of our research. Both nationally approved standards (treeknormen) and internal standards (only used at MST) are developed to measure the access times. Therefore, we distinguish two KPIs measuring the access time (the term access time is also visually represented in Figure 2.4):

KPI1 *Mean access time*

The mean time span in weeks between the request for health care and the actual appointment date, measured per quartile and per urgency code

KPI2 *Access time- internal & external standards*

The percentage of patients which get an appointment in time:

- *Internal standards*- Patients with urgency code d get an appointment within 24 hours, patients with code s get an appointment within 72 hours[2], measured per year.
- *External standards*- 80% of the patients get an appointment within three weeks, the remaining 20% within four weeks, measured per year and per urgency code

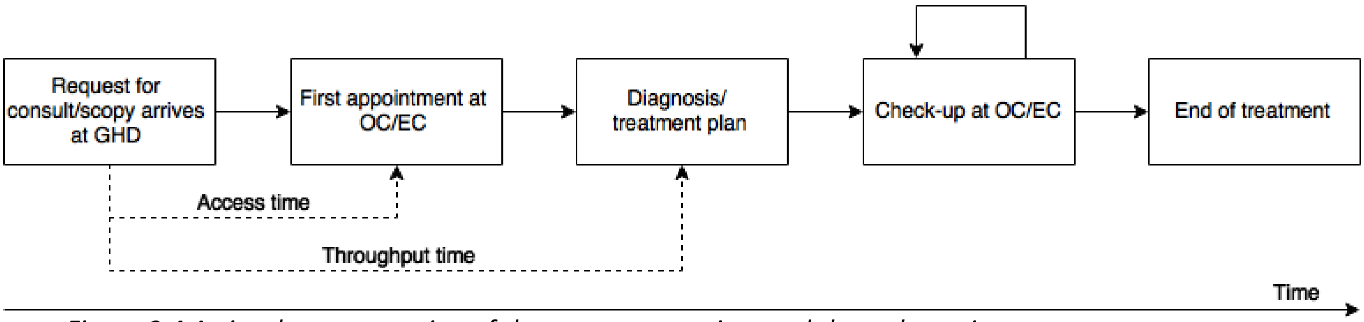


Figure 2.4 A visual representation of the terms access time and throughput time

We gain some information on the access times of the excluded patients of KPIs 1 and 2. The employee responsible for the planning of ischemic patients indicates that these patients usually get an appointment in time. Furthermore, the secretaries at the OC (responsible for scheduling check-ups) indicate that most check-up patients are scheduled in the preferred month (sometimes at the cost of scheduling a new patient).

[2] Patients with code 1 get an appointment within a week, patients with code 2 get an appointment within two weeks, patients with code 3 get an appointment within three weeks, patients with code 4 get an appointment within six weeks, and patients with code 5 get an appointment within three months

Management of the hospital

In order to work more efficiently, it is important to keep an eye on the number of patients treated by the GHD and on the number of appointments these patients have at the GHD (clinical throughput) (Kopach, DeLaurentis, Lawley, Muthuraman, Ozsen, & Rardin, 2007). Furthermore, the utilization of time and resources can be used as KPIs for measuring the efficiency as well (Kolisch & Sickinger, 2008; Huang & Marcak, 2013).

It is very difficult to develop a KPI which directly measures the balance between the EC and the OC. We, for example, have no information on the efficiency of the planning process or on other reasons which might influence the balance between the sections. To get an idea on how the GHD is performing with regard to distributing the resources over the EC and OC, we decide to measure the differences between the access times of both sections. The closer these differences are to zero, the better the resources are distributed over the sections.

For the management, we distinguish five KPIs in total (KPIs utilization and idle time are also visually displayed in Figure 2.5):

KPI3 *Clinical Throughput*

- The number of patients treated, measured per year
- The number of appointments scheduled at the GHD, measured per year

KPI4 *Utilization*

- The total duration of scheduled appointments divided by the available time of the rooms
- The total duration of scheduled appointments divided by the available time in the 'normal' programs
- The total duration of scheduled appointments divided by the available time in the emergency programs

KPI5 *Idle time*

We distinguish four types of idle time: unplanned idle time, when doctors unexpectedly finish early (1), no-shows (2), cancellations not filled again (3), and planned idle time when the planners do not fill up the schedule (4). Furthermore, we distinguish three types of resources for which the idle time should be measured: rooms (i), 'normal' program time (ii), and emergency program time (iii). Combining the types of idle time and resources results in twelve different sub KPIs, which are all measured per year. For idle type 1, we for example have:

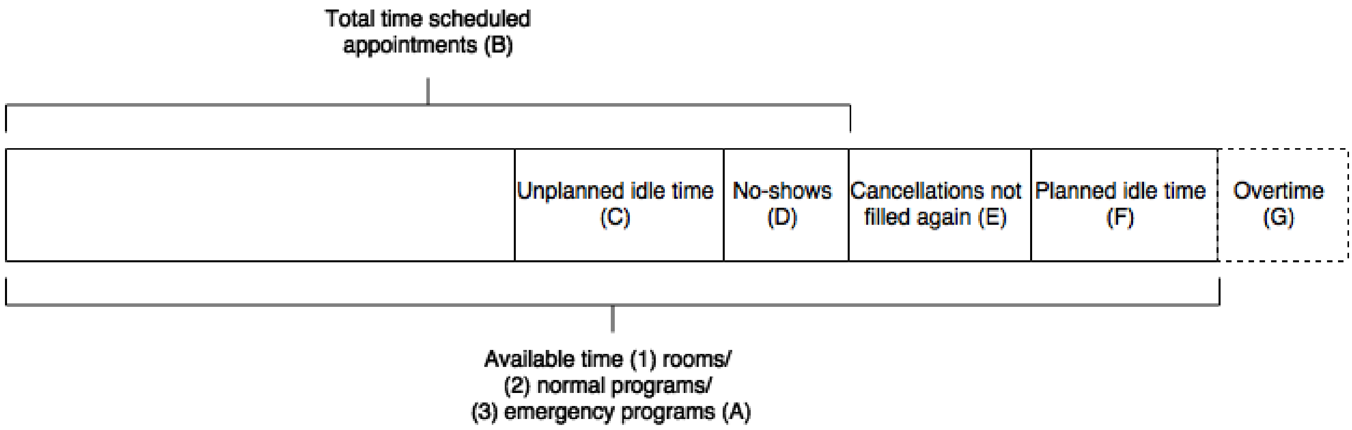
- The total unplanned idle time of the rooms divided by the available time of the rooms
- The total unplanned idle time of the normal programs divided by the available time of the normal programs
- The total unplanned idle time of the emergency programs divided by the available time of the emergency programs

KPI6 *Overtime*

- The total time the medical staff work outside the scheduled working hours divided by the total scheduled working hours, measured per year
- The total time the planners work outside the scheduled working hours divided by the total scheduled working hours, measured per year

KPI7 *Distribution of resources over sections*

The difference between the mean access time (of a section) and the mean access time (of both sections), measured per quartile and per urgency code



Utilization: B/A1, B/A2, B/A3 Idle time: C/A1, C/A2,.., F/A3

Figure 2.5 A visual representation of the KPIs utilization, and idle time

For KPI3 we classify all appointments into appointment groups, in order to keep a clear overview and to overcome differences in registration between 2013 and 2014. Since the EC sometimes deletes appointment codes when patients not show up, it is impossible to calculate the exact number of scheduled appointments per appointment group here. Therefore, we add the no-shows without appointment code to the appointment group 'remainders' here.

KPI4 is excluded since the measurements within this KPI are already included in KPI5 (idle time).

For KPI5, we exclude the unplanned idle time and the idle time of rooms due to lack of information. Furthermore, we assume measurements for this KPI result in a slightly biased view with regard to the number of no-shows of the EC. The difference is caused by the EC registering patients as no-shows not only when patients not notify the EC up front about their absence, but also when they cancel within 24 hours before the appointment.

From KPI6, we exclude the overtime of the planners due to lack of information. Furthermore, we exclude KPI6 (medical staff) in our measurements of the current performance as well, due to lack of information. However, we include the KPI for measurements of the performance of the GHD in our model if our experimental settings might lead to overtime. For example, when use overbooking levels to decrease the number of empty slots this could lead to overtime.

From KPI7, we exclude patients of the EC with urgency codes s and d, since these patients cannot be compared to patients of the OC (the OC does not use these urgency codes).

Health Insurance companies

As explained in Section 2.4.1, health care providers and health care insurers nowadays make agreements by bargaining on prices and the production of health care organizations (Thomson, Busse, Crivelli, van de Ven, & van de Voorde, 2013; Custers, Onyebuchi, & Klazinga, 2007; Schut & Varkevisser, 2013). Insurers want hospitals to fulfill these agreements. Therefore, we formulate one KPI for the insurance companies:

> **KPI8** *Realization*
> The production of the hospital divided by the production as agreed on in the contracts with the insurance companies

We exclude KPI8 since it requires too much time to perform calculations for this KPI and since fulfilling the agreements made with insurance companies not necessarily leads to lower access times. Furthermore, measuring the production is not as straightforward as it seems since the production is not measured in patients or appointments but in *Diagnose Treatment Combinations* (DTCs).

Medical Staff
The medical staff wants to keep the access times low for their patients, but on the other hand, they fear decreasing the access times leads to a higher work pressure, for example in working in overtime. In order to keep the pressure acceptable for the staff members, it is important to keep an eye on the amount of overtime. We already developed KPI6 (see paragraph 'management of the hospital') to measure this.

Patients
Quality of care, in terms of safety and effectiveness, is not really an issue for patients in the Netherlands. Amongst patients, the discussion about quality of care focuses more on topics like access times and waiting lists (Custers, et al., 2007). Patients who have a GH related problem want to get a diagnosis as fast as possible (or, they want a low throughput time). Therefore, we formulate one KPI for patients (the term throughput time is also visually represented in Figure 2.4):

> **KPI9** *Throughput time:*
> The mean time span in weeks between the request for health care and the actual diagnosis, measured per year

Planners
Planners want to maintain a good working environment for themselves and lowering the access times could have two different outcomes for them. When the access times decrease, subsequently the number of complaints and the number of agitated patients decrease as well. This would lead to an improvement of the working environment. However, when decreasing access times involves extra effort from the planners, this could result in a higher work pressure and with that working in overtime. KPI6 is already developed to measure the overtime of planners.

As already mentioned above, this part of KPI6 is excluded from this research due to lack of information.

Overview included KPIs
Summarizing the previous paragraphs, we now have the following five KPIs to measure the performance of the GHD:

KPI1 Mean access time
KPI2 Access time- internal & external standards
KPI3 Clinical Throughput
KPI4 Idle time
KPI5 Distribution of resources over sections

2.4.3 Current performance gastrointestinal and hepatology department

KPI1 Mean access time
The mean time span in weeks between the request for health care and the actual appointment date, measured per quartile and per urgency code

Appendix E shows how the data for this KPI is retrieved and filtered. Figure 2.6 shows graphs of the access times for new patients of the OC.

From Figure 2.6, we conclude the EC has lower and more stable access times than the OC. At both sections we see that the access times of urgency code 5 are much higher than access times for the other urgency codes. This is not remarkable considering the internal standards for this urgency code (patients need an appointment within three months). At the OC however, we see that the access times of urgency code 5 rise above the prescribed three months at the end of 2014. Furthermore, we also identify an upwards trend for the access times of the OC for urgency codes 3 and 4.

Since urgency code d was introduced at the EC in January 2014, this might explain the small increase of the mean access time of urgency code 1 in 2014 compared to 2013. The access times of patients with code d are separated from the patients with code 1 from 2014 onwards.

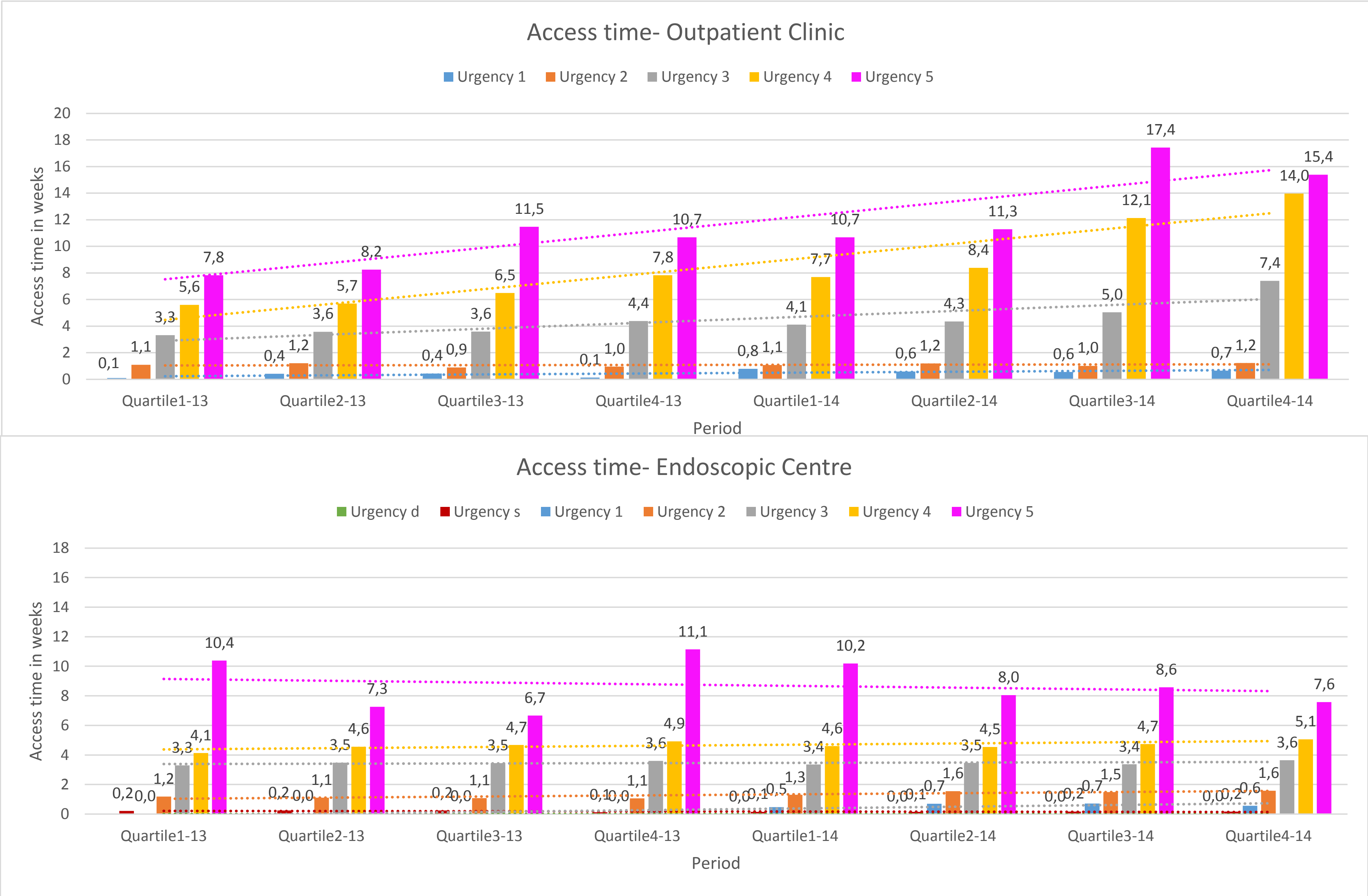


Figure 2.6 Mean access times for the OC and the EC per urgency code, per quartile (19321 patients, 2013-2014, fax reports)

KPI2 Access time- internal & external standards

Internal standards- The percentage of patients which get an appointment in time, see Table 2.6 for an overview of the internal standards for the urgency codes, measured per year.

External standards- The percentage of patients which get an appointment in time, 80% of the patients get an appointment within three weeks, the remaining 20% within four weeks, measured per year and per urgency code

Table 2.6 Urgency codes used at the GHD to prioritize patients with regard to the time-span within which a patient needs an appointment (Scheurink- Engbers, 2015)

URGENCY CODE	TIME SPAN WITHIN WHICH AN APPOINTMENT IS NEEDED
D (ONLY USED AT THE EC)	24 hours
S (ONLY USED AT THE EC)	72 hours
1	One week
2	Two weeks
3	Three weeks
4	Six weeks
5	Three months

Appendix E explains how the data for this KPI is retrieved and filtered. Table 2.7 shows the percentages of patients that had an appointment in time with regard to the internal and external standards.

From Table 2.7, we conclude that overall both the OC and the EC are performing below the standards. Only patients with urgency codes d, s, 1, or 2 (mostly) get an appointment in time. Although the EC is not fulfilling the standards, it is performing far better than the OC. Both the measurements for the internal and external standards show higher percentages at the EC. If we for example take a look at the percentages of the external standards, we see that for the OC not even half of the patients are seen in time (around 38%), while for the EC around 70% of the patients is seen in time.

Table 2.7 The percentages of patients of the OC and EC that had an appointment in time according to the internal and external standards (4453 patients, 2013-2014, fax reports)

	OUTPATIENT CLINIC				ENDOSCOPIC CENTRE			
	2013		2014		2013		2014	
	INT[3]	EXT	INT	EXT	INT	EXT	INT	EXT
URGENCY CODE D	-	-	-	-	-	-	99.8%	100%
URGENCY CODE S	-	-	-	-	90.8%	100%	100%	100%
URGENCY CODE 1	97.2%	100%	88.7%	100%	99.8%	100%	88.9%	100%
URGENCY CODE 2	92.6%	100%	88.1%	100%	86.9%	100%	83.2%	100%
URGENCY CODE 3	31.6%	51.6%	24.8%	39.7%	43.6%	63.6%	42.3%	62.3%
URGENCY CODE 4	50.1%	10.4%	20.0%	8.8%	80.3%	42.0%	80.6%	35.9%
URGENCY CODE 5	83.1%	5.4%	35.6%	3.0%	84.0%	25.3%	78.8%	22.1%
TOTAL	50.6%	38.0%	34.5%	38.2%	64.8%	72.2%	65.5%	71.0%

[3] In Table 2.7, we use INT and EXT as abbreviations for respectively internal standards and external standards.

KPI3 Clinical throughput

The number of patients treated, measured per year

The number of appointments scheduled at the GHD, measured per year, per appointment group

Confidential

KPI4 Idle time (*the unit of time used in this KPI is hours and the KPIs are measured per year)*

- The percentage of available 'normal' program time not used due to no-shows
- The percentage of available 'normal' program time not used due to planned idle time
- The total percentage of available 'normal' program time not used

- The percentage of available emergency program time not used due to no-shows (OC)
- The percentage of available emergency program time not used due to planned idle time (OC)
- The total percentage of available emergency program time not used (OC)

Table 2.9 shows the percentages of idle time for the 'normal' program time and Table 2.10 shows these percentages for the emergency programs at the OC.

From Table 2.9, we conclude that the percentage of no-shows remained relatively stable for both sections in 2013 and 2014. At the OC, the planned idle time of doctors increased strongly. Because of that, the total percentage idle time of the OC also increased. In 2013, doctors were often double booked, this could be the reason for the low percentage of planned idle time in this year. For the EC it is the other way around; the planned idle time and therefore the total percentage idle time decreased slightly here. Furthermore, we notice a relatively high percentage of planned idle time at the nurses in both years.

From Table 2.10, we conclude the percentage of no-shows remained relatively stable for the emergency programs. We see a strong decrease in the percentage of planned idle time from 2013 to 2014 here. This decrease in planned idle time is probably caused by the changed guidelines about the number of emergency programs to schedule per week (this decreased from five in 2013 to three in 2014). However, an idle time percentage of 27.5% is still relatively high, implying a lot of time is wasted.

Table 2.9 The idle time of the medical staff at the OC and the EC, split up in no-shows and planned idle time, as a percentage of the total available 'normal' program time, per year (2013-2014, X-care)

	OUTPATIENT CLINIC						**ENDOSCOPIC CENTRE**	
	2013			**2014**			**2013**	**2014**
	DOC[4]	**NURSES**	**TOTAL**	**DOC**	**NURSES**	**TOTAL**		
TOTAL PROGRAM TIME (IN HOURS)	5097.2	1162.3	6259.4	5176.4	1256.8	6433.2	4380.8	4618.0
PERCENTAGE OF TIME								
- NO-SHOWS	4.5%	5.3%	4.6%	3.9%	5.1%	4.1%	4.2%	4.2%
- PLANNED IDLE TIME	0.7%	17.7%	3.9%	7.6%	18.1%	9.7%	6.7%	5.9%
TOTAL % OF PROGRAM TME NOT FILLED	5.2%	22.9%	8.5%	11.5%	23.2%	13.8%	10.8%	10.1%

[4] In Table 2.9, we use DOC as abbreviation for the doctors.

Table 2.10 The idle time of the medical staff, split up in no-shows and planned idle time, as a percentage of the total available emergency program time, per year (2013-2014, X-care)

	EMERGENCY PROGRAMS	
	2013	**2014**
TOTAL PROGRAM TIME (IN HOURS)	521.7	436.5
PERCENTAGE OF TIME		
- NO-SHOWS	0.6%	1.1%
- PLANNED IDLE TIME	46.8%	26.3%
TOTAL % OF PROGRAM TME NOT FILLED	47.4%	27.5%

KPI5 Distribution of resources over sections

The difference between the mean access time (of a section) and the mean access time (of both sections), measured per quartile, per urgency code

Figure 2.7 until 2.10 show the distribution of resources over the sections per quartile, per urgency code.

From Figure 2.7, we conclude that the distribution of resources over the sections is relatively good for urgency codes 1 and 2: there is no clear pattern visible in this graph. However, Figures 2.10 until 2.12, how a clear trend: the access times of the OC and the EC drift further and further apart over the course of the two years indicating there is a problems with the distribution of resources over the sections.

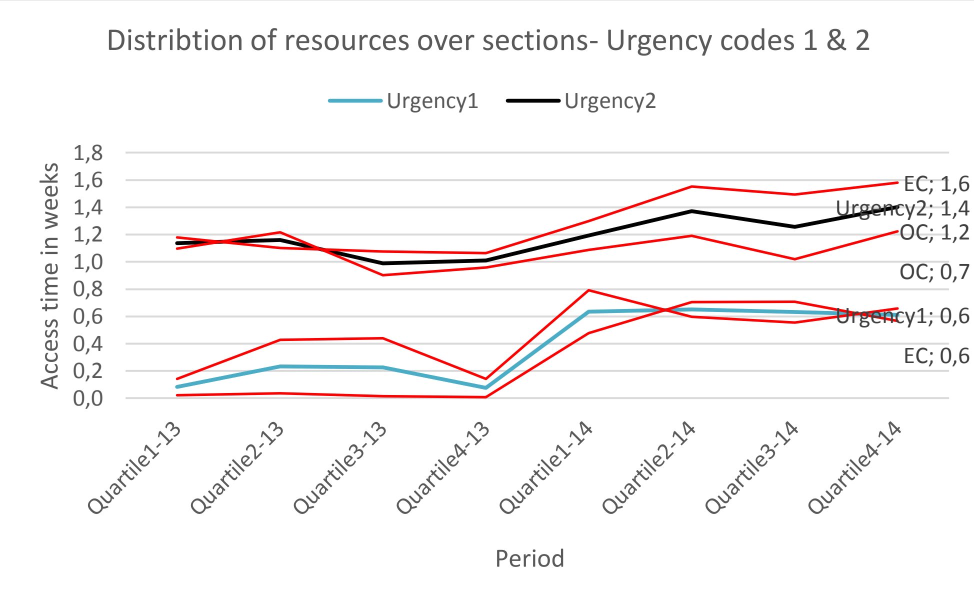


Figure 2.7 The distribution of resources over the OC and EC for urgency codes 1 and 2, per quartile (19321 patients, 2013-2014, fax reports)

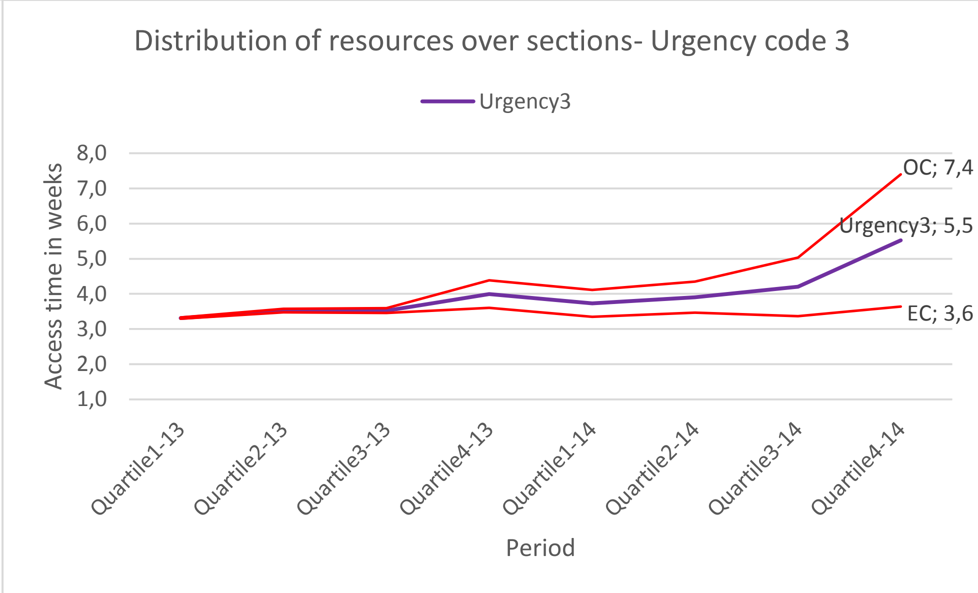


Figure 2.8 The distribution of resources over the OC and EC for urgency code 3, per quartile (19321 patients, 2013-2014, fax reports)

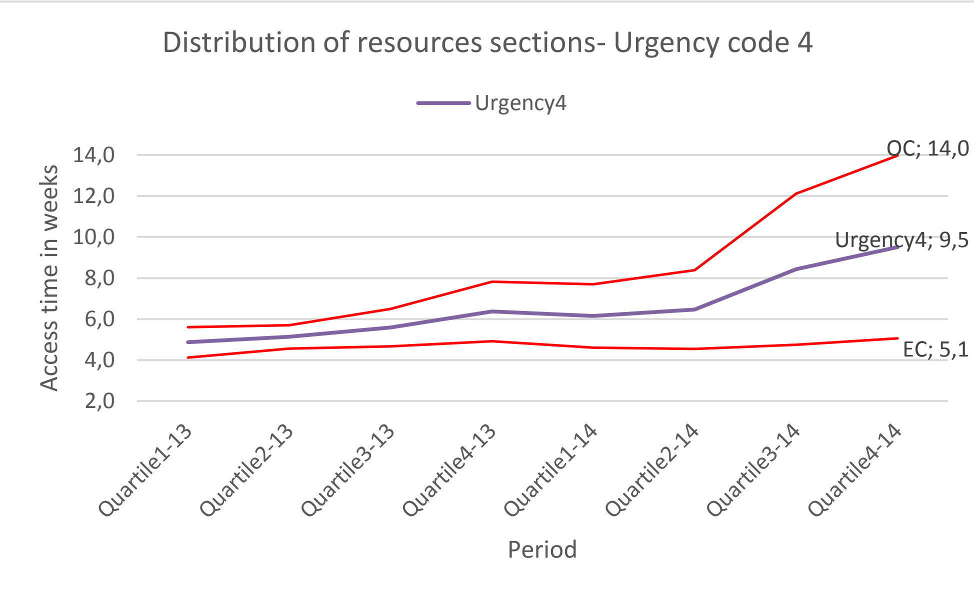


Figure 2.9 The distribution of resources over the OC and EC for urgency code 4, per quartile (19321 patients, 2013-2014, fax reports)

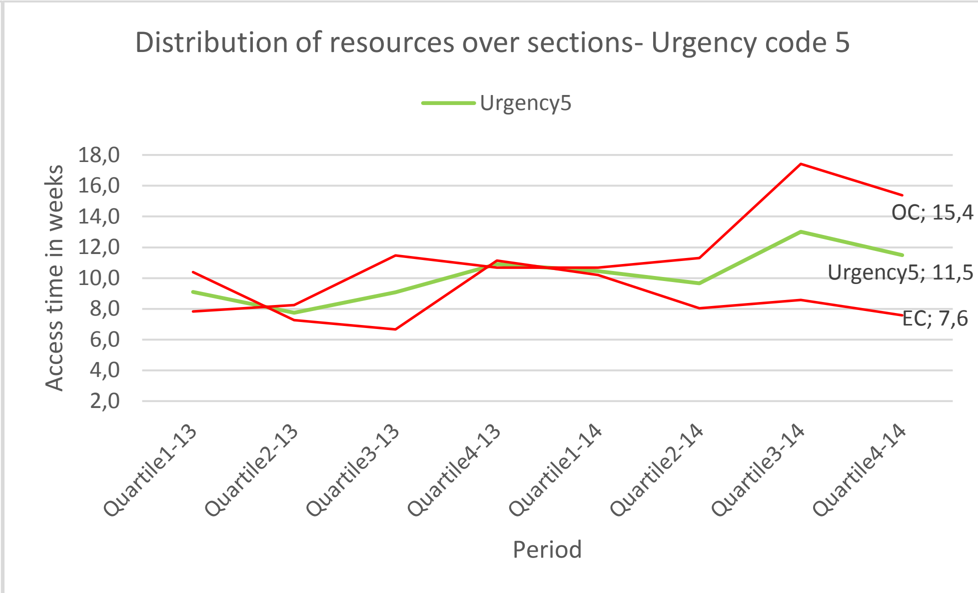


Figure 2.10 The distribution or resources over the OC and EC for urgency code 5, per quartile (19321 patients, 2013-2014, fax reports)

2.5 CONCLUSION AND DEMARCATION OF SCOPE

2.5.1 Conclusion context analysis

How can we describe the context of the GHD and what are the problems of the GHD which need our attention?

Care path

A patient is referred to the GHD by either a GP or a specialist of another discipline. The department doctor at the GHD assigns an urgency code to the patient according to the time span within which treatment is needed. Then, an appointment is scheduled for the patient. After this appointment, either the treatment ends, or the patient has to come back at / is referred to the OC or EC.

Planning & control of resources and patients

We can distinguish three steps in the planning & control cycle of resources and patients:

1. A schedule is set up in which the doctors are assigned to programs of a specific section (OC or EC). The number of programs to schedule is based on the number of programs executed last year.
2. The planners (EC) and the secretaries of the doctors (OC) fill the programs with specified appointment slots. They for example reserve slots for telephonic consults, check-up consults etcetera.
3. The appointment slots are filled with patients by the planners and the secretaries.

Problem analysis

The following two sub problems and their accompanying causes are addressed in this research:

1. *Imbalance in the distribution of program time over the EC the OC*: The access times at the OC are unstable (in contrast to the access times of the EC) and are higher than the access times at the EC.
2. *Empty slots in the schedule:* caused by slots not filled by planners, no-shows, and emergency programs not fully booked.

Furthermore, from the capacity calculations we conclude that in theory, the GHD has enough capacity to deal with the demand for GH related care. However, in the current situation, in which program time is reserved for emergency patients, the pressure on the 'normal' programs is relatively high. We will look into this issue when addressing sub problem 2 (*empty slots in the schedule*).

Analysis of current Performance

We distinguished five stakeholder groups involved and interested in the access times of the GHD. In descending order of importance these are: management of the hospital, insurance companies, medical staff, patients, and planners.

Below, we present an overview of the five included KPIs. Furthermore, a summary of the outcomes of these KPIs is given.

KPI1 Mean access time: For the OC, an increase is visible in access times of urgency codes 3, 4, and 5 and the access time for urgency code 5 is relatively high. The access times of the EC are lower and more stable.

KPI2 Access time- internal & external standards: Both the OC and the EC are performing below the standards, except for patients with urgency codes d, s, 1, or 2. The percentage of patients with acceptable access times is much higher at the EC than at the OC (considering the external standards; 70% of the EC patients get an appointment in time against 40% of the OC patients).

KPI3 Clinical throughput:

Confidential

KPI4 Idle time: For the 'normal' programs, the percentage of no-shows remained relatively stable for both sections. Furthermore, the planned idle time increased strongly for the doctors (0.7% to 7.6%) at the OC and there is a remarkable high percentage of planned idle time for the nurses (around 18%).
For the emergency programs the percentage of no-shows remained relatively stable. A strong decrease in the percentage of planned idle time can be identified (47% to 28%). However, the idle time percentage still is relatively high for these programs.

KPI 5 Distribution of resources over sections: The distribution of resources over the sections is relatively good for urgency codes 1 and 2, considering equal access times for both sections is desirable. However, this KPI scores relatively bad for urgency codes 3, 4, and 5.

2.5.2 Demarcation of scope

After a first demarcation of the scope of this research in Section 1.3.3, we now further narrow down the scope in this section using the data gathered in this chapter. From Section 2.3 we concluded our focus is on two sub problems:

1. **Imbalance in the distribution of program time over the EC and the OC:** Since we identified an increase in the access times at the OC, we assume there is an unbalance in the distribution of program time over the two sections. We will attempt to find a more efficient way of distributing the program time over the two sections.
2. **Empty slots in the schedule:** We already identified three causes for this sub problem:
    - *Slots are not filled by the planners*- it is more efficient to have no initial empty slots (or as little as possible) in the schedule.
    - *No-shows*- although the idle time caused by no-shows is relatively stable, still a lot of hours are wasted because of no-shows.
    - *Emergency programs not fully booked*- the percentage of idle time of the emergency programs is relatively high. We want to research if we could either decrease the amount of program time distributed to the emergency programs or if we could use more of the slots in these programs in order to decrease the access times,

We concluded, from the measurements for the KPIs, that the number of slots not filled by the planners is especially high for the nurse programs. We want to determine what the influence on the access time is, when these programs are filled better. We therefore specify our first cause further into nursing slots not filled by the planners.

- *Nursing slots not filled by the planners*

Although empty slots in the schedule are a problem at the EC as well, most employees at the GHD state that at the EC, overtime is more of an issue than idle time. Next to this, we expect that empty slots in the schedule will be less of a problem at the EC after introducing the solutions for the lack of screening programs. More screening programs indicate that there will be no (or less of a) shortage for screened patients in the future. We think, the problems with the idle time at the OC are larger and more important to address. Therefore, we decide to focus on the OC with sub problem 2 (empty slots in the schedule).

Recapitulating on the framework of Hans, et al (2011) described in Section 1.3.3, we place sub problem 1 on the tactical level since we are dealing with placing our staff members (staffing) at the right section. Furthermore, with sub problem 2, we again focus on staffing, plus we are focusing on admission planning. Both staffing and admission planning are elements of tactical planning. Figure 12.11 shows the framework of health care planning and control with the (now further) demarcated scope of our research.

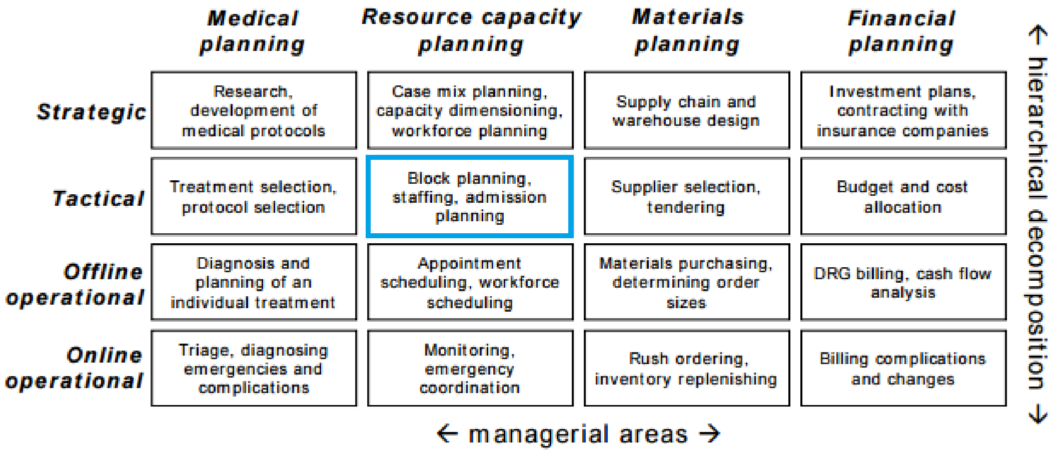


Figure 2.11 The scope of this research as part of the framework for health care planning and control (Hans, Van Houdenhoven, & Hulshof, 2011)

3 LITERATURE REVIEW

In this chapter we perform a literature review in order to gain more insight in how we should address the two sub problems formulated in the previous chapter. Section 3.1 elaborates on the tactical level of resource capacity planning. Then, Section 3.2 elaborates on interventions found in literature which focus on (one of) our sub problems. The search strategy used for this chapter is shown in *Appendix F.* The interventions found in literature are supplemented with interventions found through observations in Section 3.3. Finally, Section 3.4 draws a conclusion of Chapter 3.

3.1 RESOURCE CAPACITY MANAGEMENT

This section first focuses on tactical planning in health care organizations in general (Section 3.1.1). Then, we focus on each of the two sections of the GHD: the OC in Section 3.1.2, and the EC in Section 3.1.3. Finally, in Section 3.1.4, we focus on the importance of correctly distributing resources over multiple sections.

We use the taxonomic classification of planning decisions in health care for this section (Hulshof, Kortbeek, Boucherie, Hans, & Bakker, 2012). Within this classification different services in healthcare are positioned. Ambulatory care services are described as services where health care is provided to patients without offering a room, a bed and board. This description also fits the OC and therefore we classify the OC as an ambulatory care service. Surgical care services are described as services that provide operative procedures to patients for the correction of deformities and defects, repair of injuries, and diagnosis and cure of certain diseases. This description fits the EC and therefore we classify the EC as surgical care service.

3.1.1 Tactical planning

Tactical planning involves the allocation of resources and the development of patient admission plans, usually with achieving equitable access and treatment duration for patients as objectives (Hulshof, Boucherie, Hans, & Hurink, 2013; Hulshof, et al., 2012). Less abstract, tactical plans distribute the available time of the resources, for example of doctors, over various activities and controls the number of patients to be treated at every care stage. Decisions made on this level usually have a planning horizon of weeks or months, which is somewhere in between the strategic (long-term, mostly years) and the operational planning horizon (short-term, mostly days or weeks) (Hans, Van Houdenhoven, & Hulshof, 2011; Wachtel & Dexter, 2008). Usually the sequence of appointments is not incorporated in decisions on this level, but follows in the operational level (Oostrum, Bredenhoff, & Hans, 2010). Decisions about temporary capacity expansions (such as hiring staff or working in overtime) are made on the tactical level though (Hans, et al., 2011; Hulshof, et al., 2012). Developing tactical plans can therefore be divided into two steps:

1. Characterizing patient groups by disease type or diagnosis, urgency, and resource requirements.
2. Distributing the available resource capacities (determined on the strategic level) over these patient groups.

3.1.2 Outpatient clinic

According to the taxonomy of Hulshof et al. (2012), there are several factors of influence on the access times of outpatient clinics. First, a trade-off needs to be found between the utilization of resources and the patients' access time in order to achieve equitable distribution of access times: *capacity allocation* (Testi & Tànfani, 2009). Second, *temporary capacity change* is used to cope with fluctuations in patient demand. Third, *access policy* concerns the management and prioritization of waiting lists in order to have equally distributed access times over the different patient groups. Fourth, this policy is executed by *admission control*, including rules about which patients need to be selected and admitted from the waiting lists (Gocgun, Bresnahan, Ghate, & Gunn, 2011). Fifth, *appointment scheduling* involves creating blueprints which are used to provide a specific time and date for consults of patients. There are three key decisions of influence on appointment scheduling considering the access times: the number of patients per consultation session, overbooking, and anticipation for unscheduled patients (Carpenter, Leemis, Papir, Philips, & Philips, 2011; LaGanga & Lawrence, 2007; Dobson, Hasija, & Pinker, 2011; Hulshof, et al., 2012).

3.1.3 Endoscopic centre

The classification of Hulshof et al. (2012) for resource capacity planning, mentions four factors of influence on access times of surgical care services. First, *capacity allocation,* again in order to find a trade-off between access times and the utilization of resources. Second, *temporary capacity change* is used here as well to cope with fluctuations in patient demand. Third, *unused capacity (re)allocation,* which could lead to higher utilization of available resources (Guerriero & Guido, 2011; Gupta, 2007). Fourth, *admission control* is used to select patients from the patient groups to get an appointment (Hulshof, et al., 2012).

3.2 INTERVENTIONS

This section focuses on searching literature for interventions which address our two sub problems. Section 3.2.1 elaborates on interventions found for sub problem 1 (Imbalance in the distribution of program time over the EC and the OC). Section 3.2.2 elaborates on interventions found for sub problem 2 (empty slots in the schedule), hereby focusing on the three causes for empty slots: nursing slots not filled by planners, no-shows, and emergency programs not fully booked.

3.2.1 Sub problem 1: Imbalance in the distribution of program time over the endoscopic centre and the outpatient clinic programs

The intervention for this sub problem follows directly from the second step of creating tactical plans: Distributing the available resource capacities over the patient groups. Distributing the available resources here more specifically means distributing the resource time of medical staff members, since the amount of the other resources are fixed (the number of available staff members and the number of rooms).

3.2.2 Sub problem 2: Empty slots in the schedule

We start with a general intervention to reduce the number of empty slots: pooling.

Intervention A: Pooling

Merging two (or more) queues into one queue leads to a more efficient use of capacity. In practice, this means doctors should be able to treat multiple patient types. This approach also has drawbacks as the workload for the medical staff could become too high: staff members might experience stress when they need to be able to execute all kind of treatments/consults. However, many studies conclude that there would be a positive outcome on the utilization of resources when using pooling (Joustra, van der Sluis, & van Dijk, 2009; Kuntz, Mennicken, & Scholtes, 2014).

Pooling can also be used for time slots; time slots reserved for specific appointments could be pooled with time slots for other appointment types when these require the same equipment and/or personnel (Joustra, de Wit, Struben, Overbeek, Fockens, & Elkhuizen, 2010).

Nursing slots are not filled by the planners

A straightforward solution to decrease the nursing slots not being filled is to simply schedule more patients into the nurse programs. But, what if there are no more patients to schedule? We therefore formulate the following intervention:

Intervention B: Shifting tasks from doctors to nurses

There is not much information available on shifting tasks from doctors to nurses. However, Rosmulder, Krabbendam, Kerkhoff, Houser and, Luitse (2011) made a plan to fundamentally redistribute tasks over the doctors and nurses and tests showed that this redistribution could lead to the decrease of waiting times and to a reduction of the length of stay (Rosmulder, et al., 2011). Amongst other reasons, the shortage of doctors makes it necessary to re-examine the professional boundaries between doctors and nurses. Shifting some of the responsibilities might solve the shortage problem, even though it could also lead to an increase of the nursing workload (Toren, Nirel, Tsur, Lipschuetz, & Toker, 2014).

No-shows

Interventions dealing with no-shows can be split up into two types: interventions to reduce the number of no-shows and interventions using overbooking levels to reuse of empty slots caused by no-shows.

Intervention C: Planning with a short time horizon (reduce the number of no-shows)

Planning with a short time horizon helps patients to see their doctor when they (think they) need to, and therefore decreases the number of no-shows. The drawback is that this usually involves the introduction of an open access system (a more detailed description is found under 'emergency programs not fully booked'), which might lead to costly under- and/or over-utilization because of the variation in demand and conflicts with patients' preferences (Muthuraman & Lawley, 2008; Liu, Ziya, & Kulkarni, 2010; Daggy, et al., 2010).

Intervention D: Sending reminders to patients (reduce the number of no-shows)

Reminding patients about their appointment by sending letters, text messages or by calling them could solve the problem of patients forgetting their appointment (LaGanga & Lawrence, 2007; Liu & Ziya, 2013).

Intervention E: Provide information about public transport (reduce the number of no-shows)

Providing information about public transportation or providing transportation vouchers could motivate patients to get to their appointment when they do not own a car or have a low income (LaGanga & Lawrence, 2007; Liu & Ziya, 2013).

Intervention F: Schedule patients at their preferred doctor (reduce the number of no-shows)

Scheduling the patient at the doctor he or she prefers could motivate patient to go to their appointment (Kopach, et al., 2007; Daggy, et al., 2010).

Intervention G: Introduce penalties for not showing up (reduce the number of no-shows)

Introduction of a financial penalty for patients not showing up could motivate people to go to their appointment. In 2012, the Minister of Health Care advised hospitals in the Netherlands to introduce penalties (NOS, 2012). A drawback is the difficulty of collecting these penalties in practice (Ratcliffe, Gilland, & Marucheck, 2011).

Intervention H: Overbooking

Scheduling extra patients in a full booked program is a strategy for decreasing the access times when there is a significant chance patients do not show up for their appointment. Positive outcomes are lower access times and a higher productivity of the medical staff (Zacharias & Pinedo, 2013; LaGanga &

Lawrence, 2007). Negative outcomes are higher waiting times for patients and overtime for the medical staff. This happens if all patients do show up and the overbooked (extra booked) patients cause delays in the schedule. A balance should be found between the waiting time of the patient and the under-or overutilization of staffing time (Muthuraman & Lawley, 2008; Zacharias & Pinedo, 2013; Liu & Ziya, 2013).

Emergency programs not fully booked

Literature mentions three models, each dealing differently with emergency patients.

Intervention I: Traditional model

In the traditional model, elective patients are scheduled in advance and fill up the entire schedule. When an emergency patient shows up, the schedules of the medical staff are overbooked in order to schedule these patients. If an emergency patient cannot be squeezed into the schedule of the doctor anymore, he or she sometimes is send to the ED. Since the patient does not see the correct specialist there, this is a drawback of this model. Furthermore, Tsai and Teng (2014) and Murray and Berwick (2005) state the use of this model often leads to double appointments. Usually patients are only treated for their most urgent problem at the ED and have to come back to see a specialist in the (near) future (Murray & Berwick, 2005; Tsai & Teng, 2014).

Intervention J: Carve-out model

Within the carve-out model, some of the time slots are reserved for emergency patients and the rest of the slots are filled with elective patients in advance (Murray & Berwick, 2005; Tsai & Teng, 2014). In general, the carve-out model increases the chance emergency patients are treated in time and by a correct specialist. A drawback of the model, is that it often leads to more delayed elective appointments compared to the traditional model (Tsai & Teng, 2014; Ratcliffe, et al., 2011). There are two versions of the carve-out model:

1. There are separate emergency programs which are reserved fully for emergency patients and the remaining programs are reserved fully for elective patients. With this type of the carve-out model, patients are not always able to see their own doctor (if their doctor not has an emergency program in the close future). This might threaten the continuity of health care and it might also create artificial demand (visits to the own doctor are sometimes necessary) (Tsai & Teng, 2014).
2. For each resource (medical staff member), some slack capacity is reserved to deal with the emergency patients. Though patients are more often able to see their own doctor within this model, the drawback is that frequently more time is carved-out than necessary. This leads to delayed elective appointments (Murray & Berwick, 2005; Jebali & Diabat, 2015).

Intervention K: Advanced access model

The hospital tries to omit appointment delay entirely by aiming to offer the patient an appointment on the day or within a week of the patients' call or referral. This model is also known as the same-day access or open-access model. Significant reduction in appointment delays are the outcomes of introducing this model as well as improvements in various measures of service quality. Furthermore, the number of no-shows decreases (Liu, et al., 2010; Murray & Berwick, 2005). The chance a patient gets an appointment at his or her own physician is larger within the advanced access model compared to the other two models. All physicians have available slots instead of fully booked schedules, which increases the chance of seeing the own doctor (Murray & Berwick, 2005). However, same-day access is very vulnerable to variations in arrival demand and is also very sensitive to the imbalance between demand and capacity which could cause under- and/or overutilization of resources. This model is therefore unlikely to be sustainable for hospitals where the average patient demand is relatively close to the available capacity, since variation in demand mostly causes overutilization here (Liu, et al., 2010).

3.3 Interventions from observations

In this section, we supplement the interventions found in literature with interventions following from observations at the GHD and conversations with staff members.

We start with a general intervention to reduce the number of empty slots: reducing the variation in the number of programs per weekday.

Intervention L: Reducing the variation in the number of programs per weekday
Because of doctors working part-time and because of non-clinical days, there is variation in the number of scheduled programs per day of the week. For example, on average, on Wednesdays the lowest number of programs is executed. Reducing this variation, by spreading the total number of programs over the weekdays, might reduce the access times and fill up some of the empty slots.

No-shows

Intervention M: Referral to the GP (reduce the number of no-shows)
Patients sometimes not show up for their appointment multiple times. It might be an option to refer these patients back to their GP. In this way, they have to visit their GPs again and get a new referral before they are able to get a new appointment at the GHD. This could prevent patients from becoming a no-show.

Intervention N: Check if patients took a blood sample (reduce the number of no-shows)
For some appointments at the GHD, it is necessary the patient gets a blood sample taken, before the appointment takes place. During the appointment, the test results of the blood are then discussed. Sometimes, patients forget to get a blood sample taken and therefore not show up for their appointment. It might be useful to remind patients they have to get a blood sample taken, in order to reduce the number of no-shows.

Emergency programs not fully booked

Intervention J: Carve-out model (a third version)
Emergency patients at the OC do not need a visit the same day, but rather in the same week or within two weeks, therefore we add another version of the carve-out model. Schedule emergency programs, but fill these programs gradually with elective patients as the date of the emergency program approaches. This implies that the closer we get to the date of the emergency program, the less program time should be left open for emergency patients and the program can be filled (partly) with other patients.

3.4 Conclusion

What information about decreasing access times for health care is available in the literature?

Recapitulating on the literature described in Section 3.1, we can distinguish two steps in tactical planning at the GHD. The first step – characterizing patient groups – is performed by reviewing the *access policy, admission control* and *appointment scheduling* of a department. At the GHD, the *access policy* is mapped by categorizing patients using urgency codes according to the time span within which treatment is needed

Admission control is not so straightforward though; although there are guidelines about the preferred access times, there is no policy for the planners on what to do when for example the waiting lists are too long to deal with all the patients in time.

With regard to *appointment scheduling* at the GHD, the number of patients per consult is not fixed. At both the OC and the EC, there are different appointment durations for different appointment types and at the OC, the appointment durations also differ per doctor. Both sections do not use overbooking to decrease their access times. Emergency patients are treated in the emergency programs; at the EC there is a radiographic/ emergency shift every afternoon, and at the OC there are approximately three emergency programs scheduled per week.

The second step – distributing the available resources – is carried out by reviewing *capacity allocation*, *temporary capacity change*, and the *(re)allocation of unused capacity*. There are no clear rules at the GHD as to how to divide the available resources and unused capacity is not (re)allocated at the moment.

Achieving equitable access for the patients is our goal with regard to our first sub problem ‘imbalance in the distribution of program time over the EC and the OC’. Therefore we want to take a look at the (re)distribution of the available resources. Furthermore, with regard to our second sub problem ‘empty slots in the schedule’, Table 3.1 shows an overview of the total of interventions aimed at reducing access times, to be tested on our model of the OC.

Table 3.1 An overview of the total of interventions to be tested on our model of the OC

INTERVENTION	**DESCRIPTION OF INTERVENTION**
A	Shifting tasks from doctors to nurses
B	Overbooking
C	Carve-out model- less emergency programs
D	Carve-out model- filling emergency programs gradually with non-emergency patients when date of program approaches
E	Reducing the variation in the number of programs per weekday
F- SENSITIVITY ANALYSIS	Reducing the number of no-shows

We exclude the intervention ‘pooling’ from this research. Medical staff members working at the GHD have different qualities. However, if we exclude appointment types with a very low frequency (see Section 2.3.3), there are just a few types of appointments and accompanying types of doctors: general, liver, and IBD doctors. Therefore, the influence of pooling is not tested.

We exclude the intervention ‘traditional model’ from this research. Literature states clearly this model has more disadvantages than advantages. It is not preferable to have a high amount of overtime and therefore the influence of the traditional model is not tested.

The carve-out model is already implemented at the GHD: emergency programs which can only be used for emergency patients. It is useful to test whether different versions of this model have an (positive) influence. However due to educational restrictions for the AIOS, the OC cannot introduce the carve-out model with slack capacity (version 2) and this version is therefore not tested. We do want to test the influence of a different number of emergency programs and gradually filling the emergency patients with non-emergency patients though.

We exclude the intervention ‘advanced access model’ from this research. Introducing an open access system requires major changes in the department and since the average demand is relatively close to the available capacity at the GHD, we do not test this model in our research.

Although some of the interventions focusing on reducing the number of no-shows are already in use, they are not used consistently. For example, reminding patients about their appointment is done by some secretaries and planners sometimes take into account preferences of the patient with regard to the preferred doctor. Decreasing the number of no-shows is not easily tested since we have no information on the exact influence these interventions have on the number of no-shows. Since we do not want to exclude these interventions totally, we perform a sensitivity analysis to test what impact it would have to decrease the no-shows.

4 MODELLING THE GASTROINTESTINAL AND HEPATOLOGY DEPARTMENT

This chapter starts with a description of the model we develop to address sub problem 1 in Section 4.1 (imbalance in the distribution of program time over the EC and the OC programs). Then, Section 4.2 describes the model we develop to test the interventions developed for our second sub problem (empty slots in the schedule of the OC). Finally, Section 4.3 draws a conclusion of Chapter 4.

4.1 MODEL ADDRESSING SUB PROBLEM 1: IMBALANCE IN THE DISTRIBUTION OF PROGRAM TIME OVER THE ENDOSCOPIC CENTRE- AND THE OUTPATIENT CLINIC PROGRAMS

This section describes the model we develop to address sub problem 1. Section 4.1.1 elaborates on which type of model we develop. Then, Section 4.1.2 explains the way we gather our data. Section 4.1.3 elaborates on the calculations we perform to determine the needed program time for the EC and the OC. Finally, in Section 4.1.4, a heuristic on how to improve the distribution of program time over the EC and the OC is presented. Note, due to time restrictions and the need to also focus on sub problem 2, we only develop a very simple and basic model for this sub problem.

4.1.1 Selection of model type

Tactical resource and admission plans can be either static or dynamic. With the static approach, long-term, cyclical plans are created (Hulshof, et al., 2013). The advantage of these types of schedules is that they make demand better predictable for surgical and downstream resources (van Oostrum, van Houdenhoven, Hurink, Hans, Wullink, & Kazemier, 2008). With the dynamic approach, intermediate-term plans are created which respond to the variability in supply and demand (Hulshof, et al., 2013). Since these plans respond to variability, these are often non-cyclic. These schedules have a greater impact on the decrease of access times and staffing costs (compared to static, cyclic plans), but also make demand less predictable for downstream resources (Hulshof, et al., 2012).

In order to keep our model simple, we use a (mostly) static approach here. We develop two formulas, each calculating the number of program hours needed for a section, for every three months. The distribution of the available program time over the two sections can then be determined by taking the ratio of the two formulas. The number of program hours depends on the number of new and check-up patients being treated at the GHD. Since the GHD aims at developing schedules for their medical staff three months ahead, we choose to calculate the needed program hours every three months.

4.1.2 Data collection

We use the program X-care to gather information about all scheduled appointments (both new and check-up appointments) at the GHD from 2010 to 2014. This information includes no-shows as well, since these are appointments that need to be scheduled and therefore take up program time as well. After extracting the data from X-care, we exported the data to Excel for further processing.

4.1.3 Needed program time for the endoscopic centre and the outpatient clinic

We make the following assumptions in order to determine the needed program time for new appointments and check-up appointments:

1. The needed program time for new patients per section, is equal for every three months, and per week as well. At the OC, the amount of program time scheduled for new patients per year

increased strongly until 2012. We therefore are only able to use data from the years 2012, 2013, and 2014 for calculations on the arrival of new patients. This implies we only have three observations as to what amount of program time is needed per week. We consider this as not sufficient to see a pattern and therefore we use a fixed amount of program time needed for new patients per week at the OC.

For the EC, we are able to use the data from the years 2010 until 2014, since the amount of program time scheduled for new patients per year is more stable here. However, there is little fluctuation in the amount of program time needed for new patients per week at this section. Therefore, we also use a fixed amount of program time needed for new patients per week at the EC.

2. In order to determine the amount of program time needed for check-ups, we let the formulas use the appointments executed in the past, since these usually indicate check-up appointments. We assume that the proportion of patients going from an *initial state* to a *next state* is fixed. With 'initial states', we hereby mean an appointment at the EC or the OC. With a 'next state' we hereby mean a new appointment at the EC, the OC, or no appointment at all. When the patient gets to the next state and gets an appointment at the EC or OC, a time-span is linked to this check-up appointment. For example, we assume the proportion of patients going from a consult today (*initial state*) to a check-up consult in three to six months (*next state*) is fixed.
   - We choose to not use specific appointment types, but rather a general consult or scopy to keep the model simple and to restrict the amount of calculations necessary.
   - After discussion with a GH doctor, we decide to use six different time spans in which check-ups can take place: in less than three weeks, in three to six weeks, in six weeks to three months, in three to six months, in six to nine months, and in nine to twelve months. Appointments of patients taking place more than a year after the previous appointment are not taken into account, since these patients are seen as new patients at the GHD.

Reflecting on assumption 1, we calculate the program hours needed for new patients for every three months as follows: divide the amount of program hours used for new patients by twelve (we have three years of data, implying 36 months). These calculations result in 386.8 hours needed for new patients at the OC, and 482.9 hours for new patients at the EC.

Reflecting on assumption 2, patients either get no check-up *(possibility 1)* or have a chance of getting one of the following types of check-ups after receiving a consult or scopy (also visually expressed in Figure 4.1):

1. A check-up in less than three weeks at either the OC or the EC *(possibilities 2 and 3)*
2. A check-up in three to six weeks at either the OC or the EC *(possibilities 4 and 5)*
3. A check-up in six weeks to three months at either the OC or the EC *(possibilities 6 and 7)*
4. A check-up in three to six months at either the OC or the EC *(possibilities 8 and 9)*
5. A check-up in six to nine months at either the OC or the EC *(possibilities 10 and 11)*
6. A check-up in nine to twelve months at either the OC or the EC *(possibilities 12 and 13)*

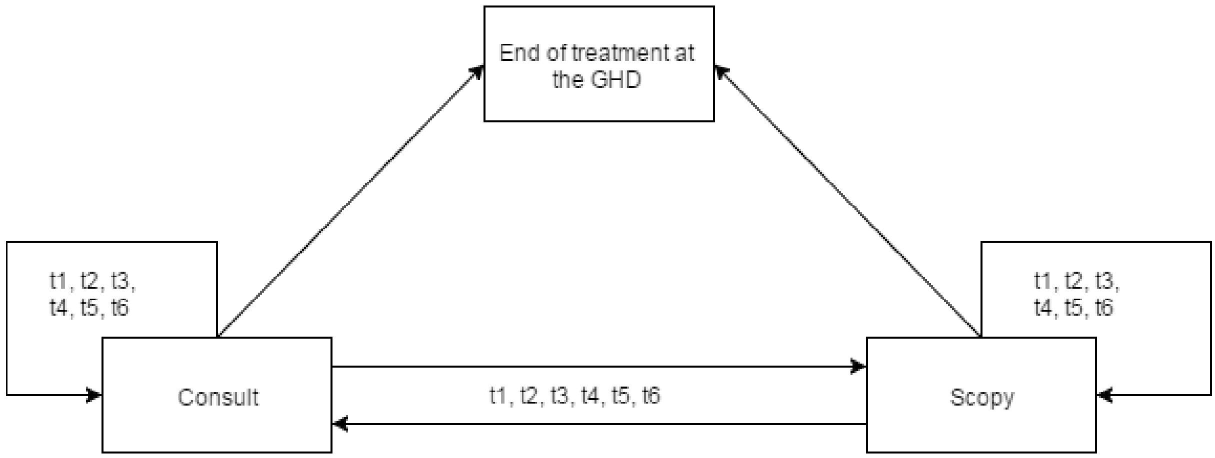


Figure 4.1 The possibilities of check-up appointments of a patient after a consult or scopy at the GHD (t1, t2, t3, t4, t5, and t6 represent the following six time spans respectively: in less than three weeks, in three to six weeks, in six weeks to three months, in three to six months, in six to nine months, and in nine to twelve months)

We now use four steps to get to the needed program time per section:

1. Using the data we gathered, we calculate the proportions of patients with a consult or scopy going to one of the thirteen check-up possibilities. In order to keep the model simple, we do not use recursion here, but look separately at each appointment to check whether this appointment gets a follow-up appointment or not.
2. We then calculate the durations of these check-up appointments. We rescaled the data such that it shows the check-up duration after one hour of consults and scopies.
3. If we multiply each proportion (see step 1) with the initial state being consult (scopy), with the accompanying duration (see step 2), we have calculated the total check-up duration coming from one hour of consults (scopies). For example, for a consult today, for check-up possibility ‘a check-up in six to nine months at the OC’, 0.071 hours of program time is needed. This is calculated by multiplying 0.047 (4.7% of consults today result in a consult in six to nine months) with 1.35 (duration of the consult in six to nine months). An overview of all these multiplications, implying all check-up durations following from one hour of consults or scopies, is found in Table 4.1.

Table 4.1 An overview of the needed program time for the OC and EC resulting from one hour of consults and scopies

	NEEDED CHECK-UP HOURS AFTER ONE HOUR OF CONSULTS	 ONE HOUR OF SCOPIES
NO CHECK-UP APPOINTMENT	0.000	0.000
CONSULT <3 WEEKS	0.192	0.130
CONSULT 3-6 WEEKS	0.147	0.030
CONSULT 6 WEEKS- 3 MONTHS	0.169	0.024
CONSULT 3-6 MONTHS	0.173	0.015
CONSULT 6-9 MONTHS	0.071	0.009
CONSULT 9-12 MONHTS	0.024	0.008
SCOPY <3 WEEKS	0.137	0.181
SCOPY 3-6 WEEKS	0.100	0.089
SCOPY 6 WEEKS- 3 MONTHS	0.053	0.033
SCOPY 3-6 MONTHS	0.028	0.013
SCOPY 6-9 MONTHS	0.013	0.006
SCOPY 9-12 MONHTS	0.017	0.005

Using the information of Table 4.1, we develop two formulas to calculate the needed program time for the OC and the EC for every three months. Tables 4.2, 4.3, and 4.4 present the meaning of the indices of the variables we used within the formulas.

Table 4.2 The sections of the GHD

SECTION i	
1	Outpatient Clinic
2	Endoscopic Centre

Table 4.3 The possible types of check-up

CHECK-UP TYPE f	
1	Consult
2	Scopy

Table 4.4 Time span

TIME SPAN t	
1	Within the past three weeks
2	Three to six weeks ago
3	Six weeks to three months ago
4	Three to six months ago
5	Six to nine months ago
6	Nine to twelve months ago

Variables

N_i = The amount of hours needed for new patients at section *i* in a time period of three months (*i* = 1,2)
Y_{it} = The amount of hours executed in time span *t* at section *i* (*t* = 1,2,..,6 and *i* = 1,2)
X_{fti} = The amount of hours check-up type *f* needed within time span *t* following from an hour of appointments at section *i* (*f* = 1,2 and *t* = 1,2,..,6 and *i* = 1,2)

Formula 1: Number of hours needed in the coming three months at the OC

$N_1 + \sum(Y_{it} * X_{2ti})$

Formula 2: Number of hours needed in the coming three months at the EC

$N_2 + \sum(Y_{it} * X_{1ti})$

4.1.4 Heuristic to improve the distribution of program time over the endoscopic centre- and the outpatient clinic programs

The formulas presented in Section 4.1.3 calculate the needed amount of program hours for the coming three months, per section. The amount of program hours is based on the amount of program hours of the past. But, what if there are not enough hours available to fulfil the needed amount of hours for a period? For the balance, it is important to divide the available program hours over the section according to the ratio determined by dividing formula 1 by formula 2. In this way, the (relative) shortage of hours is equal for both sections: both sections will experience an increase in access times, instead of one section having a large increase and the other having no increase at all. Using the ratio as a heuristic to divide the available program hours ensures a smooth patient flow.

4.2 Model addressing sub problem 2: Empty slots in the schedule

This section focuses on building a model for the second sub problem: empty slots in the schedule. First, we elaborate on the type of model we choose (Section 4.2.1). After this, we describe our model in words and present a flow chart of the model in Section 4.2.2. In Section 4.2.3, we explain how we collected and processed the data. Section 4.2.4 shows the assumptions we made before programming the model. Then, Section 4.2.5 explains how the model is programmed and finally, in Section 4.2.6 we verify and validate the model.

4.2.1 Selection of model type

According to Law (2007), there are two main ways to study systems: experimenting with the actual system and experimenting with a model of the system. Though experimenting with the actual system is desirable in terms of validating the study, this way is almost always very costly and risky. This is also the case with our sub problem: since we are dealing with the lives of patients here, it is not desirable to conduct experiments on the actual system.

Law (2007) also mentions two different ways to model a system: building a physical model or building a mathematical model. Since building a physical model is very costly, we decide to build a mathematical model. Obtaining an exact analytical solution from a mathematical model is only possible if we have insight in the exact impact of the effects our proposed interventions have. Unfortunately, we do not have this information. To get an idea of the impact of our interventions, we therefore conduct a simulation study on the model of our system. Figure 4.2 summarizes the different ways to study a system (Law, 2007).

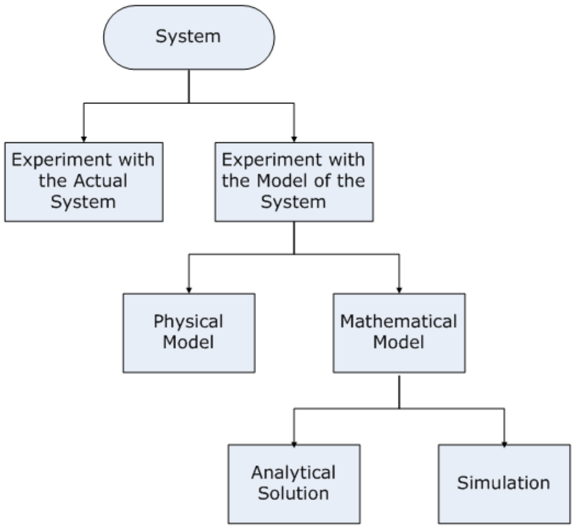


Figure 4.2 Ways to study a system (Law, 2007)

Executing a simulation study ideally involves the following ten (sometimes iterative) steps (Law, 2007):

1. Formulate the problem and plan the study
2. Collect data and define a model
3. Determine if the assumptions document is valid
4. Construct a computer program and verify
5. Make pilot runs
6. Determine if the programmed model is valid
7. Design experiments
8. Make production runs
9. Analyze the output data
10. Document, present and use the results

A visual overview of these ten steps and their iterative processes is found in *Appendix G*. These ten steps are used in the remaining sections and chapters of this report to structure our simulation research. Steps 1 until 6 are performed in this chapter (Chapter 4), steps 5 until 9 are performed in Chapter 5, and finally the results are documented and presented in Chapter 6 (step 10).

4.2.2 Conceptual model

The overall objective of this study is to bring down the access times of the OC (a section of the GHD). We hereby focus on the empty slots in the schedule caused by slots not filled by planners, no-shows, and emergency programs not fully booked. In order to design a model of the OC, we create a flow chart in order to visualize the different inputs we need. The flow chart of patients in need of an appointment at the OC is shown in Figure 4.3.

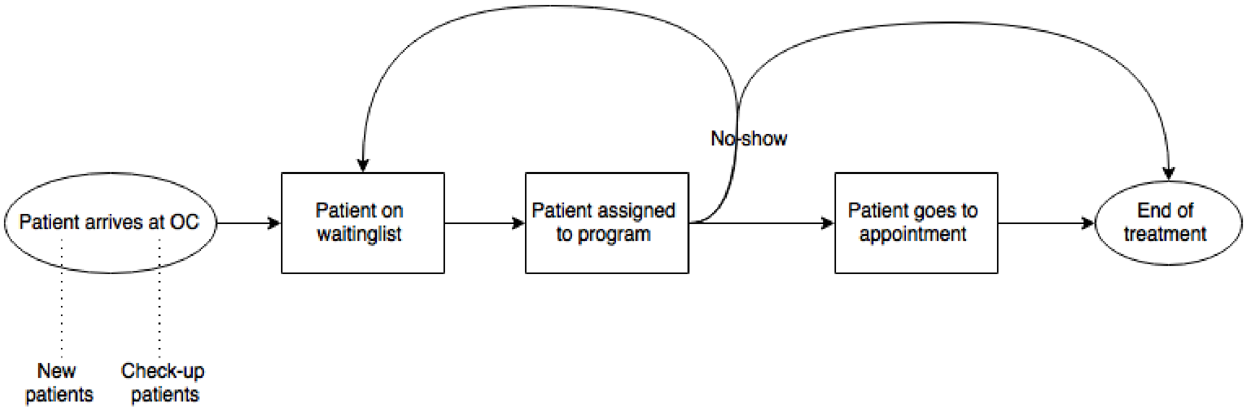


Figure 4.3 Flow chart of the patients in need of an appointment at the OC

From Figure 4.3, we recognize two different patients groups are arriving at the OC: **new patients** and **check-up patients**. For both new and check-up patients, we need to determine an arrival pattern, and the types and durations of appointments they need. Second, we need to determine what number of **programs**, types of programs and duration of programs to include in our model. And third, we need **assignment rules** to determine which patients are scheduled into which programs.

However, not all patients go to the appointment they are scheduled for. Some patients do not show up for their appointment and therefore become **no-shows**. Some of these patients do not get a new appointment at the OC after not showing up. This is caused by patients not responding to phone calls of the OC or by patients who think they not need a new appointment anymore. The patients who do want a new appointment are placed on the waiting list again. We therefore also need to take into account the number of no-shows and their chance of returning to the OC again when building a model. Next to this, it is important to take into account the time span between their no-show appointment and their replacement appointment.

4.2.3 Collecting and processing of data

We collect data of the year 2014 from X-care and the fax reports. Although it is preferable to use the most recent data, we decide not to use data from 2015. There were two doctors unavailable during the first months of 2015 and therefore the GHD was not operating under normal circumstances during that period. Furthermore, in 2013 most patients got a general appointment type (such as CP) whereas in 2014, most patients got a more specific appointment type (such as CPIBD). This caused a change in both the check-ups and the program types executed and therefore we choose to only use data from 2014 as a base of the inputs of our model.

In order to find the underlying theoretical distributions for our inputs, we use the program Minitab to statistically analyse the historical data of the OC. To test what distributions fit our data, several goodness-of-fits tests can be used. Law (2007) mentions three: the Chi-square test, the *Kolmogorov-Smirnov test* (KS test), and the *Anderson- Darling test* (AD test). With the chi-square test, a histogram is used to compare the historical data with the density or mass function of the fitted distribution. Since it is assumed to be difficult to specify the intervals for the histogram, we decide to not use the chi-square test. We decide to use the AD test to find the underlying theoretical distributions for our inputs. The AD does a better job in detecting discrepancies in the tails compared to the KS test. Many distributions show significant differences in their tails and with the KS tests, the same weight is given to the differences for every value in the data set (Law, 2007).

We use the AD test to test for the Exponential, Gamma, Weibull, Normal, and Lognormal distributions since these are the most commonly used distributions according to Law (2007). After conducting the AD test, we check the corresponding p-values. If a p-value of a distribution is higher than 0.05, we assume it is possible the historical data fits that distribution. We then check the AD value: if this value is substantially lower than the others, we assume the distribution fits the historical data. When this method results in no fit, we check the graphs presented by Minitab with the naked eye to find out whether there is a distribution which comes close to fitting our data. When this again results in no fit, we work with discrete distributions. Calculations for discrete distributions are performed in Excel.

4.2.4 Assumptions

We made the following eleven assumptions when building our model:

1. To keep a clear overview, we use a 2% cut-off point in some of the calculations. A 2% cut-off point means that when a value of a variable occurs less than 2% of the time, this value is omitted from the model. For example, when less than 2% of the appointments of type NP have a duration of 0.25 hours, we exclude a duration of 0.25 from the inputs. To avoid bias caused by missing data due to our cut-off point, we sometimes create remainder groups for variables. In Section 4.3.5, which introduces our inputs, it is indicated when the cut-off point is used and how we avoided bias.
2. The arrival of patients and the number of programs scheduled at the OC are influenced by the day of the week and the week of the year. There might be more external factors of influence, but since there is not much known about these influences and since they are (almost) not predictable, we omitted other factors. Including day and week variation is chosen because the number of staff members available varies over the days of the week (due to non-clinical days) and per week of the year (due to holidays). Furthermore, we assume the number of patients visiting their GP for a referral to the GHD varies over the days of the weeks (for example due to complaints during the weekends which can wait until Monday) and per week of the year as well (again, due to holidays).
3. We model the arrival of new patients and check-up patients separately. It would be more logical to let new patients stay in the system and after some time return for a check-up. But since we only have reliable data of a year, this is not possible and we simulate both patient groups separately.
4. When there is no significant difference between to samples (for example Mondays and Thursdays), we merge these samples into one sample and fit it to one distribution.
5. The distribution over the different program types, appointment types, program durations, appointment durations, and no-show proportions is independent of the day of the week and the week of the year. Although it would be better to use a day- and week factor for these variables as well, this is not possible since we only have very small samples in this case.
6. Appointment durations of the check-up patients and replacement appointments of no-shows are equal. The appointment types for both groups are equal and therefore we assume the durations are equal as well.
7. There is a maximum of one emergency program per day. In 2014 there were only two days with two emergency programs scheduled (on a total of 131 days with emergency programs).
8. The correct data is situated in BO and the fax reports contain some mistakes. There is a difference between these two data sources and since the fax reports are adapted manually, we assume these include some mistakes.
9. Patients arrive in batches per day without specific arrival times. Since our research does not include measurements on hours (but on access time in weeks), we do not need more specific arrival time measurements.

10. Within the data set, we delete replacement appointments of no-shows when calculating arrival patterns of new and check-up patients. These replacement appointments are included with the 'input' no-shows.
11. After discussion with a GH doctor, we decide to use six different time spans in which replacement appointments of no-shows can take place: in less than three weeks, in three to six weeks, in six weeks to three months, in three to six months, in six to nine months, and in nine to twelve months.

4.2.5 Programmed model

Input factor new patients

Arrival pattern

The mostly used distribution to model the arrival process of customers (e.g. patients) is the Poisson process. There are three main requirements for an arrival process to be a Poisson process (Law, 2007):

1. Customers arrive one at a time
2. The number of arrivals in a time interval is independent of the number of arrivals in an earlier time interval
3. The number of arrivals does not depend on the time of the day, the day of the week, etc.

However, since two of the three requirements of the Poisson process are not met by the arrival process of new patients, we cannot use the Poisson process. Doctors only process the arrivals once a day (they check the pile of referrals once a day) and since the exact time of arrival does not matter for our model (we are only interested in access time in weeks), we assume our patients arrive in batches. Thus, we do not meet requirement 1. Next to this, we assume there is a difference in arrivals per day of the week and per week number of the year. Thus, we do not meet requirement 3 as well. Therefore, we obtain a parameter Anew (Arrival of new patients) by calculating the number of patients arriving per day (depending on the day of the week) and multiplying this number with a week factor.

$Anew_{d,w} = \alpha_d * \beta_w$

$Anew_{d,w}$	Number of new patients arriving per day d in week w with $d \in 1,2,..,5$ and $w \in 1,2,..,52$
α_d	Number of arrivals per day d with $d \in 1,2,..,5$
β_w	Week factor w with $w \in 1,2,..,52$

To overcome the difference between the arrival of new patients in the fax reports and X-care, we decide to use the number of arrivals of X-care, but the arrival dates of the fax reports (there are no arrival dates registered in X-care). We first use two-sample t-tests to determine whether there are significant differences between the days of the weeks. The outcomes of these tests are found in Table 4.5.

Table 4.5 The p-values of the two-sample t-tests used to find out if there are significant differences between the days of the weeks considering the arrival of new patients (Confidential, X-care & Fax reports, 2014)

	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
MONDAY	0.632	0.083	0.089	0.914
TUESDAY	-	0.190	0.198	0.688
WEDNESDAY	-	-	0.978	0.080
THURSDAY	-	-	-	0.087
FRIDAY	-	-	-	-

From Table 4.5, we conclude there are no significant differences between the days of the week. However, some of the p-values are relatively low and therefore we distinguish two different groups: Monday & Tuesday & Friday and Wednesday & Thursday. We try to fit statistical distributions against our historical data. However, merging (some of) our data resulted in no fitting statistical distributions at all (see *Appendix H1*). Therefore, we decide to determine distributions for the days of the weeks separately. Table 4.6 shows the fitted distributions and their parameters according to the AD tests. *Appendix H1* shows the outcomes of the AD tests for all tested distributions. *Appendix H1* also shows the graphs of the distributions where no match was found according to the p-values and where we used the naked eye to fit a distribution.

Table 4.6 The distribution functions used to model the number of new patients arriving per day of the week (Confidential, Fax reports & X-care, 2014)

DAY FACTORS FOR	**DISTRIBUTION**	**PARAMETERS**[5]	
		P1	P2
MONDAY			
TUESDAY			
WEDNESDAY	*Confidential*		
THURSDAY			
FRIDAY			

Figure 4.4 shows a graph of the week factors used for parameter Anew. We calculate the number of programs executed per week and calculate how far this number is from the average number of programs executed per week. Unfortunately, we only have data of 2014 and we therefore have to take into account that the week factors we calculate might not be (entirely) correct. Furthermore, there is no clear pattern visible for the week factors as well. To overcome this bias, we used the week factors randomly over the course of the year. This means, each week we select a random week factor out of the calculated week factors. After a week factor is used, it is deleted for the rest of the year in order to use all week factors calculated only once a year.

[5] *Confidential*

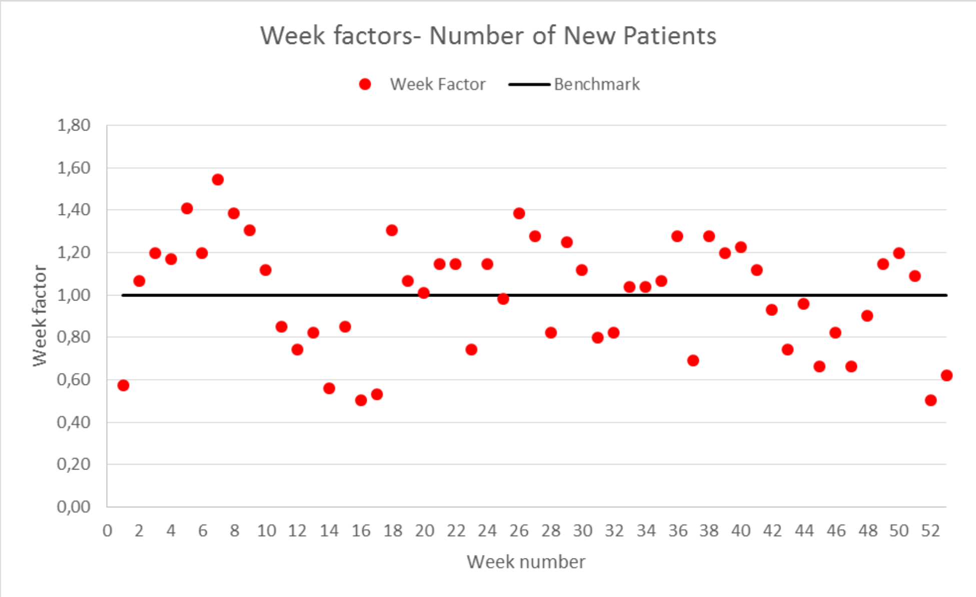


Figure 4.4 The week factors with regard to the number of new patients arriving at the OC (Confidential, Fax reports & X-care, 2014)

Appointment types

New patients are assigned an urgency code by the department doctor according to the urgency with which they need an appointment. Urgency codes vary between 1 and 5, where 1 indicates the patient needs an appointment within a time span of a week and 5 indicates the patient needs an appointment within a time span of three months. More information about the urgency codes is found in Chapter 2.2.4.

Figure 4.5 shows a pie chart of the proportions of each urgency code within the total number of new patients.

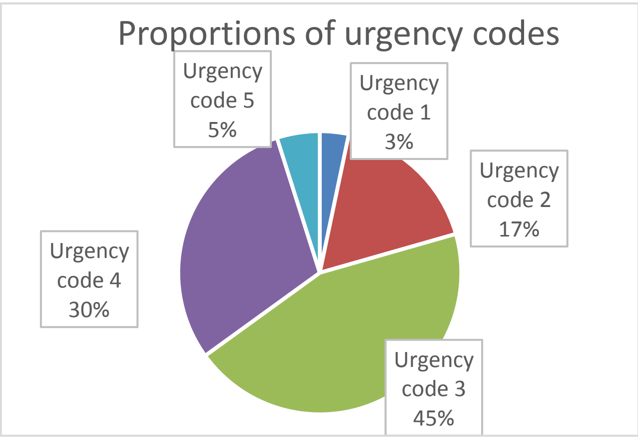


Figure 4.5: Proportion of the separate urgency codes within total number of new patient appointments (Confidential, Fax reports & X-care, 2014)

Appointment durations

We used discrete distributions for the durations of the appointments of new patients. These durations are found in Table 4.7. We use the 2% cut-off point here, and omit patients with durations that occur in less than 2% of the appointments.

Table 4.7 Proportions of appointment durations within the total number of new patient appointments (Confidential, Fax reports & X-Care, 2014)

URGENCY CODES 1 &2 **DURATION PROGRAM** (IN HOURS)	**PROPORTION**
0.5	0.061
0.75	0.939

URGENCY CODES 3, 4 & 5 **DURATION PROGRAM** (IN HOURS)	**PROPORTION**
0.25	0.034
0.33	0.065
0.5	0.247
0.75	0.539
1	0.115

Input factor check-up patients & input factor programs

The input factors check-up patients and programs are calculated in a similar way as the input factor new patients. We again calculated arrival patterns (or number of programs, for the input factor programs) varying for days of the weeks and for weeks of the year. Furthermore, we calculated the proportions in which appointment- and program durations occur. Because these calculations are approximately equal to the calculations for the new patients, we do not present them here, but they are presented in *Appendix H2 and H3.* We do present the included appointment types for the check-up patients, and the included program types below.

Appointment types (check-up patients)

We include appointment types CP, *Check-up patient doctor* (CPdoc), CPIBD, CPL, TC, VCP, and remainder. Appointments CP, CPIBD, CPL, TC, and VCP are included by using the 2% cut-off point. The total appointment duration of these types made up more than 2% of the total appointment duration of all appointment types in 2014. To avoid bias by leaving out several appointment types, we created types: remainder, and CPdoc. Remainder includes all remaining appointment types executed by both doctors and nurses. CPdoc includes all remaining appointment types executed by doctors only. Remaining appointment types only executed by nurses are merged with appointment type VCP. An overview of the proportions of each included appointment type of the total number of check-up patients is found in Figure 4.6.

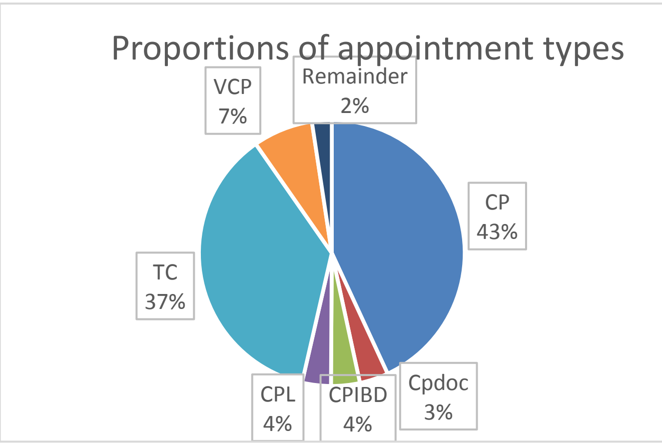


Figure 4.6 Proportion of the separate appointment types within total number of check- up appointments (Confidential, X-care, 2014)

Program types

We distinguish five different program types in our model: emergency, general, IBD, liver, and nurse programs. Doctors have different abilities in terms of which appointment types they are able to execute. For simplicity, we assume that appointment type remainder can be executed by all doctors and nurses. Combining these abilities with the included appointment types described above (NP, CP, CPdoc, CPIBD, CPL, TC, VCP, and remainder), we have four groups of doctors. Furthermore, we include emergency programs for patients with urgency codes 1 or 2. Table 4.8 gives an overview of the included program types and the appointments executed within these programs

Table 4.8 The program types included in the model and the appointments executed within these programs

PROGRAM TYPE	APPOINTMENTS EXECUTED IN THE PROGRAM
EMERGENCY PROGRAM	NP (Urgency codes 1 and 2)
GENERAL PROGRAM	NP (Urgency codes 3, 4, 5), CP, CPdoc, TC, and Remainder
IBD PROGRAM	NP (Urgency codes 3, 4, 5), CP, CPdoc, CPIBD, TC, and Remainder
LIVER PRORAM	NP (Urgency codes 3, 4, 5), CP, CPdoc, CPL, TC, and Remainder
NURSE PROGRAM	CP, CPIBD, TC, VCP, and Remainder

An overview of the proportions of each included program type of the total number of programs is found in Figure 4.7.

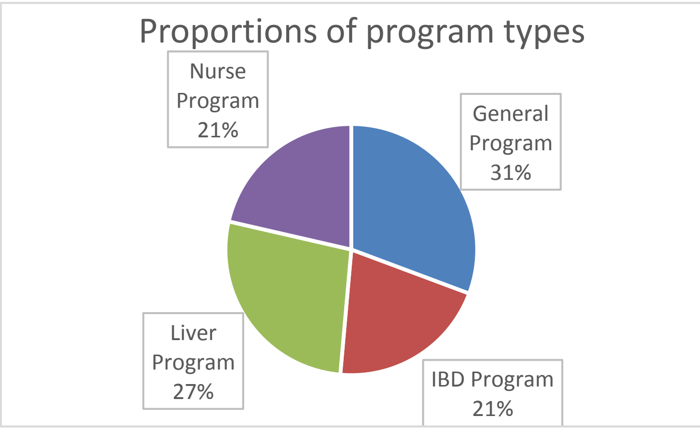


Figure 4.7 Proportion of the separate program types within total number of programs (2617 programs, X-care, 2014)

Input factor no-shows

Number of no-shows

The secretaries state that there is a difference in no-show rates per appointment type, for example liver (alcoholic) patients tend to not show up for their appointment more often than other type of patients. Therefore, we determine the chance of becoming a no-show per appointment type. This information is presented in Table 4.9.

Table 4.9 Proportion of no-shows, measured per appointment type (Confidential, X-care, 2014)

APPOINTMENT TYPE	PROPORTION NO-SHOWS
NP	0.041
CP	0.055
CPDOC	0.034
CPIBD	0.049
CPL	0.070
TC	0.011
VCP	0.093
REMAINDER	0.010

Chance of returning to the OC

When patients not show up for their appointment, they usually get a new appointment date and time. However, some of these patients do not respond to phone calls of the OC to reschedule, and some patients think they do not need a new appointment. Therefore, some of the no-shows are not returning to the OC anymore. When a patient does not get a new appointment within a year, we mark this patient as 'no new appointment after no-show'. We choose a year as a cut-off point, since the OC recognizes all patients that had no consult in the past year, as new patients.

When patients do return, they usually return for the same type of appointment, but it also happens that they come back for a different type of appointment. For example, a patient not showing up for his or her nursing consult (VCP) might visit the OC again for a check-up consult at a doctor (CP). Whenever patients return to the OC for a replacement appointment, it is of importance to determine the time span within which they return.

To summarize, a no-show patient has three possible routes: no new appointment (1), a replacement appointment of the same type (2), or a replacement appointment of a different type (3). We calculate the proportion of patients following each route, per appointment type. These proportions are found in Table 4.10. We used the 2% cut-off point here and left out patients with routes occurring less than 2% of the time.

Table 4.10 Proportion of patients following a particular route after not showing up for their appointment, per appointment type (951 no-shows, X-care, 2014)

	NP	CP	CPDOC	CPIBD	CPL	TC	VCP	REMAINDER
NO NEW APPOINTMENT (ROUTE 1)	0.452	0.262	0.294	0.143	0.143	0.282	0.034	0.000
SAME APPOINTMENT (ROUTE 2)	0.476	0.539	0.529	0.357	0.536	0.459	0.545	0.000
DIFFERENT APPOINTMENT (ROUTE 3)	0.071	0.199	0.176	0.500	0.321	0.259	0.420	1.000

Then, we determine the time spans within which new appointments take place for route 2 (again using the 2% cut-off point). We also determine which combinations of appointments (no-show appointment and replacement appointment) are taken for route 3 and determine the time spans for this route as well. The outcomes of the calculations for routes 2, and 3 are found in *Appendix H*.

Assignment rules

All patients arriving at the OC are sorted once they enter the waiting list. They are sorted on the days they have left until they should get an appointment (ascending), their urgency code (ascending), and their appointment duration (descending). In this way, we determine which patient has the highest priority to be scheduled. We hereby choose to schedule patients with the longest duration first, because it is more difficult to fit these patients into the programs. Since patients with urgency 1 are always scheduled as fast as possible, we set the 'days left' for these patients at 0.

We loop over all the available programs and make several checks to determine whether the patient of consideration fits into a program. The questions below need to be answered with a yes before the patient is scheduled.

1. Is the patient suitable, with regard to his or her appointment type?
2. Does adding the patient to the program not result in overtime?
3. Is the program date equal to or later than the entrance date of the patient?

Furthermore, there are several slots reserved for new patients. If these are filled, new patients cannot be scheduled into these programs anymore. If these are filled, but there is still some time left intended for new patients (occurs when a new patient appointment was shorter than anticipated), this time is made available for check-up appointments again.

Our model is built with PlantSimulation, a discrete-event simulation program. Figure 4.8 shows a screenshot of the main frame of our model.

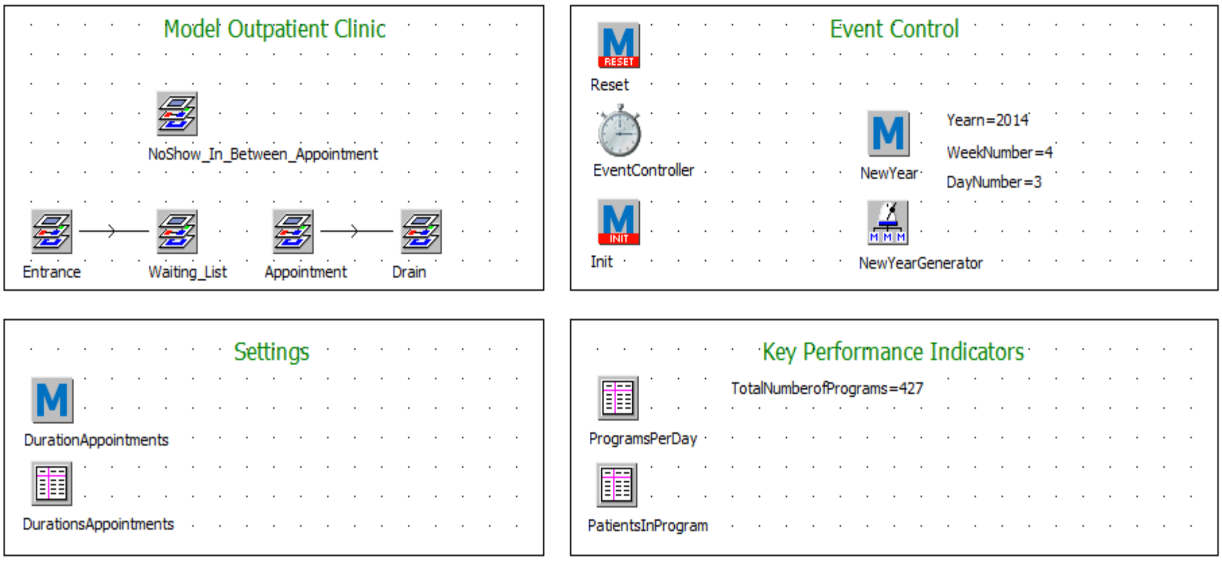


Figure 4.8 A screenshot of the main frame of the model of the OC (PlantSimulation, 2015).

4.2.6 Verification and validation of the model

Verification

When a model is programmed, the model should be verified before it is used to test interventions. Verification is concerned with whether the assumptions document has been correctly translated into a programmed simulation model (Law, 2007). Verification tries to find an answer on the question: Are we building the product right? (Scottish Qualifications Authority (SQA), 2006)?

Law (2007) describes various techniques used to verify simulation models of which several were used to verify our programmed model. First, we developed a simplified model of the OC and checked this for bugs. After this, we gradually added more and more details to make it a good representation of the real OC. After each addition, we ran the program again and debugged it. With this iterative process, we overcame the problem of untraceable debugs after programming an entire model at once.

Second, we ran the model with various settings of the input parameters in order to check the reasonability of the output. Third, we observed animations of the simulation output during the programming to see if there were any errors visible with the naked eye. This led to the discovery of several errors. At several points in time, it seemed patients got stuck somewhere in the process of getting an appointment. These errors were easily discovered by watching the simulation animation.

A final technique used to verify our model was the comparison between the input factors as calculated in the simulation model and the historical data we based our input factors on. Table 5.10 shows the differences between the data in the model and the historical data with regard to the mean number of arrivals of new- and check-up patients, and the mean number of programs scheduled, per day of the week. Verification of the proportions of appointment- and program types, appointment- and program durations, and no-shows are presented in *Appendix I*. We used a rung length of six years here, and made eight replications. Since our inputs are measured per (working) day of the week (implying more than 12,000 measurements are included), we assume this is sufficient.

Since we used our week factors randomly over the course of a year, it is hard to verify this part of the inputs. Therefore, we assume that when the daily arrivals and the total arrivals per year are similar to the values of the historical data, the week factors in the model are acceptable as well.

We assume the input parameters of Table 4.11 are acceptable, since they show a maximum difference of 5.4%, indicating the modelled inputs do not differ greatly from the historical data. We detected one error: on Thursdays and Fridays too many check-up patients were arriving. We therefore split up those two days again and determined their distribution functions separately. *Appendix I* shows the outcomes of the AD tests for the tested distributions, and the shape and scale factor of the best fitting distributions.

Table 4.11 The differences between the data in the model and the historical data with regard to the mean number of arrivals of new- and check-up patients, and the mean number of programs scheduled, per day of the week (Confidential number of new and check-up patients & 115,718 programs, Fax reports & X-care, 2014)

INPUT FACTOR	**DAY OF THE WEEK**	**MEAN -MODEL** (MEASURED IN WEEKS)	**MEAN –HISTORICAL DATA** (MEASURED IN WEEKS)	**DIFFERENCE IN PERCENTAGE**
NEW PATIENTS	Monday			
	Tuesday			
	Wednesday			
	Thursday			
	Friday		*Confidential*	
CHECK-UP PATIENTS	Monday			
	Tuesday			
	Wednesday			
	Thursday			
	Friday			

PROGRAMS	Monday	10.3	10.8	4.5%
	Tuesday	11.9	12.3	3.8%
	Wednesday	7.5	7.9	5.4%
	Thursday	10.6	11.0	3.4%
	Friday	9.1	9.6	4.9%

Validation

Validating the model involves determining whether a simulation model is an accurate representation of the actual system which is being studied (Law, 2007). Validation tries to find an answer on the question: Are we building the right product (Scottish Qualifications Authority (SQA), 2006)?

Law (2007) describes various classes of techniques used to increase the validity and credibility of simulation models. Several of those techniques were used to validate our simulation model. The first technique we used, is collecting high-quality information and data by having conversations with subject-matter experts. We discussed the goal, the different interventions and the input factors with GH doctors, and the team managers of the GHD. Half-way through the process we also presented our observations with the GH doctors. During this meeting, we were, amongst other things, notified about the different proportions of no-shows amongst the various appointment types. This prevented us from a programming error for the input parameter no-shows. We also observed the system to ensure we collect high-quality information: we used X-care, and the fax reports to obtain historical data for the input factors and the existing system. Furthermore, we observed the way of planning patients by following the planners during a day of work.

A second technique we used is interacting with the manager on a regular basis. We had several meetings with the team managers, business manager, and the medical manager of the department. We thereby tried to involve them into the process, plus we presented and checked our assumptions with them.

Third, as presented in Section 4.3.4, we made an assumptions document which sums up all the assumptions we made during the process of programming the model of the OC. Some of the assumptions were only made to restrict the number of details in the model, others were made because of the lack of information.

Fourth, we used animation again to check for errors in the process flow of the model.

Finally, we compared the output of our model with the output of the existing system by comparing the measurements of the KPIs of Chapter 2 with the output tables of our model. This comparison resulted in the discovery of two errors. The first mistake we discovered was the utilization rates of the emergency programs being too low. Although it is not possible according to the rules and regulations of the GHD, non-emergency patients are sometimes scheduled in the emergency programs. We calculated that on average 0.31 hour of an emergency program is used by non-emergency patients. Therefore we decided to let non-emergency patients fill up a maximum of 0.33 hours of the total program time of an emergency program.

The second mistake: though the employees of the OC state they reserve two slots for new patients in each A(N)IOs program and one slot for a new patient in each doctor program, this does not match reality. According to the data extracted from BO, the OC reserves far less spots for new patients. When check-up patients need an appointment, secretaries sometimes delete reservations for new patients.

We therefore made the assumption that there are only spots reserved in general programs with a duration of 2.5 hours or longer and in IBD and liver programs with a duration of 2.75 hours or longer. This assumption is made because this results in a similar amount of new patient slots as we saw in the real system. This assumption gets us closer to the way of operating at the OC, but since exact calculations are not possible here, this still results in some bias.

Table 4.12 shows the differences between the data in the model and the historical data with regard to the KPIs clinical throughput and idle time. We used a rung length of six years here, and made eight replications. Since our outputs are measured either per program implying more than 90 000 programs or per year, we assume this is sufficient. We assume the output parameters of Table 4.12 are acceptable, since they show a maximum difference of 5.0%, indicating the outputs of the model do not differ greatly from the historical data.

It is difficult to directly compare the access times of the model with the access times of the existing system. This is firstly caused due to the fact there in practice is no clear rule for reserving slots for the new patients. Second, in reality, doctors sometimes are slightly more flexible in expanding their program time a little to fit in that last patient in need of an appointment. Both are reasons for (slightly) biased access times in the model. From the existing system we conclude the access times for new patients are increasing, since this is also notable in the model and since it is impossible to perfectly match the model with reality, we do not further adapt the model.

Table 4.12 The differences between the data in the model and the historical data with regard to the KPIs clinical throughput and idle time (48 years and 115,718 programs, Fax reports & X-care, 2014)

KPI		**MEAN** (MODEL)	**MEAN** (HISTORICAL DATA)	**DIFFERENCE IN PERCENTAGE**
3. CLINICAL THROUGHPUT (PER YEAR)	NP			
	CP			
	CPdoc			
	CPIBD		*Confidential*	
	CPL			
	TC			
	VCP			
	Remainder			
4. IDLE TIME	Doctors	10.1%	11.5%	
	Nurses	23.9%	23.2%	
	Emergency program	26.7%	27.5%	

4.3 Conclusion

How can we model the GHD in such a way that we can assess interventions focusing on the decrease of access times?

Sub problem 1: Imbalance in the distribution of program time over the EC and the OC
Because of the time restrictions and the importance of sub problem 2, we decided to construct a simple, basic model to address this sub problem. We developed two formulas, each calculating the amount of program time needed for the coming three months for one of the two sections (OC and EC).

The formulas determine the program time needed by measuring the amount of consultation and/or scopy hours within a certain time span following from one hour of consultations or scopies in the past. The amount of program hours needed for each section according to these calculations is supplemented with the influx of new patients for each section. The inputs for the formulas are based on historical data of the GHD.

The balance in the distribution of the program time is improved by dividing the available program hours over the EC and the OC according to a ratio. This ratio is calculated by dividing formula 1 by formula 2. For example, if according to the formulas the OC needs 20 hours of program time and the EC needs 10, the ratio is 2:1. To keep the access times of both sections in balance, the ratio is important even if there is less or more program time available than the total needed hours.

Sub problem 2: Empty slots in the schedule
For the second sub problem we developed a simulation model with a discrete simulation program. We choose to construct a simulation model since analytically solving our problem is impossible due to the unknown (precise) impact of the various interventions.

We programmed the model with the use of several input factors. We simulated new- and check-up patients arriving at the OC and the number of programs scheduled at the OC. Furthermore, we determined the influence of no-shows and took into account the care paths of these no-shows as well. The input factors are calculated by using the available historical data. For both the patients and the programs we take into account differences over the days of the week and over the weeks of the year. We had to make some assumptions on the input factors, because of the lack of data and in order to keep our model from getting too detailed. We for example did not include all, at the GHD available, appointments types in our model.

Exactly translating the OC into a model is impossible. There are, for example, no unambiguous rules available for the reservation of slots for new patients. Furthermore, doctors tend to be more flexible in times of high work pressures and sometimes expand their program time a little to fit in that last patient in need of an appointment. Notwithstanding these limitations of our model, we verified and validated our model by comparing the input- and output factors of the model with the historical data of the OC. We conclude that our model performs sufficiently similar to reality to test our interventions on it.

5 EXPERIMENTS & RESULTS

In this chapter, we first present the experimental approach (Section 5.1). Furthermore, in Section 5.2, we show the results of the executed experiments and provide insight in whether the experiments yield statistical significant improvements. Finally, Section 5.3 draws a conclusion of Chapter 5.

5.1 EXPERIMENTAL APPROACH

This section explains the experimental approach of our research. We start with an overview of the experiments we want to execute using the model we built in Chapter 4 (Section 5.1.1). Then, we present the sensitivity analysis we use to detect the influence of decreasing the number of no-shows (Section 5.1.2). In Section 5.1.3, we recapitulate on the KPIs we use to measure the influence of the interventions on the performance of the OC. Then, we elaborate on the needed warm-up period for our model (Section 5.1.4) and finally, in Section 5.1.5 we determine the number of replications needed in order to draw reliable conclusions from our experiments.

5.1.1 Overview of the experiments

As explained in Chapter 3 and 4, we have several interventions we want to test on our model in order to find the influence on the access times of the OC. Recapitulating on these chapters, an overview of the interventions is presented in Table 5.1.

Table 5.1 An overview of the interventions to be tested on our model of the OC

INTERVENTION	DESCRIPTION OF INTERVENTION
A	Shifting tasks from doctors to nurses
B	Overbooking
C	Carve-out model- less emergency programs
D	Carve-out model- filling emergency programs gradually with non-emergency patients when date of program approaches
E	Reducing the variation in the number of programs per weekday

We translate these five interventions into five experiments. A more comprehensive description of the experiments, as well as the settings used in these experiments is found below:

Experiment 1- Shifting tasks from doctors to nurses

In this experiment we want to test the influence of spreading all patients equally over the available doctors and nurses. In the current situation, nurse programs have a fill rate of around 80%, where the doctor programs are filled for around 90% of the time. We set the fill rate of both the doctor and the nurse programs to 92.4% in our experiment, which is the (exact) current fill rate of the doctors. Furthermore, within the experiments, we do take the restrictions of the medical staff into account with regard to their ability to execute appointment types (for example, nurses do not execute new patient appointments).

We made the decision to restrict the overall fill rate, since we think it is not realistic to have a fill rate of 100% due to the need of some flexibility in the programs. Next to this, having no restrictions on the fill rate will lead to a biased view on the clinical throughput, since we then not only measure the influence of shifting tasks, but also the influence of scheduling more patients into the schedules of all medical staff members. This is not realistic, since it is stated that the doctors already have very full programs.

Experiment 2- Overbooking

In this experiment, we want to test the influence of scheduling more patients into the programs than official possible with regard to the available program time. In the current situation, no overbooking levels are used. Since it is fairly difficult to predict the influence of overbooking on both access times and overtime, we choose to execute this experiment with two different settings. In the first setting, we use an overbooking level of 0.25 hours for liver programs (implying 0.25 hours may be filled outside the actual program times) longer than 2.5 hours and an overbooking level of 0.33 hours for nurse programs longer than 2.5 hour. In the second setting, we use the same overbooking levels, but then for program durations longer than 2.75 hours (for both the liver- and the nurse programs).

We choose to use 0.25 hours and 0.33 hours as overbooking levels, since the mean durations of respectively CPL and VCP appointments are approximately equal to 0.25 hours and 0.33 hours. Most researches tested overbooking for patient groups with no-show percentages of at least 10% which is not comparable to the situation of this research were the mean no-show percentage is 4.1%. However, Zacharias and Pinedo (2013) also provide information on optimal overbooking levels for no-show rates of 5%. Since the appointment types CPL and VCP have the highest no-show percentages (see Section 4.3.5), we decided to only test overbooking levels on the liver- and nurse programs. Furthermore, the 5% no-show rate of Zacharias and Pinedo (2013) is based on programs containing eighteen appointments. To get close to these assumptions, we only use the longest liver- and nurse programs. Since we do not exactly meet the 'demands' of Zacharias and Pinedo (2013), we decide to test overbooking for two different program durations.

Experiment 3- Carve-out model, less emergency programs

In this experiment, we want to test the influence of decreasing the number of emergency programs scheduled per week. In the current situation 2.56 emergency programs are scheduled per week resulting in a fill rate of 64% (assuming only emergency patients are scheduled in these programs). Since a small decrease of the number of emergency programs might already lead to a large increase in the access times of emergency patients, we want to increase the fill rate to 70% by scheduling 2.35 emergency programs per week. In this experiment, we only use the emergency programs for the patients they are intended for, since this is the desired situation.

Since we schedule less emergency programs, we now have extra program time which will be distributed to general programs. Because of this redistribution of program time, we determined new statistical distributions for the input factor programs. *Appendix J* shows the outcomes of the AD tests for all tested distributions per day of the week and shows the shape and scale factor of the best fitting distributions. Furthermore, A*ppendix J* shows the graphs of the distributions where no match was found according to the p-values and where we used the naked eye to fit a distribution. Also, a graph of the new week factors, and a table showing the division of the programs over the different program types is presented in *Appendix J.*

Experiment 4- Carve-out model, filling emergency programs gradually with non-emergency patients when the date of the emergency program approaches

In this experiment, we want to test the influence of filling emergency programs with non-emergency patients when the date of the emergency program approaches. In the current situation, emergency programs are (officially) only used by emergency patients. We test the influence of filling up the program 72 hours (three days) before the program date until 0.75 hour (time needed for one emergency patient) is left empty in the emergency program.

We could have chosen many other settings for this experiment. However, due to time restrictions we choose for this setting, since it seems the most promising one. We choose 72 hours since that is a time-span already discussed for this purpose at the GHD and because there (almost) always is another emergency program within a week from that moment. If the program fills up entirely, urgency 1 patients then have a relatively high chance to be able to be scheduled in a next emergency program, which is still within the required time span of a week. Furthermore, we choose to keep 0.75 hours open for emergency patients, to be more certain these patients have acceptable access times.

Experiment 5: Reducing the variation in the number of programs per weekday
In this experiment, we want to test the influence of reducing the variation in the number of programs per weekday. In the current situation, there is a significant variation visible over the days of the week. We test the impact of an equal spread of programs over the days of the week.

We need to determine a new distribution for the number of programs to be scheduled where we merge all days into one big sample. Figure 5.1 visualizes the merge of the programs into one sample. *Appendix J* shows the outcomes of the AD tests for all tested distributions per day of the week and the graph of the fitted distribution since there was no match found according to the p-values and we used the naked eye to fit a distribution.

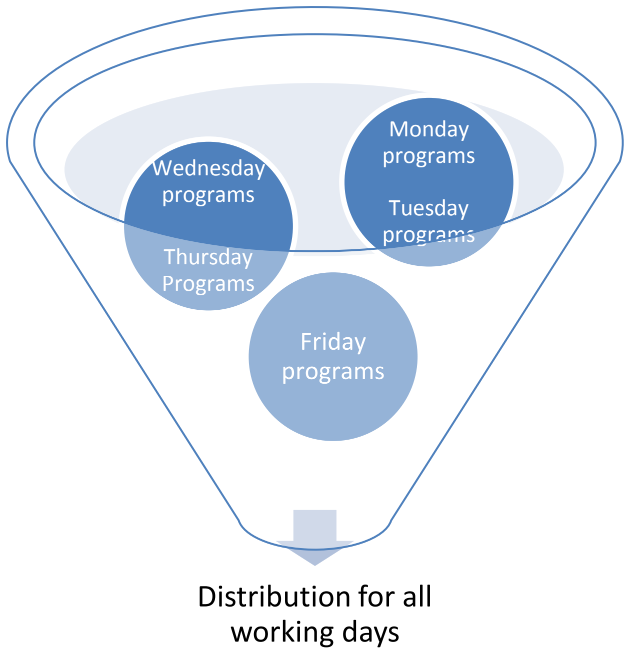


Figure 5.1 A visualization of the distribution function that needs to be fitted for experiment 5

5.1.2 Sensitivity analysis
As explained in Chapter 3 and 4, we want to perform a sensitivity analysis in order to measure that decreasing the no-shows could have on the access times of the OC. Since we are not sure if, and with what percentage we are able to decrease the no-shows, we decide to use two different settings in the sensitivity analysis. We run the model with no-show rates that are 10% and 20% lower than the no-show rates of the current situation. Table 5.2 shows the proportion of no-shows per appointment type in the current, and the two experimental situations.

Table 5.2 Proportion of no-shows, measured per appointment type (Confidential number of no shows in the current situation, X-care, 2014)

APPOINTMENT TYPE	PROPORTION OF NO-SHOWS		
	CURRENT SITUATION	10% DECREASE	20% DECREASE
NP	0.041	0.037	0.033
CP	0.055	0.049	0.044
CPDOC	0.034	0.031	0.027
CPIBD	0.049	0.044	0.039
CPL	0.070	0.063	0.056
TC	0.011	0.010	0.009
VCP	0.093	0.084	0.075
REMAINDER	0.010	0.009	0.008

5.1.3 Key performance indicators used to measure the effects of the interventions

Table 5.3 recapitulates on the KPIs we described in Section 2.4.2. These KPIs are used to measure the effects of the interventions on the performance of the OC.

Table 5.3 The KPIs used to evaluate the interventions tested on the model of the OC

KPI	*DESCRIPTION*
1. MEAN ACCESS TIME	The mean access time in weeks, per urgency code
2. ACCESS TIMES- INTERNAL & EXTERNAL STANDARDS	The percentage of patients which had an appointment in time according to the internal and external standards
3. CLINICAL THROUGPUT	The number of appointments scheduled per year
4. IDLE TIME	a. The amount of no-show hours as a percentage of the total amount of program hours (for doctors, nurses, and emergency programs separately) b. The amount of not used hours (hours not filled + no-shows) as a percentage of the total amount of program hours (for doctors, nurses, and emergency programs separately)
5. OVERTIME MEDICALL STAFF	The amount of overtime in hours divided by the total amount of program time in hours

5.1.4 Warm-up period

Simulations are either *terminating* or *nonterminating*; a simulation is terminating when there is a 'natural' event specifying the length of each run (replication). When there is no such event and one is interested in the behavior of the system in the long run with a 'normally' operating system, one is dealing with a nonterminating simulation (Law, 2007). We have three different KPIs intended for the measurements in this model: access times, clinical throughput, and idle time of the medical staff. Both the idle time and the clinical throughput get into a steady state after some time (the access times keeps increasing over time). We want to know the value of these steady state parameters on the long term (under normal conditions). Since we are dealing with steady state parameters, our simulation is a nonterminating simulation.

For non-terminating simulations, observations from the beginning of a simulation run, depend on the initial conditions (in this case an empty planning), and are not representative for steady state behavior. These first observations (the warm-up period) should therefore be ignored in calculating the performance of the system (Law, 2007). In order to decide how many observations we have to omit to correctly calculate the performance of the system, we use the graphical method of Welch to determine the length of the warm-up period.

Using Welchs graphical method, we determine the warm-up period for the clinical throughput per day. The idle time percentages are dependent on the clinical throughput and therefore we do not calculate a warm-up period for this KPI separately. We assume the parameter clinical throughput takes about a year to get stable due to no-show patients which have a chance to come back to the OC within a year after not showing up. The no-show patients can get such a replacement appointment within a year in all experiments, so therefore we can use any of the experiments or the current situation for Welchs graphical method. We use the current situation to determine the warm-up period.

Figure 5.2 shows the graph with the moving averages. From this graph we conclude, we indeed need a warm-up period from approximately a year (260 observations).

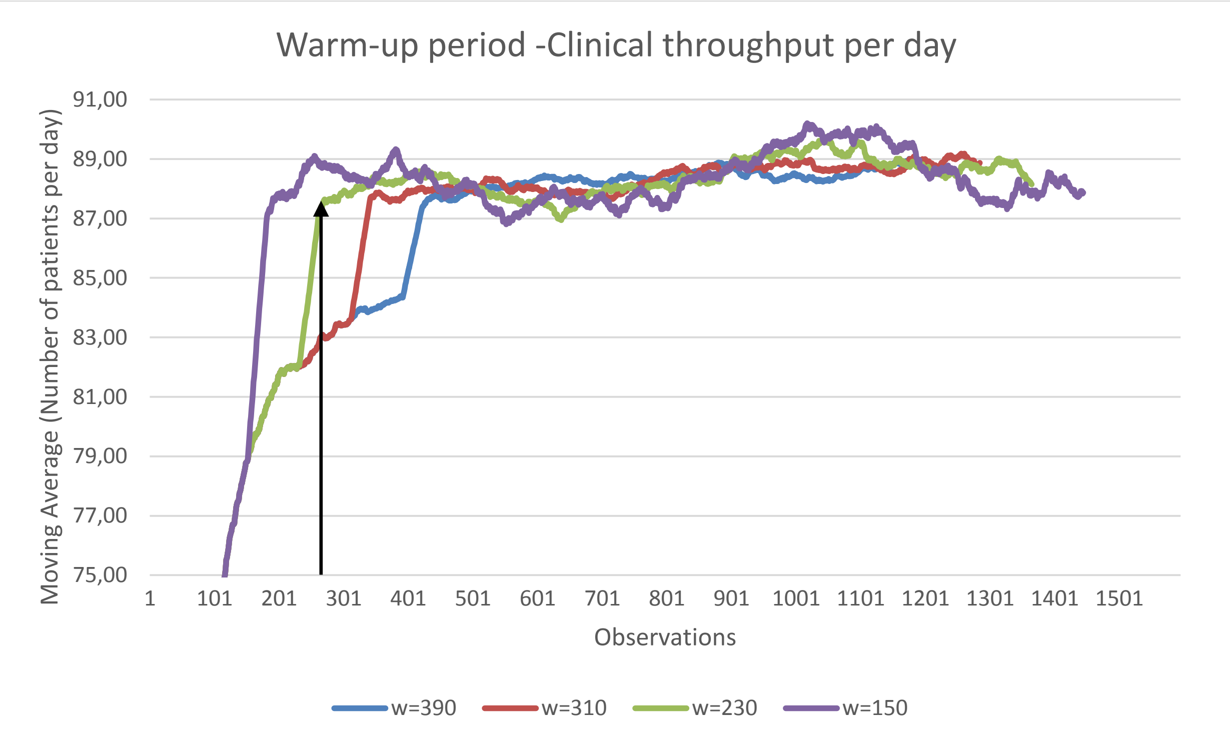


Figure 5.2 The moving averages (calculated with Welchs' method) of the daily throughput of patients, the arrow indicates the warm up period h (260 working days)

5.1.5 Number of replications

We decide to use a run length of six years since Law (2007) explains one should specify a run length much larger than the warm-up period. In order to determine the steady state parameters it is important to use an adequate number of runs (or replications). We calculate the number of runs necessary with use of the relative error. According to Law (2007), we need to determine for which minimal n* the estimated relative error ≤ γ'. n* Is calculated by comparing the left hand side of the formula below with the estimate of the relative error (the right hand side of the formula below).

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

We again use the clinical throughput per day as the base of our calculations. The access time of urgency 5 patients is the most fluctuating variable, due to the low priority of helping these patients. Therefore, we use the mean access time per year for this patient group to determine the number of runs. Running the model 28 times is sufficient to determine a point estimate with a relative error of 10% on a 90% confidence interval. We conclude that we should use 28 replications of a run to be able to determine the value of the steady state parameters.

5.2 RESULTS

This section elaborates on the results of the experiments and the sensitivity analysis we conducted on our model of the OC. We start with a description of the results of our five experiments in Section 5.2.1. Afterwards we describe the results of the sensitivity analysis (Section 5.2.2).

5.2.1 Results of the experiments

Tables 5.4 until 5.8 present the results of the current situation and the experiments with regard to respectively KPIs 1, 2, 3, 4, and 5. For experiment 2, A and B are used to indicate respectively the first and second setting. For KPIs 1 and 3, we execute two-sample t-tests where we compare the current situation to the experimental situation in order to determine whether the difference between these two is significant. An asterisk next to a value in Tables 5.4 and 5.6, implies there is no significant difference between the current situation and the experimental situation in question.

Note, as explained in Section 4.3.6, the measurements of the KPIs for the current situation are not an exact match with the measurements of the real system. However, we do use these measurements to be able to make a comparison between the current and experimental situations.

Table 5.4 The outcomes of the KPI Mean access time (KPI1), including the mean access times in 2015 and 2019, with the green, bold values representing the values of the experiments scoring the best on this KPI (we use EXP as abbreviation off experiment)

KPI1 MEAN ACCESS TIME (IN WEEKS)	**CURRENT SITUATION** ('15-'19)	**EXP. 1** ('15-'19)	**EXP. 2A** ('15-'19)	**EXP. 2B** ('15-'19)	**EXP. 3** ('15-'19)	**EXP. 4** ('15-'19)	**EXP. 5** ('15-'19)
URGENCY 1	**0.8 (0.8-0.8)**	**0.8* (0.8-0.9)**	**0.8* (0.8-0.9)**	**0.8* (0.8-0.9)**	1.4 (1.4-1.6)	1.0 (1.0-1.0)	**0.8* (0.9-0.7)**
URGENCY 2	**0.9 (0.9-0.9)**	**0.9* (0.8-0.9)**	**0.9* (0.9-0.9)**	**0.9* (0.9-0.9)**	1.5 (1.6-1.7)	1.1 (1.1-1.1)	**0.9* (1.0-0.8)**
URGENCY 3	5.7 (4.7-6.4)	5.1 (4.5-5.4)	4.9 (4.5-5.0)	5.0 (4.5-5.2)	5.0 (4.1-5.4)	**3.2 (2.7-3.5)**	5.4 (4.2-6.3)
URGENCY 4	7.1 (5.2-8.2)	6.0 (4.9-6.4)	5.5 (4.9-5.7)	5.7 (4.9-6.0)	5.8 (4.5-6.4)	**3.7 (3.0-4.0)**	6.6 (4.7-8.0)
URGENCY 5	10.0 (6.6-11.8)	7.9 (6.1-8.5)	7.0 (6.0-7.3)	7.5 (6.1-7.9)	7.5 (5.3-8.4)	**4.5 (3.4-4.4)**	9.3 (5.9-11.7)
ALL NEW PATIENTS	5.3 (4.1-6.0)	4.6 (3.9-4.9)	4.4 (3.9-4.5)	4.5 (4.0-4.7)	4.6 (3.7-2.4)	**3.0 (2.5-3.2)**	5.0 (3.8-5.9)
ALL PATIENTS	2.9 (1.6-3.8)	1.7 (1.1-2.0)	**1.2 (1.0-1.3)**	1.5 (1.1-1.6)	2.0 (1.3-2.4)	1.7 (1.3-1.9)	2.6 (1.4-3.7)

Table 5.5 The outcomes of the KPI Access time- patients in time according to internal & external standards (KPI2), with the green, bold values representing the values of the experiments scoring the best on this KPI (we use EXP as abbreviation off experiment, INT as abbreviation of internal standards, and EXT as abbreviation of external standards)

KPI2 ACCESS TIMES- INTERNAL & EXTERNAL STANDARDS	**CURRENT SITUATION** (INT-EXT)	**EXP. 1** (INT-EXT)	**EXP. 2A** (INT-EXT)	**EXP. 2B** (INT-EXT)	**EXP. 3** (INT-EXT)	**EXP. 4** (INT-EXT)	**EXP. 5** (INT-EXT)
URGENCY 1	72.8% - 98.9%	72.4% - 98.9%	72.4% - 98.9%	72.3% - 98.9%	54.2% - 93.2%	65.5% - 99.0%	**72.7% - 99.1%**
URGENCY 2	89.6% - 98.8%	89.0% - 98.9%	89.0% - 98.8%	89.0% - 98.9%	73.3% - 92.7%	87.1% - 98.9%	**89.6% - 99.1%**
URGENCY 3	8.0% - 13.4%	10.3% - 17.8%	11.0% - 20.0%	10.3% - 18.0%	13.4% - 23.3%	**49.6% - 61.7%**	10.6% - 18.1%
URGENCY 4	42.8% - 12.6%	57.6% - 16.7%	64.5% - 18.4%	60.7% - 16.7%	62.3% - 21.8%	**84.0% - 58.8%**	48.2% - 17.6%
URGENCY 5	56.8% - 12.4%	73.8% - 16.4%	81.8% - 17.9%	77.1% - 16.2%	76.3% - 21.8%	**90.9% - 57.5%**	61.3% - 17.1%
ALL NEW PATIENTS	37.2% - 30.8%	43.3% - 34.1%	46.1% - 35.7%	44.4% - 34.2%	39.8% - 37.1%	**69.0% - 68.3%**	40.1% - 34.7%
ALL PATIENTS	74.6% (ext)	90.5% (ext)	94.4% (ext)	92.5% (ext)	88.2% (ext)	**92.8% (ext)**	79.4% (ext)

Table 5.6 The outcomes of the KPI Clinical throughput (KPI3), with the green, bold values representing the values of the experiments scoring the best on this KPI (we use EXP as abbreviation off experiment)

KPI3 CLINICAL THROUGHPUT (PER YEAR)	**CURRENT SITUATION**	**EXP. 1**	**EXP. 2A**	**EXP. 2B**	**EXP. 3**	**EXP. 4**	**EXP. 5**
TOTAL NUMBER OF APPOINTMENTS	*Confidential*						

Table 5.7 The outcomes of the KPI Idle time, with the green, bold values representing the values of the experiments scoring the best on this KPI (we use EXP as abbreviation off experiment)

KPI4 MEAN IDLE TIME (AS A PERCENTAGE OF THE TOTAL PROGRAM TIME)		**CURRENT SITUATION**	**EXP. 1**	**EXP. 2A**	**EXP. 2B**	**EXP. 3**	**EXP. 4**	**EXP. 5**
DOCTOR	NO-SHOW	4.1%	4.1%	**3.6%**	3.7%	4.1%	4.1%	4.1%
	TOTAL	**9.9%**	11.4%	10.1%	10.0%	10.4%	10.2%	**9.9%**
NURSE	NO-SHOW	5.6%	5.9%	**4.3%**	4.6%	5.5%	5.5%	5.6%
	TOTAL	24.1%	**15.7%**	16.0%	17.6%	24.2%	24.2%	24.1%
EMERGENCY	NO-SHOW	3.1%	3.0%	3.1%	3.2%	3.3%	3.7%	3.1%
	TOTAL	26.7%	26.3%	26.3%	26.3%	21.1%	**12.9%**	26.7%

Table 5.8 The outcomes of the KPI Overtime, with the green, bold values representing the values of the experiments scoring the best on this KPI (we use EXP as abbreviation off experiment)

KPI5 OVERTIME MEDICALL STAFF (AS A PERCENTAGE OF THE TOTAL PROGRAM TIME)	**CURRENT SITUATION**	**EXP. 1**	**EXP. 2A**	**EXP. 2B**	**EXP. 3**	**EXP. 4**	**EXP. 5**
DOCTOR -OVERTIME	**-**	**-**	0.6% (1.7% for liver doctors)	0.5% (1.3% for liver doctors)	**-**	**-**	**-**
NURSE -OVERTIME	**-**	**-**	1.2%	0.9%	**-**	**-**	**-**

Experiment 1
From Tables 5.4 until 5.8, we conclude experiment 1 results in a significant improvement compared to the current situation. The mean access times of urgency code 3, 4, and 5 patients show a decrease. For example, the mean access time of urgency code 5 patients decreases from 10 to 7.9 weeks. As expected, since we did not change the emergency programs, the access times of the emergency patients (urgency codes 1 and 2) stayed equal. In line with the mean access time, we also notice an improvement of the percentage of non-emergency patients seen in time according to the internal- and external standards.

Since the nurses are handling more patients in this experiment (we set their fill rate higher), the clinical throughput increased significantly. Increasing the fill rate also resulted in less idle time for the nurses.

Experiment 2
From Tables 5.4 until 5.8, we conclude experiment 2 results in significant improvements compared to the current situation on most measured KPIs. However, since this is the only experiment were overtime was allowed, the experiment scored worst on KPI5. The mean access times of urgency code 3, 4, and 5 patients show a decrease. For example, the mean access time of urgency code 5 patients decreases from 10 to 7.0 and 7.5 weeks for respectively settings 1 and 2. As expected, since we did not change the emergency programs, the access times of the emergency patients (urgency codes 1 and 2) stayed equal. In line with the mean access time, we also notice an improvement of the percentage of non-emergency patients seen in time according to the internal- and external standards.

Since we overbooked some of the programs in these experiments, the clinical throughput increased significantly. Furthermore, the idle time due to no-shows decreased in this experiment since we focused on overbooking the programs with the most no-shows. The overall idle time for doctors slightly increased though. This can be explained by the nurses handling more patients in this experiment than in the current situation and they therefore take over part of the work of the doctors.

An important issue of this experiment is the trade-off between the positive effects (decreased access times, higher clinical throughput, less idle time due to no-shows) and the negative effects (overtime) of overbooking. In Figure 5.3, this trade-off is visualized by showing the access time for urgency 5 patients and the overtime of the liver doctors of setting 1 and 2 of experiment 2.

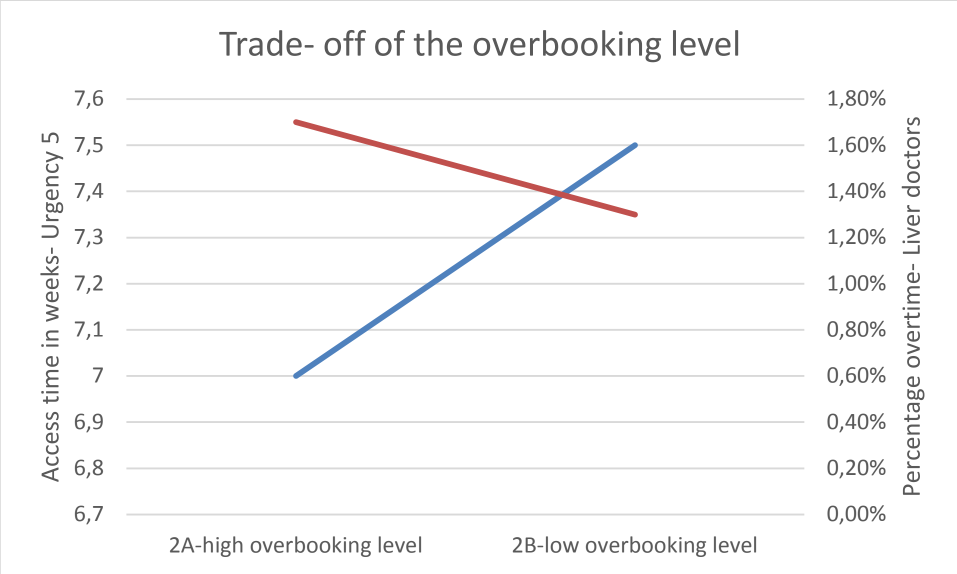


Figure 5.3 The trade-off between access time and percentage overtime when overbooking programs, the red line is indicating the access time and the blue line is representing the percentage overtime

Experiment 3

From Tables 5.4 until 5.8, we conclude experiment 3 results in significant improvements compared to the current situation on most measured KPIs, but the experiment scored worse on KPI1 and 2 with regard to the emergency patients. The mean access times of patients with urgency codes 3, 4, and 5 show a decrease. For example, the mean access time of urgency code 5 patients decreases from 10 to 7.5 weeks. However, creating more programs for check-up patients and less programs for emergency patients, resulted in an increase of the mean access time of the emergency patients with urgency code 1, from 0.8 weeks to 1.4 weeks (an increase of 75%). Since this is above the internal standards, this is not preferable for the OC. In line with the mean access time, we also notice a deterioration in the percentage of emergency patients seen in time according to the internal- and external standards.

The clinical throughput did not change significantly in this experiment. As expected, we see a small decrease in the total idle time of the emergency programs. In line with the decrease of idle time of emergency programs, we see a small increase in the overall idle time of the doctor programs (doctors are more flexible since they have more programs to schedule their patients).

Experiment 4

From Tables 5.4 until 5.8, we conclude experiment 4 results in significant improvements compared to the current situation. The mean access times of urgency code 3, 4, and 5 patients show a large decrease. For example, the mean access time of urgency code 5 patients decreases from 10 to 4.5 weeks. Since some of the non-emergency patients are now seen in the emergency programs, the access times for emergency patients show a significant (but small) increase. Emergency patients with urgency code 1, now have a mean access time of 1.0 week instead of 0.8 weeks in the current situation (an increase of 25%). However, the new access times are still within the internal norms and the percentage of patients seen in time only decreased with 7%.

As expected, we see a large decrease in the percentage of total idle time of the emergency programs (from 26.7% to 12.9%). This decrease of idle time also explains the significant increase of the clinical throughput. Furthermore, we see a small increase in the overall idle time of the doctor programs (doctors are more flexible now since they have more programs to schedule their non-emergency patients).

Experiment 5

From Tables 5.4 until 5.8, we conclude experiment 5 results in a small, but significant improvement compared to the current situation. The access times of urgency code 3, 4, and 5 patients show a slight decrease. The mean access time for urgency 5 patients for example decreases from 10 to 9.3 weeks. As expected, since we did not change the emergency programs, the mean access times of the emergency patients (urgency codes 1 and 2) stayed equal. We see a small increase in the percentage of emergency patients seen in time according to the internal- and external standards. However, this increase is so small that we do not see this as a great improvement. There were no significant improvements or deteriorations visible in the other KPIs.

5.2.2 Results of the sensitivity analysis

Tables 5.9 until 5.12 present the results of the current situation and the settings of the sensitivity analysis with regard to respectively KPIs 1, 2, 3, and 4. We use 'sensitivity-A' and 'sensitivity-B' to indicate respectively the first and second setting of the sensitivity analysis. For KPIs 1 and 3, we execute two-sample t-tests where we compare the current situation to the experimental situations in order to determine whether the differences between these two are significant. An asterisk next to a value in Tables 5.9 and 5.11, implies there is no significant difference between the current situation and the experimental situation in question.

Table 5.9 The outcomes of the KPI Mean access time (KPI1), including the mean access times in 2015 and 2019

KPI1 MEAN ACCESS TIME (IN WEEKS)	**CURRENT SITUATION** ('15-'19)	**SENSTIVITY-A** ('15-'19)	**SENSITIVITY-B** ('15-'19)
URGENCY 1	0.8 (0.8-0.8)	0.8 (0.8-0.8)*	0.8 (0.8-0.8)*
URGENCY 2	0.9 (0.9-0.9)	0.9 (0.9-0.9)*	0.9 (0.9-0.9)*
URGENCY 3	5.7 (4.7-6.4)	5.6 (4.6-6.1)	5.5 (4.6-5.9)
URGENCY 4	7.1 (5.2-8.2)	6.8 (5.1-7.7)	6.6 (5.1-7.4)
URGENCY 5	10.0 (6.6-11.8)	9.5 (6.5-11.0)	9.1 (6.3-10.4)
ALL NEW PATIENTS	5.3 (4.1-6.0)	5.2 (4.1-5.7)	5.0 (4.0-5.5)
ALL PATIENTS	2.9 (1.6-3.8)	2.6 (1.5-3.4)	2.4 (1.4-3.0)

Table 5.10 The outcomes of the KPI Access time- patients in time according to internal & external standards (KPI2), (we use INT as abbreviation of internal standards, and EXT as abbreviation of external standards)

KPI2 ACCESS TIMES- INTERNAL & EXTERNAL STANDARDS	**CURRENT SITUATION** (INT-EXT)	**SENSITIVITY-A** (INT-EXT)	**SENSITIVITY-B** (INT-EXT)
URGENCY 1	72.8% - 98.9%	72.9% - 99.0%	73.3% - 99.1%
URGENCY 2	89.6% - 98.8%	89.6% - 98.9%	89.8% - 99.0%
URGENCY 3	8.0% - 13.4%	8.2% - 14.3%	8.7% - 15.2%
URGENCY 4	42.8% - 12.6%	47.0% - 13.3%	49.2% - 14.2%
URGENCY 5	56.8% - 12.4%	61.3% - 13.3%	63.6% - 14.0%
ALL NEW PATIENTS	37.2% - 30.8%	38.7% - 31.5%	39.8% - 32.2%
ALL PATIENTS	74.6% (ext)	78.7%	81.2%

Table 5.11 The outcomes of the KPI Clinical throughput (KPI3)

KPI3 CLINICAL THROUGHPUT (PER YEAR)	**CURRENT SITUATION**	**SENSITIVITY-A**	**SENSITIVITY-B**
TOTAL NUMBER OF APPOINTMENTS	*Confidential*		

Table 5.12 The outcomes of the KPI Idle time

KPI4 MEAN IDLE TIME (AS A PERCENTAGE OF THE TOTAL PROGRAM TIME)		**CURRENT SITUATION**	**SENSITIVITY-A**	**SENSITIVITY-B**
DOCTOR	NO-SHOW	4.1%	3.7%	3.4%
	TOTAL	9.9%	9.7%	9.5%
NURSE	NO-SHOW	5.6%	4.9%	4.5%
	TOTAL	24.1%	23.4%	23.0%
EMERGENCY	NO-SHOW	3.1%	2.7%	2.5%
	TOTAL	26.7%	26.4%	26.2%

From Tables 5.9 until 5.12, we conclude that decreasing the proportions of no-shows over the different appointment types, has a positive impact on all KPIS. This is in line with what we expected from the sensitivity analysis. We see that the influence of decreasing the no-shows is greater when the initial access times are higher. Figure 5.4 shows the influence of decreasing the no-shows with 0%, 10%, and 20% on the access times for patients with urgency code 3 and patients with urgency code 5. Since the initial access times of urgency code 5 patients were higher, we see a bigger impact of decreasing the no-shows here.

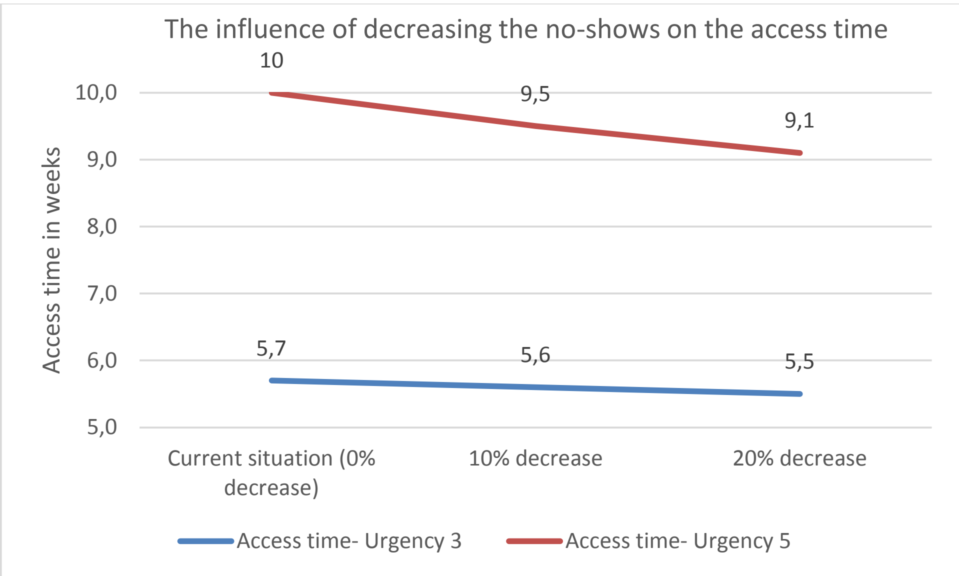


Figure 5.4 The influence of decreasing the number of no-shows on the access times of new patients with urgency codes 3 and 5

5.3 Conclusion

How can we set up our experiments and what are the results of executing these experiments?

Below, an overview of the five experiments we set up to test our interventions and a short explanation of the experiment if necessary.

1. **Experiment 1- Shifting tasks from doctors no nurses**
   In this experiment we test the influence of spreading all patients equally over the available doctors and nurses.
2. **Experiment 2- Overbooking**
   In this experiment we test the influence of scheduling more patients into the programs than official possible with regard to the available program time.
3. **Experiment 3- Carve-out model, less emergency programs**
4. **Experiment 4- Carve-out model, filling emergency programs gradually with non-emergency patients when the date of the program approaches**
5. **Experiment 5: Reducing the variation in the number of programs per weekday**
   In this experiment, we test the influence of having no variation in the number of programs per weekday.

After determining the warm-up period and the number of replications needed to correctly calculate the performance of the system, we executed our experiments. To obtain some insight in the performance of the interventions, we visualized the improvements and deteriorations with regard to the KPIs in Tables 5.13 until 5.17. A black dash equals no significant improvement or deterioration in comparison with the current situation, a green arrow indicates a significant improvement, a red arrow indicates a significant deterioration. Furthermore, bold, underlined arrows indicate the intervention scoring the best on that particular KPI. We merged urgency code 1 and 2 patients into emergency patients and urgency codes 3, 4, and 5 into non-emergency patients for Tables 5.13 and 5.14

Table 5.13 The improvements and deteriorations of the KPI Mean access time (KPI1), for all experiments (we use EXP as abbreviation off experiment)

KPI1 MEAN ACCESS TIME (IN WEEKS)	**EXP. 1**	**EXP. 2A**	**EXP. 2B**	**EXP. 3**	**EXP. 4**	**EXP. 5**
EMERGENCY PATIENTS	-	-	-	↑	↑	-
NON-EMERGENCY PATIENTS	↓	↓	↓	↓	**↓**	↓
ALL NEW PATIENTS	↓	↓	↓	↓	**↓**	↓
ALL PATIENTS	↓	**↓**	↓	↓	↓	↓

Table 5.14 The improvements and deteriorations of the KPI Access time- patients in time according to internal & external standards (KPI2), for all experiments (we use EXP as abbreviation off experiment)

KPI2 ACCESS TIMES- INTERNAL & EXTERNAL STANDARDS	**EXP. 1**	**EXP. 2A**	**EXP. 2B**	**EXP. 3**	**EXP. 4**	**EXP. 5**
EMERGENCY PATIENTS	-	-	-	↓	↓	-
NON-EMERGENCY PATIENTS	↑	↑	↑	↑	**↑**	↑
ALL NEW PATIENTS	↑	↑	↑	↑	**↑**	↑
ALL PATIENTS	↑	**↑**	↑	↑	↑	↑

Table 5.15 The improvements and deteriorations of the KPI Clinical throughput (KPI3), for all experiments (we use EXP as abbreviation off experiment)

KPI3 CLINICAL THROUGHPUT (PER YEAR)	**EXP. 1**	**EXP. 2A**	**EXP. 2B**	**EXP. 3**	**EXP. 4**	**EXP. 5**
TOTAL NUMBER OF APPOINTMENTS	-	**↑**	↑	-	↑	-

Table 5.16 The improvements and deteriorations of the KPI Idle time, for all experiments (we use EXP as abbreviation off experiment)

KPI4 MEAN IDLE TIME (AS A PERCENTAGE OF THE TOTAL PROGRAM TIME)		**EXP. 1**	**EXP. 2A**	**EXP. 2B**	**EXP. 3**	**EXP. 4**	**EXP. 5**
DOCTOR	NO-SHOW	-	**↓**	↓	-	-	-
	TOTAL	↑	↑	↑	↑	↑	-
NURSE	NO-SHOW	↑	**↓**	↓	-	-	-
	TOTAL	**↓**	↓	↓	-	-	-
EMERGENCY	NO-SHOW	-	-	-	↑	↑	-
	TOTAL	-	-	-	↓	**↓**	-

Table 5.8 The outcomes of the KPI Overtime, with the green, bold values representing the values of the experiments scoring the best on this KPI (we use EXP as abbreviation off experiment)

KPI5 OVERTIME MEDICALL STAFF (AS A PERCENTAGE OF THE TOTAL PROGRAM TIME)	**EXP. 1**	**EXP. 2A**	**EXP. 2B**	**EXP. 3**	**EXP. 4**	**EXP. 5**
DOCTOR -OVERTIME	-	↑	↑	-	-	-
NURSE -OVERTIME	-	↑	↑	-	-	-

Next to testing the interventions we executed a sensitivity analysis to test the influence of decreasing the number of no-shows on the KPIs. As expected, decreasing the no-shows has a (small) positive impact on all KPIs.

6 CONCLUSIONS & RECOMMENDATIONS

In this chapter we recapitulate at our research objective as formulated in Chapter 1, to see whether we reached our research goal (Section 6.1). Furthermore, we present recommendations on which of the interventions should be further tested, and which interventions we advise to implement at the GHD (Section 6.2). Finally, in Section 6.3, we present some general recommendations for the GHD.

6.1 RESEARCH CONCLUSION

The main objective of this research, as formulated in Chapter 1, is:

To develop and assess interventions that can lead to the decrease of access times at the Gastrointestinal and Hepatology Department of Medisch Spectrum Twente in order to meet the nationally approved treeknormen.

We distinguished two main problems related to the high access times of the GHD: Imbalance in the distribution of program time over the EC- and OC programs (Section 6.1.1) and empty slots in the schedule of the OC (Section 6.1.2). We focused on solutions for these two problems in order to reach our research objective.

6.1.1 Sub problem 1: Imbalance in the distribution of program time over the endoscopic centre- and the outpatient clinic programs

We developed a heuristic that leads to a better distribution of program time over the two sections of the GHD, the OC and the EC. We developed two formulas, each calculating the amount of program time needed for the coming three months for one of the two sections. These formulas determine the program time needed by measuring the amount of consultation and/or scopy hours within a certain time span following from one hour of consultations or scopies. The amount of program hours needed for each section according to these calculations are supplemented with the influx of new patients for each section. The variables of the formulas are based on historical data of the GHD. These variables and their indices are presented in Tables 6.1 until 6.3.

Table 6.1 The sections of the GHD

SECTION i	
1	Outpatient Clinic
2	Endoscopic Centre

Table 6.2 The possible types of check-up

CHECK-UP TYPE f	
1	Consult
2	Scopy

Table 6.3 Time span

TIME SPAN t	
1	Within the past three weeks
2	Three to six weeks ago
3	Six weeks to three months ago
4	Three to six months ago
5	Six to nine months ago
6	Nine to twelve months ago

Variables used in the formulas

N_i = The amount of hours needed for new patients at section *i* in a time period of three months (*i* = 1,2)
Y_{it} = The amount of hours executed in time span *t* at section *i* (*t* = 1,2,..,6 and *i* = 1,2)
X_{fti} = The amount of hours check-up type *f* needed within time span *t* following from an hour of appointments at section *i* (*f* = 1,2 and *t* = 1,2,..,6 and *i* = 1,2)

Formula 1: Number of hours needed in the coming three months at the OC

$$N_1 + \sum(Y_{it} * X_{2ti})$$

Formula 2: Number of hours needed in the coming three months at the EC

$$N_2 + \sum(Y_{it} * X_{1ti})$$

The balance in the distribution of the program time is improved by dividing the available program hours over the EC and the OC according to a ratio. This ratio is calculated by dividing formula 1 by formula 2. For example, if according to the formulas the OC needs 20 hours of program time and the EC needs 10, the ratio will be 2:1. To keep the access times of both sections in balance, the ratio is important even if there is less or more program time available than the total needed hours.

6.1.2 Sub problem 2: Empty slots in the schedule of the OC

To address the second sub problem, we developed a simulation model with a discrete simulation program. This model was then used to test interventions focusing on the decrease of access time we found in literature and through observations at the GHD. The interventions we tested are summarized in Table 6.4.

Table 6.4 The interventions tested on the model of the OC

INTERVENTION		DESCRIPTION OF INTERVENTION
A	Shifting tasks from doctors to nurses	Increasing the fill rate of nurse programs. In this way, nurses can take over appointments from doctors
B	Overbooking	Scheduling more patients into liver and nurse programs than possible according to the available program time. In this way, unused program time due to no-shows can be filled up again.
C	Carve-out model- less emergency programs	Scheduling less emergency programs than in the current situation. In this way, unused emergency programs are redistributed to general programs and more non-emergency patients can be seen.
D	Carve-out model- filling emergency programs gradually with non-emergency patients when date of program approaches	The emergency programs are reserved for emergency patients until 72 hours before the date of the program. Then, non-emergency patients are allowed into the emergency programs as well. In this way, more non-emergency patients can be seen.
E	Reducing the variation in the number of programs per weekday	The number of programs are equally spread over the days of the week. In this way, the capacity of the OC is more stable and this might lead to lower overall access times.

The effects of the interventions were tested with the use of KPIs. We used five KPIs for this purpose:

1. Mean Access time: the mean access time in weeks
2. Access times- internal- and external standards: the percentage of patients seen in time according to the internal- and external standards for access times
3. Clinical Throughput: the amount of appointments scheduled at the OC
4. Idle time: the percentage of the program time not filled due to no-shows, and the percentage of the program time not filled in total.

5. Overtime: the total time the medical staff worked outside the scheduled working hours divided by the total scheduled working hours (expressed as a percentage)

With regard to KPI1, all tested interventions showed a significant improvement for non-emergency patients. The largest decrease of the access time was seen at intervention D where the access times for urgency code 5 patients decreased from 10.0 to 4.5 weeks. However, for interventions C and D, the access times for the emergency patients showed an increase. The emergency patients are still seen in time in the case of intervention D according to the internal norms (urgency code 1 patients need an appointment within a week). In the case of intervention C, however, the access times of emergency patients are too high according to these norms (1.4 week for urgency code 1 patients). The total percentages of patients seen in time according to the internal- and external norms (KPI2) are in line with the measurements of KPI1: the percentages increased for each tested intervention.

With regard to KPI3, there were no significant differences visible for interventions C and E. The other interventions showed a small improvement, with intervention B scoring best with an increased clinical throughput of approximately 200 patients a year.

With regard to KPI4, the percentage of idle time due to no-shows only decreased with intervention B (as expected beforehand). For the doctor programs, the no-show percentage decreased from 4.1% to 3.6% and 3.7% (depending on the settings used for overbooking) and for the nurse programs the no-show percentage decreased from 5.9% to 4.3% and 4.6%. Furthermore, in line with expectations as well, overbooking resulted in increased overtime. For the liver doctors an overtime of 1.7% and 1.3% was measured and for the nurse programs an overtime of 1.2% and 0.9% was measured. One could say, there is a trade-off visible within intervention B: decreased idle time due to no-shows goes hand in hand with overtime for the medical staff and the lower the idle time, the higher this overtime.

Next to testing the interventions we executed a sensitivity analysis to test the influence of decreasing the number of no-shows on the KPIs. As expected, decreasing the no-shows has a (small) positive impact on all KPIs. The impact on the access times of urgency code 4 and 5 patients is the largest. With regard to KPI2, we see that the percentage of patients seen in time according to the internal standards increased from 57% to 64% for urgency code 5 patients. We therefore include that decreasing the proportion of no-shows yields positive results; even though we should note that the improvements cannot be considered spectacular.

6.2 RECOMMENDATIONS FOR DECREASING ACCESS TIMES

With regard to our first sub problem (Imbalance in the distribution of program time), we recommend to use the heuristic described in Section 4.1 to better distribute the available program time over the EC and the OC. It is an easy step to develop an Excel tool which automatically calculates the amount of program time for each section based on the amount of program time of the past months. We advise to build such a tool in order to facilitate the data manager to use the heuristic.

With regard to our second sub problem, we recommend to implement intervention A (shifting tasks from nurses to doctors). On the basis of this research, we expect that introducing this intervention will have a positive influence on the access time for non-emergency patients and will result in a higher clinical throughput. Furthermore, this intervention is expected to result in the lowest idle time for nurses. Shifting some of the tasks from the doctors towards nurses lowers the work pressure of the doctors, which is relatively high in the current situation (only 3.7% of their program time is not filled). However, introducing this intervention does require a cultural change at the GHD. From observations at the GHD, we conclude that some doctors are more likely to let chronically ill patients visit a nurse for a check-up than others. Doctors have to reconsider which type of patients they need to see themselves and which check-ups can be executed by nurses.

With regard to intervention B (overbooking), it is more difficult to come up with a straightforward recommendation. In our model, a lot of KPIs are expected to improve with the introduction of overbooking: the access times of non-emergency patients should decrease and the percentage of idle time due to no show of doctor- and nurse programs should decrease as well. Furthermore, the clinical throughput is expected to be the highest of all interventions. However, these improvements come at the cost of the medical staff expectedly working in overtime. There is a clear trade-off between the decrease of access times (and the decreased no-show percentage) and the overtime of the medical staff. It is up to the GHD whether having an overtime percentage of 0.5% to 1.7% is acceptable or not. Since we think that introducing the intervention will lead to relatively large improvements, we do believe it is worth considering it.

We recommend against implementing intervention C (less emergency programs). This intervention only has an expected positive influence on the access times of non-emergency patients, but this influence is similar to the influence of other interventions. All the other KPIs are expected to deteriorate or remain the same when introducing this intervention. In consultation with the GHD, we conclude that especially the high access times of emergency patients are unacceptable with this intervention. The access times of urgency code 1 patients increased to 1.4 weeks, where the internal standard requires it to be under a week.

We recommend to implement intervention D (filling emergency programs gradually with non-emergency patients when date of program approaches). This intervention only showed expected deterioration on the access times of the emergency patients, but the access times still remain under the internal standards and are therefore acceptable. Furthermore, all other KPIs showed large expected improvements: the access times of the non-emergency patients decreased the most in this intervention, the clinical throughput increased significantly, and the emergency programs have the lowest idle time percentage of all interventions. The effort needed to implement this intervention is minimal, so we advise the GHD to implement this intervention as soon as possible.

For future researches, it would be interesting to test different variants of intervention D. One could for example test the influence of filling the emergency program with non-emergency patients on different points in time (more or less than three days in advance) and one could test the influence of reserving no slots for emergency patients at all after filling the programs with non-emergency patients.

We recommend to implement intervention E (reducing the variation in the number of programs per weekday). This intervention is expected to result in slightly lower access times for non-emergency patients. There are no other expected clear improvements or deteriorations visible in the KPIs. There are less consultation rooms available in the new building of MST and therefore decreasing the variation in programs per weekday is necessary. Since introducing this intervention also yields small, yet statistically significant improvements of the access times, this can be seen as an extra motivation to implement intervention E. A difficulty with implementing this intervention again, is the cultural change which has to take place. The variation of the number of programs over the week is caused by, amongst others, doctors scheduling their non-clinical day on a day they prefer. Most doctors prefer their non-clinical day on Wednesdays, which results in the Wednesdays having the lowest average number of programs scheduled. These preferences make it difficult to implement intervention E.

We recommend to conduct further research on the influence of the interventions focusing on the reduction of the number of no-shows. Decreasing the number of no-shows has a significant positive influence on all KPIs, but the improvements are small. The costs of implementing these interventions, should be further examined, before deciding whether it is desirable to implement (one of) these interventions.

6.3 Other recommendations

During the period this research was executed, there were several things we noticed when being present at the GHD of MST. Below, we give some recommendations that do not directly involve the decrease of the access times, but rather are global improvements of the processes at the GHD. We are informed about the plans of MST to introduce an *Electronic Patient File* (EPF) in the near future. When our recommendations state that 'this should be included in the system', we thereby mean that it should be considered to be included in the EPF.

Handling the referrals of new patients is done in a relatively time consuming way. First, GPs fax or email their requests to the GHD were the planners print them. Second, the requests are registered in the fax reports and brought to the department doctor who has to determine the urgency code of the patient. Third, the request is given back to the planner who then registers this extra information in the fax reports. It would be better to include this process in the system since this could not only save time, but also prevents mistakes. If a patient is referred to the GHD, the planners should import the request into the system where the department doctor can judge the request at any time and the planner can immediately see when the request is reviewed. This saves time since planners and doctors do not constantly have to wait for each other to bring the files back and forth. Furthermore, it could also reduce the amount of registration mistakes. It for example would be relatively easy to include an error notification in the EPF when a planner registers an impossible appointment date (in the fax reports, we found appointment dates in 1915 instead of 2015).

Although the guidelines for new patients for the access times per urgency code are clear, there are no guidelines for the admission control of these patients. The planners are assumed to find their own way in scheduling the patients by looking through the pile of requests and pick out the right patient at the right time. There is no clarity in what to do when the lengths of the waiting lists prevent the planners from scheduling all patients in time. A consideration could be to let the system automatically propose a sequence in which patients could be scheduled.

Patients with a telephonic consult are informed about their consult through an appointment letter in which a specific appointment time is mentioned (for example: 15:20-15:25). However, it is hard to 'predict' a specific appointment time for these consults: doctors often call earlier or later than the time mentioned in the appointment letter due to no-shows, appointments which take slightly longer than anticipated etcetera. Since doctors frequently do not call during the mentioned time spans, the OC often receives phone calls of agitated patients and patients sometimes miss their consult. It would therefore be useful to not mention a specific appointment time, but to rather state a broader time span in the appointment letter, of for example an hour.

Furthermore, we recommend the EC to schedule patients in a doctor program instead of a room program. Since the patients are not seen by their own doctor at the EC, and since the schedules are made per room instead of per doctor, it is not possible to check which doctor executed which scopy.

The current way of registration makes it impossible to perform calculations on for example the productivity or overtime per doctor.

Information is sometimes registered sloppy; if a patient does not show up for his or her scopy, he or she should be registered as a no-show (WE) in the 'consult code' column of X-care, but often the appointment code is changed into WE, making it impossible to afterwards track the type of scopy not executed due to no-show. Another problem with the no-show registrations is that the definition of a no-show differs per section. Whereas patients at the OC are only seen as a no-show when they do not turn up for their appointment, patients at the EC are also registered as a no-show when they cancel within 24 hours before the appointment. The choice for a definition is not the important issue here, but it is preferable to use the same definition to keep both sections comparable.

It is impossible to correctly track the access times of the check-up patients at the OC because of the way of registration. Check-ups are scheduled with a WAC code when patients need a check-up appointment somewhere in the future (beyond the time-span for which a schedule already exists). However, once the check-up is actually scheduled, the WAC code is deleted and replaced by an appointment code making it impossible to determine the time span between the preferred appointment date (the date of the WAC code) and the actual appointment date.

Finally, as already mentioned before, registering in Excel easily leads to mistakes since there are no built in error notifications here. It would be preferable to register all details of a patient in one system that does notify for errors. This not only reduces the amount of errors, it is also preferable for the staff members to have all information of patients in one system to keep a clear overview.

7 BIBLIOGRAPHY

Arnwine, D. (2002). Effective governance: the roles and responsibilities of board members. *Baylor University Medical Center Proceedings*(15), 19-22.

Bazzoli, G., Brewster, L., Liu, G., & Kuo, S. (2003). Does US hospital capacity need to be expanded? *Health Affairs, 22*(6), 40-54.

Campbell, S., Braspenning, J., Hutchinson, A., & Marshall, M. (2002). Research methods used in developing and applying indicators in primary care. *Quality Safety Health Care, 11*(4), 358-364.

Carpenter, A., Leemis, L., Papir, A., Phillips, D., & Phillips, G. (2011). Managing magnetic resonance imaging machines: support tools for scheduling and planning. *Health Care Management Science, 14*, 157-173.

Colak, M. (2014, May 25). *MNC Consulting Group*. Retrieved April 15, 2015, from Solving problems using an A3: http://mncconsultinggroup.com/category/process-visual/

Custers, H., Onyebuchi, A., & Klazinga, N. (2007). Is there a business case for quality in the Netherlands? A critical analysis of the recent reforms of the health care system. *Health Policy, 82*, 226-239.

Daggy, J., Lawley, D., Willis, D., Thayer, C., Suelzer, P., DeLaurentis, A., . . . Sands, L. (2010). Using no-show modeling to improve clinic performance. *Health Informatics Journal, 16*(4), 246-259.

Dobson, G., Hasija, S., & Pinker, E. (2011). Reserving capacity for urgent patients in primary care. *Production and Operations Management, 20*(3), 456-473.

Freeman, R. (2010). *Strategic Management: a Stakeholder Approach.* Cambridge University Press.

Gocgun, Y., Bresnahan, B., Ghate, A., & Gunn, M. (2011). A Markov decision process approach to multi-category patient scheduling in a diagnostic facility. *Artifical Intelligence in Medicine, 53*(2), 73-81.

Guerriero, F., & Guido, R. (2011). Operational research in the management of the operating theatre: a survey. *Health Care Management Science, 14*, 89-114.

Gupta, D. (2007). Surgical suites' operations management. *Production and Operations Management, 16*(6), 689-700.

Hans, E., Van Houdenhoven, M., & Hulshof, P. (2011, February). *Universiteit Twente.* Retrieved January 22, 2015, from Department of Applied Mathematics: http://doc.utwente.nl/76144/1/memo1938.pdf

Health Information and Quality Authority. (n.d.). *Key Performance Indicators*. Retrieved March 27, 2015, from Health Information and Quality Authority- Safer Better Care: http://hiqa.ie/healthcare/health-information/key-performance-indicators

Huang, Y., & Marcak, J. (2013). Radiology scheduling with consideration of patient characteristics to improve patient access to care and medical resource utilization. *Health Systems, 2*(2), 93-102.

Hulshof, P., Boucherie, R., Hans, E., & Hurink, J. (2013). Tactical resource allocation and elective patient admission planning in care processes. *Health Care Management Science, 16*(2), 152-166.

Hulshof, P., Kortbeek, N., Boucherie, R., Hans, E., & Bakker, P. (2012). Taxonomic classification of planning decisions in health care: a structured review of the state of the art in OR/MS. *Health Systems*(1), 129-175.

Jebali, A., & Diabat, A. (2015). A stochastic model for operating room planning under capacity constraints. *International Journal of Production Research*.

Joustra, P., de Wit, J., Struben, V., Overbeek, B., Fockens, P., & Elkhuizen, S. (2010). Reducing access ties for an endoscopy department by an iterative combination of computer simulation and linear programming. *Health Care Management, 13*, 17-26.

Joustra, P., van der Sluis, E., & van Dijk, N. (2009). To pool or not to pool in hospitals: a theoretical and practical comparison for a radiotherapy outpatient department. *Annal Operations Research, 178*, 77-89.

Kolisch, R., & Sickinger, S. (2008). Providing radiology health care services to stochastic demand of different customer classes. *OR spectrum, 30*, 375-395.

Kopach, R., DeLaurentis, P., Lawley, M., Muthuraman, K., Ozsen, L., & Rardin, R. e. (2007). Effects of clinical characteristics on successful open access scheduling. *Health Care Management Science, 10*(2), 111-124.

Kuntz, L., Mennicken, R., & Scholtes, S. (2014). Stress on the ward: evidence of safety tipping points in hospitals. *Management Science, 61*(4), 754-771.

LaGanga, L., & Lawrence, S. (2007). Clinic overbooking to improve patient access and increase provider productivity. *Decision Sciences, 38*(2), 251-276.

Law, A. (2007). *Simulation modeling & analysis* (International Edition ed.). Singapore: McGraw-Hill.

Liu, N., & Ziya, S. (2013). Panel size and overbooking decisions for appointment-based services under patient no-shows.

Liu, N., Ziya, S., & Kulkarni, V. (2010). Dynamic scheduling of outpatient appointments under patient no-shows and cancellations. *Manufacturing Service Operations Management, 12*(2), 347-364.

Medical Dictionary. (n.d.). *Ischemia*. Retrieved November 3, 2015, from TheFreeDictionary: http://medical-dictionary.thefreedictionary.com/ischemia

Medisch Spectrum Twente. (n.d.). *Topklinisch ziekenhuis Medisch Spectrum Twente*. Retrieved from MST: https://www.mst.nl/wps/portal/p/over-mst/

Medspace. (n.d.). *Rooster.* Retrieved January 14, 2015, from http://www.maagdarmleverziektenmst.medspace.nl/mst/mdl.nsf/rst_start?openform&disp=week&anyPar=0.3034089300784012

Mind Tools. (n.d.). *Mind Tools- essential skills for an excellent career*. Retrieved April 15, 2015, from Stakeholder Analysis: http://www.mindtools.com/pages/article/newPPM_07.htm

Murray, M., & Berwick, D. (2005). Advanced access- reducing waiting and delays in primary care. *Innovations in Primary Care*, 1035-1040.

Murray, M., & Tantau, C. (2000). Same-day appointments: exploding the acess paradigm. *Family Practice Management*(7), 45-50.

Muthuraman, K., & Lawley, M. (2008). A stochastic overbooking model for outpatient clinical scheduling with no-shows. *Institute of Industrial Engineers Transactions, 40*(9), 820-837.

Nederlandse Vereniging van Maag-darm-leverartsen. (n.d.). *MDL*. Retrieved from Gastroscopie: http://www.mdl.nl/p_onderzoek?wid=63&func=viewSubmission&sid=26&pageId=4&noCache=286;1448551655

Nederlandse Vereniging van Ziekenhuizen. (n.d.). *Bekostiging ziekenhuiszorg.* Retrieved February 9, 2015, from NVZ: http://www.nvz-ziekenhuizen.nl/onderwerpen/bekostiging-ziekenhuiszorg

NOS. (2012, April 11). *Boete negeren ziekenhuisafspraak*. Retrieved from NOS.nl: http://nos.nl/artikel/361060-boete-negeren-ziekenhuisafspraak.html

Oostrum, J., Bredenhoff, E., & Hans, E. (2010). Suitability and managerial implications of a master surgical scheduling approach. *Annals of Operations Research, 178*, 91-104.

Ratcliffe, A., Gilland, W., & Marucheck, A. (2011). Revenue management for outpatient appointments: join capacity control and overbooking with class-dependent no-shows. *Flexibel Services and Manufacturing, 24*, 516-548.

Requirement Techniques. (n.d.). *Requirement Techniques- make the right choice- know what requirements technique to use*. Retrieved April 15, 2015, from Stakeholder power/interest analysis: https://requirementstechniques.wordpress.com/stakeholder-analysis/stakeholder-powerinterest-analysis/

Rijksinstituut voor Volksgezonheid en Milieu. (n.d.). *Bevolkingsonderzoek darmkanker*. Retrieved from RIVM: http://www.rivm.nl/Onderwerpen/B/Bevolkingsonderzoek_darmkanker/

Rijksoverheid. (n.d.). *Prestaties belonen in ziekenhuizen.* Retrieved February 9, 2015, from Prestatiebekostiging ziekenhuizen: http://www.rijksoverheid.nl/onderwerpen/prestaties-belonen-in-ziekenhuizen/prestatiebekostiging

RIVM. (2014, October 1). *Het treekoverleg: streefnormen wachttijden curatieve sector*. Retrieved January 30, 2015, from Zorgatlas: http://www.zorgatlas.nl/thema-s/wachtlijsten/wachtlijsten-ziekenhuiszorg/het-treekoverleg-streefnormen-wachttijden-curatieve-sector

Rosmulder, R., Krabbendam, J., Kerkhoff, A., Houser, C., Luitse, J., & . (2011). Computer simulation within action research: a promising combination for improving healthcare delivery? *System Practice Action Research, 24*, 397-412.

Rouppe van der Voort, M., van Merode, F., & Berden, B. (2010). Making sense of delays in outpatient specialty care: a system perspective. *Health Policy, 97*, 44-52.

Scheurink-Engbers, I. (2015, March 12). (S. Busscher, Interviewer)

Schippers, E. (2015, February 6). *Rijksoverheid.* Retrieved February 12, 2015, from Ministerie van Volksgezondheid, Welzijn en Sport: http://www.rijksoverheid.nl/onderwerpen/betaalbaarheid-van-de-zorg/documenten-en-publicaties/kamerstukken/2015/02/06/kamerbrief-over-verbeteren-kwaliteit-en-betaalbaarheid-zorg.html

Schut, F., & Varkevisser, M. (2013). Tackling hospital waiting times: the impact of past and current policies in the Netherlands. *Health Policy, 113*, 127-133.

Scottish Qualifications Authority (SQA). (2006). *Verification and Validation*. Retrieved September 15, 2015, from SQA: http://www.sqa.org.uk/e-learning/SDPL03CD/page_16.htm

Silvester, K., Lendon, R., Bevan, H., Steyn, R., & Walley, P. (2004). Reducing waiting times in the NHS: is lack of capacity the problem? *Clinician in Management*(12), 1-8.

Sink, D. (1985). *Productivity management: planning, meausurement and evaluation, control and improvement.* John Wiley and Sons Inc.

Testi, A., & Tànfani, E. (2009). Tactical and operational decisions for operating room planning: efficiency and welfare implications. *Health Care Management Science, 12*, 363-373.

Thomson, S., Busse, R., Crivelli, L., van de Ven, W., & van de Voorde, C. (2013). Statutory health insurance competition in EuropeL: a four-country comparison. *Health Policy, 109*, 209-225.

Toren, O., Nirel, N., Tsur, Y., Lipschuetz, M., & Toker, A. (2014). Examining professional boundaries between nurses and physicians in neonatal intensive care units. *Israel Journal of Health Policy Research, 43*.

Tsai, P., & Teng, G. (2014). A stochastic appointment scheduling system on multiple resources with dynamic call-in sequence and patient no shows for an outpatient clinic. *European Journal of Operations Research, 239*, 427-436.

van den Akker-Ploemacher, J. (2013, July 11). *Sterke stijging dagbehandelingen chronische darmontstekingen.* Retrieved January 30, 2015, from Centraal Bureau voor de Statistiek: http://www.cbs.nl/nl-NL/menu/themas/gezondheid-welzijn/publicaties/artikelen/archief/2013/2013-3855-wm.htm

van Oostrum, J., van Houdenhoven, M., Hurink, J., Hans, E., Wullink, G., & Kazemier, G. (2008). A master surgical scheduling approach for cyclic scheduling in operating room departments. *Operations Research Spectrum, 30*, 355-374.

Wachtel, R., & Dexter, F. (2008). Tactical increases in operating rooms block time for capacity planning should not be based on utilization. *Anesthesia and Analgesia, 106*(1), 215-226.

Zacharias, C., & Pinedo, M. (2013). Appointment scheduling with no-shows and overbooking. *Production and Operations Management, 23*(5), 788-801.

APPENDICES

APPENDIX A- ASSESSMENT FORM FOR EVALUATING NEW PATIENTS

<table>
<tr><td colspan="2">Formulier nieuwe verwijzing

- met brief verwijzer
- met uitdraai lab/röntgen (scopie laatste 2 jaar)</td><td colspan="5">Sticker</td></tr>
<tr><td>datum
brief binnen</td><td></td><td colspan="2">datum
beoordeling</td><td colspan="3"></td></tr>
<tr><td>beoordeeld door</td><td colspan="6"></td></tr>
<tr><td>hoofdklacht/
opmerkingen</td><td colspan="6"></td></tr>
<tr><td>poli</td><td>Urgentie code</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>lab</td><td colspan="6"></td></tr>
<tr><td>röntgen</td><td colspan="6"></td></tr>
<tr><td>scopie</td><td colspan="6"></td></tr>
<tr><td>opvragen</td><td colspan="6"></td></tr>
<tr><td rowspan="4">scopie</td><td>Urgentie code</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td colspan="6">bestemd voor: ◻ MDL ◻ IG ◻ VE</td></tr>
<tr><td>Screening</td><td colspan="5">Oldenzaal</td></tr>
<tr><td>◻ ja ◻ nee</td><td colspan="5">◻ ja ◻ nee</td></tr>
<tr><td>onderzoek</td><td colspan="6"></td></tr>
</table>

Legend

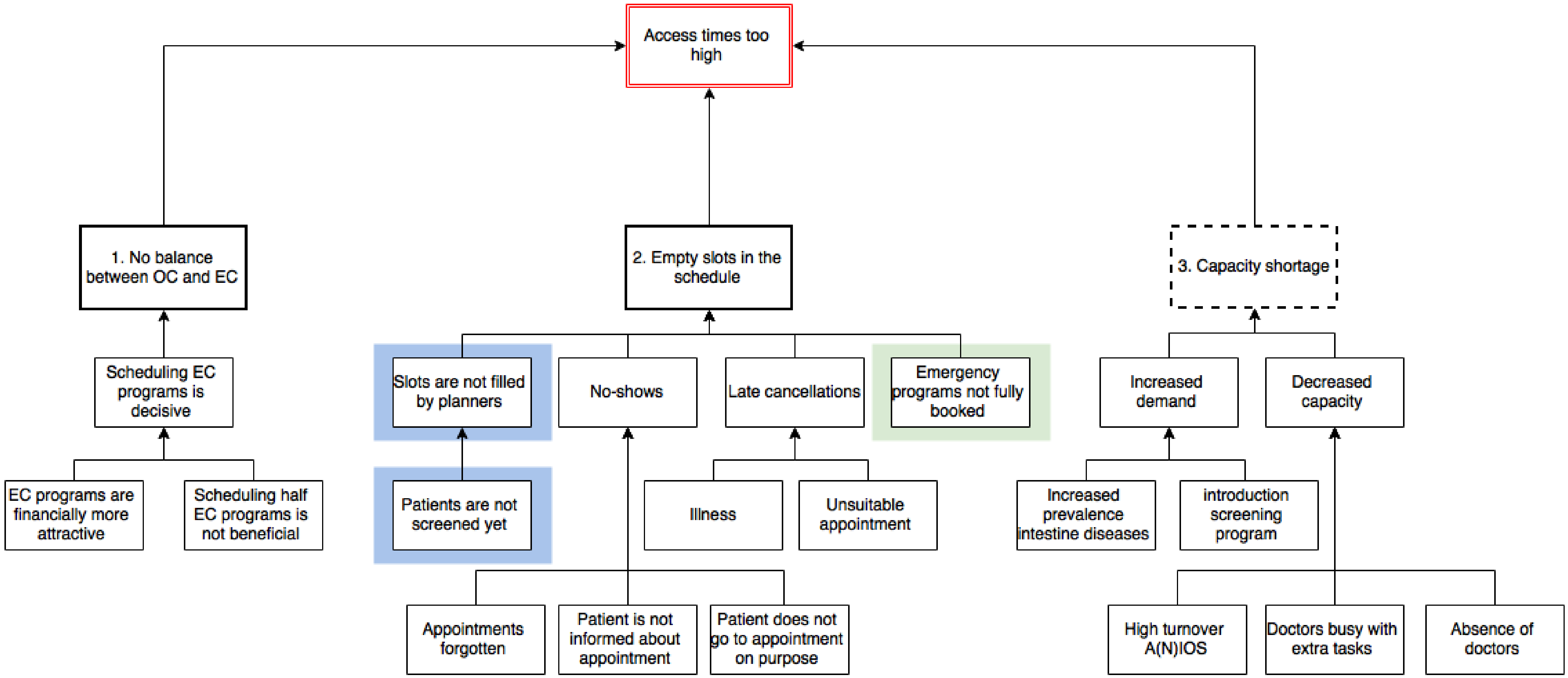
MDL:	Scopy/ consult must be executed by a GH doctor
IG:	Scopy/ consult can be executed by an internist
VE:	Scopy/ consult can be executed by a endoscopic nurse
Screening:	The patient needs a screening consult at a nurse before receiving the scopy

APPENDIX B- GUIDELINE NUMBER OF CONSULTATION- AND SCOPY PROGRAMS PER WEEK

	NUMBER OF PROGRAMS TO BE SCHEDULED PER WEEK	
TYPE OF WEEK	**MINIMUM**	**MAXIMUM**
REGULAR WEEKS – 35 WEEKS PER YEAR		
CONSULTATION PROGRAMS	30	36
SCOPY PROGRAMS	33	39
PUBLIC HOLIDAYS – 3 WEEKS PER YEAR		
CONSULTATION PROGRAMS	24	28
SCOPY PROGRAMS	26	31
AUTUMN/SPRING/MAY – 4 WEEKS PER YEAR		
CONSULTATION PROGRAMS	22	26
SCOPY PROGRAMS	24	28
SUMMER/CHRISTMAS – 8 WEEKS PER YEAR[6]		
CONSULTATION PROGRAMS	20	24
SCOPY PROGRAMS	22	26

[6] Note that summing the number of weeks mentioned in column 1 results in a total of 50 weeks. The two missing weeks are 'NVGE'- weeks for which no information about the minimum and maximum number of programs is available.

APPENDIX C- PROBLEM BUNDLE 'HIGH ACCESS TIMES' GASTROINTESTINAL AND HEPATOLOGY DEPARTMENT [7]



[7] Blue components represent problems observed at the EC, green components represent problems observed at the OC, and no color indicates the problems occur at both sections.

APPENDIX D- CAPACITY CALCULATIONS

D1 The specific appointment types executed per group of staff members

GROUPS	CP	CPIBD	CPL	NP	TC	VPN/VCP	REMAINDER[8]	NP-EMERGENCY
1 DOCTORS LIVER	X		X	X	X		X	
2 DOCTORS GENERAL	X			X	X		X	
3 DOCTORS IBD[9]	X	X		X	X		X	
4 NURSES	X	X			X	X	X	
5 EMERGENCY PROGRAMS								X

D2 Determining minimum utilization rates of the outpatient clinic

Below, we present the linear optimization model we used in calculating the minimum utilization rates.

Decision variables

T_{ia} = The amount of program time of staff member group i, distributed to appointment type a

i = {liver, general, IBD, nurses, emergency programs}

a = {CP, CPIBD, CPL, NP, TC, VCP/VPN, Remainder, NP-emergency}

STAFF MEMBER GROUP I		AVAILABLE PROGRAM TIME (IN HOURS) 2013	2014	APPOINTMENT TYPE A		DEMAND APPOINTMENTS (IN HOURS) 2013	2014
1	LIVER	-	1664.4	1	CP		
2	GENERAL	4575.5	1802.7	2	CPIBD		
3	IBD	-	1272.8	3	CPL		
4	NURSES	1162.3	1256.8	4	NP	*Confidential*	
5	EMERGENCY	521.7	436.5	5	TC		
				6	VCP/VPN		
				7	Remainder		
				8	NP-emergency		

Objective function

$$\sum_{i}\sum_{a} T_{ia}$$

Restrictions -2013

$T_{i2}, T_{i3} = 0$

$T_{1a}, T_{3a} = 0$

$T_{26}, T_{28} = 0$

$T_{44}, T_{48} = 0$

$T_{51}, T_{52},\ldots, T_{57} = 0$

2014

$T_{12}, T_{16}, T_{18} = 0$

$T_{22}, T_{23}, T_{26}, T_{28} = 0$

$T_{33}, T_{36}, T_{38} = 0$

$T_{43}, T_{44}, T_{48} = 0$

$T_{51}, T_{52},\ldots, T_{57} = 0$

All $T_{ij} \geq 0$

[8] We assume 'remainder' consults can be executed by all staff members, except in emergency programs.

[9] *Inflammatory Bowel Disease* (IBD)

Appendix E- Measuring the current performance

E1 Calculation of the access times

We combine the fax reports of the past few years and then we delete the following data:

- All patients with a request from before 2013 or after 2014
- All patients with a birthday date after 2014 or with a non-existing birthday date
- All patients with an ischemic referral
- All patients with a referral to another department
- Patients from the screening program (these programs have a different procedure for referrals)
- All patients with a 'n' in the appointment cell; these are patients for which an appointment is not necessary (anymore)
- All patients without an urgency code or with a non-existing urgency code
- All double patients
- All patients with a negative access time
- All patients which arrived before September 2014, but did not have an appointment yet (we assume they do not need an appointment anymore)

We delete outliers with regard to the access times by omitting all patients with access times below the minimum or above the maximum. First, the mean and *standard deviations* (stdev) of the access times per urgency code, per year are calculated. Subsequently we subtract two times the stdev from the mean to obtain the minimum and add two times the stdev to the mean to obtain the maximum.

$$Minimum = \mu - 2\delta$$
$$Maximum = \mu + 2\delta$$

Not all patients of the OC of 2014 of the months September, October, November, and December received a consult at the moment of writing (12th of March 2015). To get some insight in their access times, we assume that all these patients get an appointment at the 12th of March. This results in a biased and a too 'positive' view, but since this still shows increasing access times at the end of 2014 for the OC, we include these numbers.

E2 Determination of appointment groups

We create appointment groups by merging comparable appointment types into one group. A group covers at least 5% of the total appointment time of the year 2013 or 2014. Table E.1 shows the appointment groups for the OC and the EC. Since the EC sometimes deletes appointment codes when patients do not show up, it is impossible to calculate the exact number of scheduled appointments per appointment group for this section. We therefore add the no-shows without appointment code to the appointment group 'remainders' here.

Table E.1 The appointment groups of the OC and the EC and the percentage of appointment time they cover, split our per year (Confidential, 2013-2014, X-care)

OUTPATIENT CLINIC			**ENDOSCOPIC CENTRE**		
APPOINTMENT GROUP	**2013**	**2014**	**APPOINTMENT GROUP**	**2013**	**2014**
CHECK-UPS	61.7%	52.8%	COLONOSCOPIES	51.6%	53.9%
NEW PATIENTS	23.4%	22.1%	GASTROSCOPIES	24.7%	23.0%
TELEPHONIC CONSULTS	12.6%	15.1%	ENDO-ECHO SCOPIES	5.8%	5.0%
NURSING CONSULTS	2.3%	10.1%	ERCPS	5.8%	6.8%
			REMAINDERS	12.2%	11.2%

APPENDIX F- SEARCH STRATEGY

We used search engines Sciencedirect and Scopus for our literature review. Furthermore, we used the search option on the website of the library of the University of Twente. We searched for articles for which the content was fully available, which were written in English or Dutch and which were published from 2005 onwards in order to prevent using outdated information. Furthermore, we filtered out the not relevant journals[10]. They key words we used for searching literature are found in Table F.1. We let the search engines search for the key words in the abstract, title and keywords

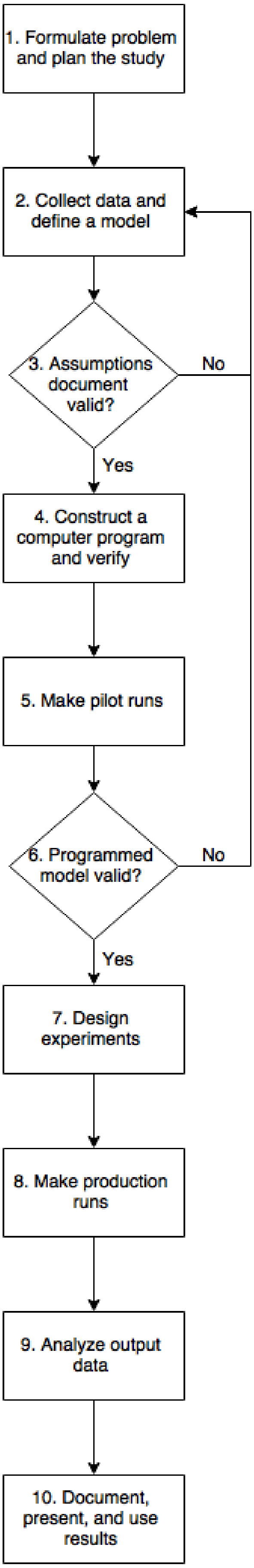
Table F.1 The key words used to search for literature for the sections of Chapter 3

SECTION	KEY WORDS
3.1.1 TACTICAL PLANNING	Tactical planning, tactical level, and tactical decisions combined with key words health care (three different combinations)
3.1.2 OUTPATIENT CLINIC	Tactical level, access times, and waiting lists combined with key words outpatient, outpatient clinic, and ambulatory care services (nine different combinations)
3.1.3 ENDOSCOPIC CENTRE	Tactical level, access times, and waiting lists combined with key words surgeries and surgical care services (six different combinations)
3.2.1 SUB PROBLEM 1	Integration, balance sections, and intersectional balance combined with key words healthcare, and outpatient operating room (six different options)
3.2.2 SUB PROBLEM 2	Utilization nurse, nursing time, and nursing staffing combined with key words shifting tasks doctors and appointment scheduling (six different options) No-show health care combined with key words overbooking, solutions, and interventions (three different combinations) Emergency program and emergency patients combined with key words appointment scheduling, slack, and reservation slots (six different combinations)

[10] Excluded Publication Titles for Science Direct: Anaesthesia & Intensive Care Medicine, Biochemical Pharmacology, International Journal for Parasitology, Joint Bone Spine, The Journal of Urology, Medicine, Journal of Otology, American Journal of Obstrics and Gynaecology, International Journal of Pharmaceutics, Animal Feed Science and Technology, Aquaculture, Veterinary Parasitology, European Journal of Pharmaceutics and Biopharmaceutics, Food Research International, Carbohydrate Polymers, Advanced Drug Delivery Reviews, Biomaterials, Orthopaedics & Traumatology: Surgery & Research, Obstrics Gynaecology & Reproductive Medicine, Clinical Neurology and Neurosurgery, European Journal of Pharmaceutical Sciences, Food Chemistry, International Journal of Biological Macromolecules, Toxicology and Applied Pharmacology, Journal of Exotic Pet Medicine, Rheumatologic Clinical, Veterinary Journal, American Journal of Cardiology, and Journal of Paediatric Surgery

Excluded Subject Areas for Scopus: Medicine, Biochemistry Genetics and Molecular Biology, Pharmacology Toxicology & Pharmaceutics, Agricultural and Biological Sciences, Veterinary, Chemical Engineering, Chemistry, Physics and Astronomy, Immunology and Microbiology, Dentistry, Earth and Planetary Sciences, Neuroscience, and Psychology

APPENDIX G- STEPS IN A SIMULATION STUDY



Appendix H- Calculations input parameters of the model of the outpatient clinic

H1 New patients

Tables H.1 and H.2 show the outcomes of the AD-tests for identifying the distributions of Monday & Tuesday & Friday and Wednesday & Thursday. However, this resulted in no fitting distributions. Therefore, the data for these days is split up in separate days again. Tables H.3 until H.5 show the outcomes of the AD-tests for respectively Monday, Tuesday, and Wednesday. Figures H.1 and H.2 show the outcomes of the AD-tests and the graphs fitting our data against the chosen distributions of respectively Thursday and Friday.

Table H.1 Outcomes of the Anderson-Darling test for identifying the distribution of Monday & Tuesday & Friday (Confidential, X-care & Fax reports, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL			WEIBULL		
LOGNORMAL	*Confidential*		GAMMA	*Confidential*	
EXPONENTIAL					

Table H.2 Outcomes of the Anderson-Darling test for identifying the distribution of Wednesday & Thursday (Confidential, X-care & Fax reports, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL			WEIBULL		
LOGNORMAL	*Confidential*		GAMMA	*Confidential*	
EXPONENTIAL					

Table H.3 Outcomes of the Anderson-Darling test for identifying the distribution of Monday (Confidential, X-care & Fax reports, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL			WEIBULL		
LOGNORMAL	*Confidential*		GAMMA	*Confidential*	
EXPONENTIAL					

Table H.4 Outcomes of the Anderson-Darling test for identifying the distribution of Tuesday (Confidential, X-care & Fax reports, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL			WEIBULL		
LOGNORMAL	*Confidential*		GAMMA	*Confidential*	
EXPONENTIAL					

Table H.5 Outcomes of the Anderson-Darling test for identifying the distribution of Wednesday (Confidential X-care & Fax reports, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL			WEIBULL		
LOGNORMAL	*Confidential*		GAMMA	*Confidential*	
EXPONENTIAL					

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL	Confidential		WEIBULL	Confidential	
LOGNORMAL			GAMMA		
EXPONENTIAL					

Confidential

Figure H.1 Outcomes of the Anderson-Darling test for identifying the distribution of Thursday and the data from Thursdays fitted against the Weibull distribution (Confidential, X-care & Fax-reports, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL	Confidential		WEIBULL	Confidential	
LOGNORMAL			GAMMA		
EXPONENTIAL					

Confidential

Figure H.2 Outcomes of the Anderson-Darling test for identifying the distribution of Friday and the data from Fridays fitted against the Normal distribution (Confidential, X-care & Fax reports, 2014)

H2 Check-up patients

Arrival pattern

We now use parameter ACheckup by calculating the number of check-up patients arriving per day (depending on the day of the week) and multiplying this number with a week factor.

$ACheckup_{d,w} = \gamma_d * \delta_w$

$ACheckup_{d,w}$	Number of new patients arriving per day *d* in week *w* with $d \in 1,2,..,5$ and $w \in 1,2,..,52$
γ_d	Number of arrivals per day *d* with $d \in 1,2,..,5$
δ_w	Week factor *w* with $w \in 1,2,..,52$

Table H.6 shows the outcomes of the two sample t-tests used to determine whether there are significant differences between days of the weeks. Since the p-value for the combination Thursday & Friday is relatively high, we combine these two days into one sample. All other p-values are relatively low (most of them showing significant differences) and therefore, we do not further merge these samples. We now have, four distributions: Monday, Tuesday, Wednesday, and Thursday & Friday. Figure H.3 shows the outcomes of the AD-tests and the graph fitting our data against the chosen distribution for Monday. Tables H.7 until H.9 show the outcomes of the AD-tests for respectively Tuesday, Wednesday, and Thursday & Friday.

Table H.6 The p-values of the two-sample t-tests used to find out if there are significant differences between the days of the weeks considering the arrival of check-up patients (Confidential, X-care, 2014)

	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
MONDAY	0.073	0.000*	0.001*	0.001*
TUESDAY	-	0.000*	0.000*	0.000*
WEDNESDAY	-	-	0.056	0.129
THURSDAY	-	-	-	0.860
FRIDAY	-	-	-	-

* indicates a statistical significant difference (with $\alpha = 0.05$)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL			WEIBULL		
LOGNORMAL	*Confidential*		GAMMA	*Confidential*	
EXPONENTIAL					

Confidential

Figure H.3 Outcomes of the Anderson-Darling test for identifying the distribution of Monday and the data from Mondays fitted against the Normal distribution (Confidential, X-care, 2014)

Table H.7 Outcomes of the Anderson-Darling test for identifying the distribution of Tuesday (Confidential, X-care, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL			WEIBULL		
LOGNORMAL	*Confidential*		GAMMA	*Confidential*	
EXPONENTIAL					

Table H.8 Outcomes of the Anderson-Darling test for identifying the distribution of Wednesday (Confidential, X-care, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL			WEIBULL		
LOGNORMAL	*Confidential*		GAMMA	*Confidential*	
EXPONENTIAL					

Table H.9 Outcomes of the Anderson-Darling test for identifying the distribution of Thursday & Friday (Confidential, X-care, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL			WEIBULL		
LOGNORMAL	*Confidential*		GAMMA	*Confidential*	
EXPONENTIAL					

Table H.10 shows the fitted distributions and their parameters according to the AD tests.

Table H.10 The distribution functions used to model the number of check-up patients arriving per day of the week (Confidential, X-care, 2014)

DAY FACTORS FOR	DISTRIBUTION	PARAMETERS[11]	
		P1	P2
MONDAY			
TUESDAY	*Confidential*		
WEDNESDAY			
THURSDAY & FRIDAY			

Figure H.4 shows a graph of the week factors used for parameter ACheckup. We again only have data of 2014, and no clear pattern is visible in the week factors. To overcome this bias, we again used the week factors randomly over the course of the year.

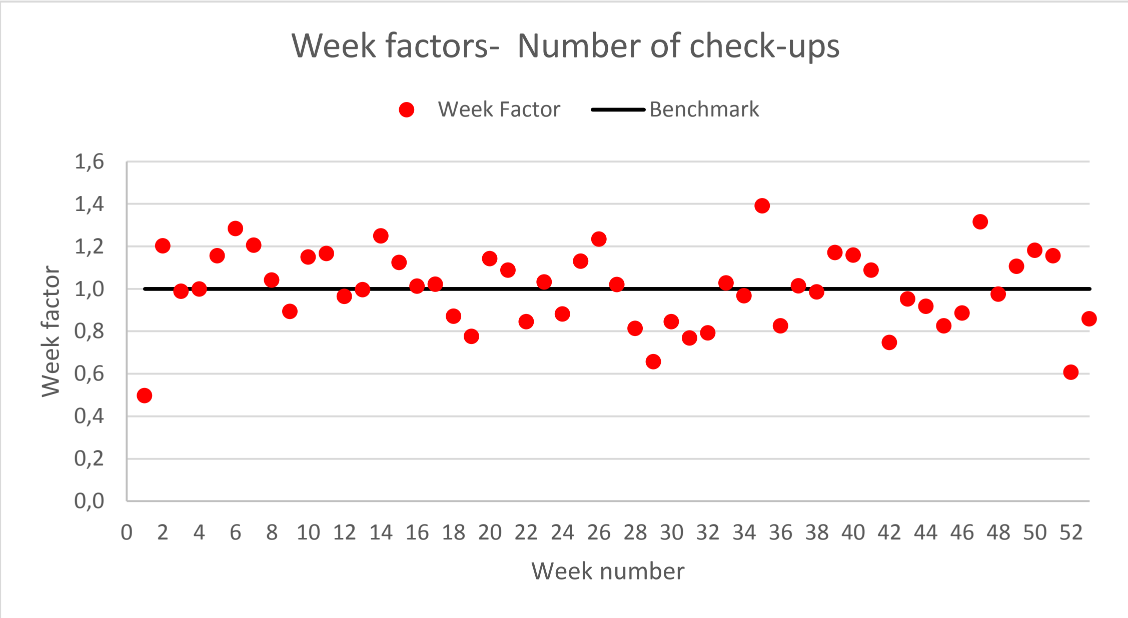


Figure H.4 The week factors with regard to the number of check-up patients arriving at the OC (X-care, 2014)

Appointment durations

We used discrete distributions for the durations of the appointments of check-up patients. These durations are found in Tables H.11 until H.17.

Table H.11 Proportions of CP appointment durations within the total number of CP appointments (Confidential, X-Care, 2014)

APPOINTMENT DURATION	PROPORTION
0.17	0.212
0.25	0.666
0.33	0.046
0.5	0.053
0.75	0.023

Table H.12 Proportions of CPdoc appointment durations within the total number of CPdoc appointments (Confidential, X-Care, 2014)

APPOINTMENT DURATION	PROPORTION
0.08	0.210
0.25	0.057
0.33	0.139
0.5	0.372
0.75	0.221

[11] *Confidential*

Table H.13 Proportions of CPIBD appointment durations within the total number of CPIBD appointments (Confidential, X-Care, 2014)

APPOINTMENT DURATION	PROPORTION
0.17	0.150
0.25	0.630
0.33	0.220

Table H.14 Proportions of CPL appointment durations within the total number of CPL appointments (Confidential, X-Care, 2014)

APPOINTMENT DURATION	PROPORTION
0.17	0.320
0.25	0.651
0.33	0.029

Table H.15 Proportions of TC appointment durations within the total number of TC appointments (Confidential, X-Care, 2014)

APPOINTMENT DURATION	PROPORTION
0.08	0.754
0.17	0.224
0.25	0.021

Table H.16 Proportions of VCP appointment durations within the total number of VCP appointments (Confidential, X-Care, 2014)

APPOINTMENT DURATION	PROPORTION
0.17	0.037
0.33	0.770
0.5	0.170
0.75	0.023

Table H.17 Proportions of remainder appointment durations within the total number of remainder appointments (Confidential, X-Care, 2014)

APPOINTMENT DURATION	PROPORTION
0.08	0.069
0.17	0.739
0.25	0.074
0.33	0.082
0.5	0.036

H3 Programs

Number of programs

We now use parameter P by calculating the number of programs scheduled per day (depending on the day of the week) and multiplying this number with a week factor.

$P_{d,w} = \varepsilon_d * \zeta_w$

$P_{d,w}$ Number of programs to be scheduled per day d in week w with $d \in 1,2,..,5$ and $w \in 1,2,..,5$

ε_d Number of arrivals per day d with $d \in 1,2,..,5$

ζ_w Week factor w with $w \in 1,2,..,52$

We exclude the emergency programs from parameter P. The data manager intends to schedule three emergency programs per week and states the week of the year is of little influence on this number. We decide to use an uniform distribution to decide whether or not there is an emergency program scheduled on a certain working day. Dividing the number of emergency programs of 2014 by the amount of working days of that year, we get a chance of 0.512 of having an emergency program scheduled on a working day.

Table H.18 shows the outcomes of the two sample t-tests used to determine whether there are significant differences between days of the weeks. Since the p-value for the combination Monday & Thursday is relatively high, we combine these two days into one sample. All other p-values show significant differences, and therefore we do not further merge these samples. We now have, four distributions: Monday & Thursday, Tuesday, Wednesday, and Friday.

Table H.18 The p-values of the two-sample t-tests used to find out if there are significant differences between the days of the weeks considering the number of programs (2,617 programs, X-care, 2014)

	TUESDAY	**WEDNESDAY**	**THURSDAY**	**FRIDAY**
MONDAY	0.003*	0.000*	0.699	0.013*
TUESDAY	-	0.000*	0.010*	0.000*
WEDNESDAY	-	-	0.000*	0.002*
THURSDAY	-	-	-	0.005*
FRIDAY	-	-	-	-

* indicates a statistical significant difference (with α = 0.05)

Table H.19 shows the outcomes of the AD-tests for identifying the distributions of Monday & Thursday. However, this resulted in no fitting distributions. Therefore, the data for these days is split up in separate days again. Tables H.20 until H.23 show the outcomes of the AD-tests for respectively Monday, Tuesday, Wednesday, and Friday. Figure H.5 shows the outcomes of the AD-tests and the graphs fitting our data against the chosen distributions of Thursday.

Table H.19 Outcomes of the Anderson-Darling test for identifying the distribution of Monday & Thursday (2,617 programs, X-care, 2014)

MONDAY & THURSDAY

	AD-value	p-value		AD-value	p-value
NORMAL	0.889	0.022	WEIBULL	1.402	<0.010
LOGNORMAL	1.381	<0.005	GAMMA	1.124	0.006
EXPONENTIAL	28.367	<0.003			

Table H.20 Outcomes of the Anderson-Darling test for identifying the distribution of Monday (2,617 programs, X-care, 2014)

	AD-VALUE	**P-VALUE**		**AD-VALUE**	**P-VALUE**
NORMAL	0.608	0.108	WEIBULL	0.626	0.097
LOGNORMAL	0.851	0.027	GAMMA	0.735	0.057
EXPONENTIAL	14.070	<0.003			

Table H.21 Outcomes of the Anderson-Darling test for identifying the distribution of Tuesday (2,617 programs, X-care, 2014)

	AD-VALUE	**P-VALUE**		**AD-VALUE**	**P-VALUE**
NORMAL	0.434	0.291	WEIBULL	0.606	0.113
LOGNORMAL	0.526	0.172	GAMMA	0.430	>0.250
EXPONENTIAL	14.497	<0.003			

Table H.22 Outcomes of the Anderson-Darling test for identifying the distribution of Tuesday (2,617 programs, X-care, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL	0.698	0.064	WEIBULL	0.723	0.056
LOGNORMAL	0.636	0.092	GAMMA	0.553	0.174
EXPONENTIAL	11.622	<0.010			

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL	0.841	0.028	WEIBULL	1.110	<0.010
LOGNORMAL	0.953	0.015	GAMMA	0.853	0.029
EXPONENTIAL	14.381	<0.003			

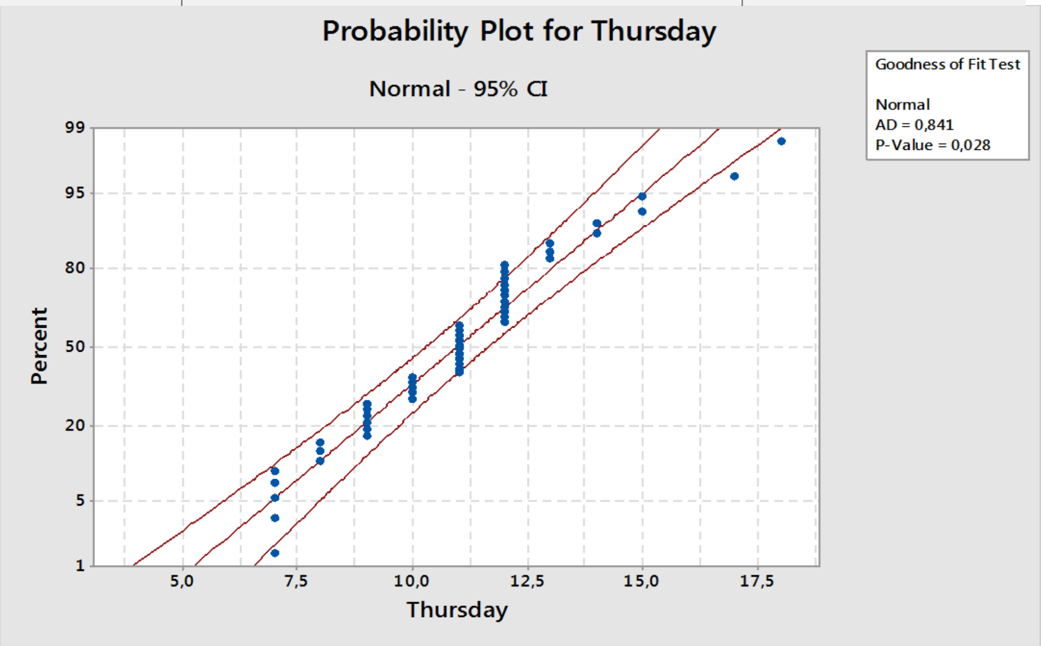


Figure H.5 Outcomes of the Anderson-Darling test for identifying the distribution of Thursday and the data from Thursdays fitted against the Normal distribution (2,617 programs, X-care, 2014)

Table H.23 Outcomes of the Anderson-Darling test for identifying the distribution of Friday (2,617 programs, X-care, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL	0.749	0.048	WEIBULL	0.672	0.078
LOGNORMAL	1.298	<0.005	GAMMA	1.071	0.009
EXPONENTIAL	12.778	<0.003			

Table H.24 shows the fitted distributions and their parameters according to the AD tests.

Table H.24 The distribution functions used to model the number of programs per day of the week (2,617 programs, X-care, 2014)

DAY FACTORS FOR	DISTRIBUTION	PARAMETERS[12]	
		P1	P2
MONDAY	Normal	10.776	2.285
TUESDAY	Gamma	18.769	0.657
WEDNESDAY	Gamma	10.256	0.774
THURSDAY	Normal	10.960	2.449
FRIDAY	Weibull	4.311	10.479

Figure H.6 shows a graph of the week factors used for parameter P. We again only have data of 2014, and no clear pattern is visible in the week factors. To overcome this bias, we again used the week factors randomly over the course of the year.

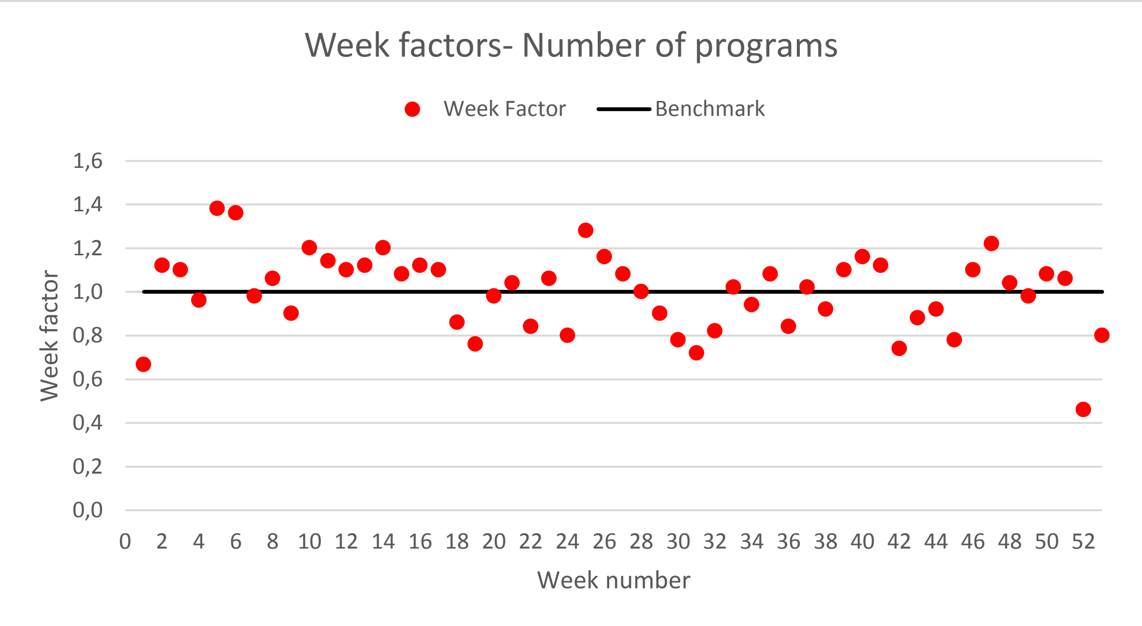


Figure H.6 The week factors with regard to the number of programs (2,617 programs, X-care, 2014)

Program durations

We used discrete distributions for the durations of the programs. These durations are found in Tables H.25 until H.29.

Table H.25 Proportions of emergency program durations within the total number of emergency programs (133 programs, X-Care, 2014)

PROGRAM DURATION	PROPORTION
2.75	0.048
3	0.234
3.25	0.056
3.5	0.637
3.75	0.024

Table H.26 Proportions of general program durations within the total number of general programs (804 programs, X-Care, 2014)

PROGRAM DURATION	PROPORTION
0.08	0.057
0.17	0.034
0.25	0.070
0.5	0.100
1.5	0.043
2	0.024

[12] Confidential

2.25	0.037
2.5	0.060
2.75	0.044
3	0.117
3.25	0.071
3.5	0.313
3.75	0.030

Table H.27 Proportions of IBD program durations within the total number of IBD programs (539 programs, X-Care, 2014)

PROGRAM DURATION	PROPORTION
0.08	0.027
0.17	0.034
0.25	0.048
0.5	0.085
1	0.036
1.5	0.034
2	0.075
2.5	0.126
2.75	0.159
2.83	0.060
3	0.087
3.25	0.034
3.5	0.092
3.75	0.104

Table H.28 Proportions of liver program durations within the total number of liver programs (713 programs, X-Care, 2014)

PROGRAM DURATION	PROPORTION
0.17	0.044
0.25	0.059
0.5	0.084
0.75	0.027
1	0.030
2	0.042
2.25	0.028
2.5	0.121
2.75	0.151
3	0.042
3.25	0.077
3.5	0.144
3.75	0.152

Table H.29 Proportions of nurse program durations within the total number of nurse programs (561 programs, X-Care, 2014)

PROGRAM DURATION	PROPORTION
0.17	0.037
1	0.030
1.67	0.067
1.83	0.043
2	0.120
2.33	0.085
2.5	0.372
2.67	0.057
2.83	0.041
3.08	0.072
3.17	0.076

H4 No-shows

Tables H.30 until H.37 show what proportions of no-shows get a same or a different replacement appointment within a specific time span. After discussion with a GH doctor, we decide to use six different time spans in which no-shows can get a replacement appointment: in less than three weeks, in three to six weeks, in six weeks to three months, in three to six months, in six to nine months, and in nine to twelve months.

H.30 The proportions of NP no-shows getting a replacement appointment (of either the same or a different type) within specific time spans (Confidential, X-care, 2014)

APPOINTMENT TYPE	**TIME SPAN UNTIL REPLACEMENT APPOINTMENT** (IN WEEKS)	**PROPORTION**
NP	[0,3)	0.275
	[3,6)	0.150
	[6,13)	0.400
	[13,26)	0.175
TOTAL		1.000
CP	[6,13)	0.500
	[13,26)	0.500
TOTAL		1.000
TC	[0,3)	0.250
	[3,6)	0.250
	[6,13)	0.250
	[13,26)	0.250
TOTAL		1.000

H.31 The proportions of CP no-shows getting a replacement appointment (of either the same or a different type) within specific time spans (Confidential, X-care, 2014)

APPOINTMENT TYPE	**TIME SPAN UNTIL REPLACEMENT APPOINTMENT** (IN WEEKS)	**PROPORTION**
CP	[0,3)	0.330
	[3,6)	0.309
	[6,13)	0.255
	[13,26)	0.069
	[26,39)	0.018
	[39,52)	0.018
TOTAL		1.000
CPIBD	[0,3)	0.059
	[3,6)	0.588
	[6,13)	0.176
	[13,26)	0.118
	[26,39)	0.059
TOTAL		1.000
CPL	[3,6)	0.286
	[6,13)	0.143
	[13,26)	0.286
	[26,39)	0.143
	[39,52)	0.143
TOTAL		1.000

TC	[0,3)	0.500
	[3,6)	0.284
	[6,13)	0.122
	[13,26)	0.041
	[26,39)	0.041
	[39,52)	0.014
TOTAL		1.000
VCP	[0,3)	0.143
	[3,6)	0.286
	[6,13)	0.190
	[13,26)	0.286
	[26,39)	0.095
TOTAL		1.000

H.32 The proportions of CPdoc no-shows getting a replacement appointment (of either the same or a different type) within specific time spans (Confidential, X-care, 2014)

APPOINTMENT TYPE	**TIME SPAN UNTIL REPLACEMENT APPOINTMENT** (IN WEEKS)	**PROPORTION**
CPDOC	[0,3)	0.222
	[3,6)	0.444
	[6,13)	0.222
TOTAL		1.000
CP	[0,3)	1.000
TOTAL		1.000
VCP	[0,3)	0.500
	[13,26)	0.500
TOTAL		1.000

H.33 The proportions of CPIBD no-shows getting a replacement appointment (of either the same or a different type) within specific time spans (Confidential, X-care, 2014)

APPOINTMENT TYPE	**TIME SPAN UNTIL REPLACEMENT APPOINTMENT** (IN WEEKS)	**PROPORTION**
CPIBD	[0,3)	0.400
	[3,6)	0.300
	[6,13)	0.200
	[13,26)	0.100
TOTAL		1.000
CP	[0,3)	0.333
	[3,6)	0.167
	[6,13)	0.333
	[13,26)	0.167
TOTAL		1.000

TC	[0,3)	0.667
	[3,6)	0.333
TOTAL		1.000
VCP	[0,3)	0.500
	[3,6)	0.250
	[6,13)	0.250
TOTAL		1.000
REMAINDER	[0,3)	1.000
TOTAL		1.000

H.34 The proportions of CPL no-shows getting a replacement appointment (of either the same or a different type) within specific time spans (Confidential, X-care, 2014)

APPOINTMENT TYPE	**TIME SPAN UNTIL REPLACEMENT APPOINTMENT** (IN WEEKS)	**PROPORTION**
CPL	[0,3)	0.133
	[3,6)	0.600
	[6,13)	0.267
TOTAL		1.000
CP	[6,13)	0.500
	[26,39)	0.500
TOTAL		1.000
TC	[3,6)	0.500
	[26,39)	0.500
TOTAL		1.000
VCP	[3,6)	0.250
	[6,13)	0.500
	[13,26)	0.250
TOTAL		1.000
REMAINDER	[26,39)	1.000
TOTAL		1.000

H.35 The proportions of TC no-shows getting a replacement appointment (of either the same or a different type) within specific time spans (Confidential, X-care, 2014)

APPOINTMENT TYPE	**TIME SPAN UNTIL REPLACEMENT APPOINTMENT** (IN WEEKS)	**PROPORTION**
TC	[0,3)	0.744
	[3,6)	0.205
	[6,13)	0.051
TOTAL		1.000

CP	[0,3)	0.167
	[3,6)	0.222
	[6,13)	0.278
	[13,26)	0.222
	[26,39)	0.111
TOTAL		1.000
CPDOC	[26,39]	1.000
TOTAL		1.000
CPIBD	[13,26)	1.000
TOTAL		1.000
VCP	[0,3)	0.500
	[26,39)	0.500
TOTAL		1.000

H.36 The proportions of VCP no-shows getting a replacement appointment (of either the same or a different type) within specific time spans (Confidential, X-care, 2014)

APPOINTMENT TYPE	**TIME SPAN UNTIL REPLACEMENT APPOINTMENT** (IN WEEKS)	**PROPORTION**
VCP	[0,3)	0.667
	[3,6)	0.167
	[6,13)	0.146
	[26,39)	0.021
TOTAL		1.000
CP	[0,3)	0.462
	[3,6)	0.077
	[6,13)	0.154
	[13,26)	0.308
TOTAL		1.000
CPIBD	[0,3)	0.250
	[6,13)	0.250
	[13,26)	0.500
TOTAL		1.000
CPL	[6,13)	1.000
TOTAL		1.000
TC	[0,3)	0.800
	[6,13)	0.133
	[13,26)	0.067
TOTAL		1.000

REMAINDER	[0,3)	0.333
	[3,6)	0.333
	[6,13)	0.333
TOTAL		1.000

H.37 The proportions of remainder no-shows getting a replacement appointment (of either the same or a different type) within specific time spans (Confidential, X-care, 2014)

APPOINTMENT TYPE	TIME SPAN UNTIL REPLACEMENT APPOINTMENT (IN WEEKS)	PROPORTION
CPIBD	[3,6)	1.000
TOTAL		1.000
TC	[0,3)	1.000
TOTAL		1.000
VCP	[0,3)	1.000
TOTAL		1.000

APPENDIX I- VERIFYING INPUT PARAMETERS

Table I.1 shows the differences between the data in the model and the historical data with regard to the proportions of new appointment, check-up appointment- and program types. Furthermore, Table I.2 shows this same information for the duration of appointments and programs. Table I.3 show the difference between the data in the model and the historical data with regard to the proportion of no-shows per appointment type. We assume the input parameters of Tables I.1 until I.3 are acceptable, since they show a maximum difference of 4.4%, indicating the modelled inputs do not differ greatly from the historical data.

Table I.1 The differences between the data in the model and the historical data with regard to the proportions of new appointment, check-up appointment- and program types (Confidential & 115,718 programs, Fax reports & X-care, 2014)

INPUT FACTOR	TYPE	PROPORTION-MODEL	PROPORTION-HISTORICAL DATA	DIFFERENCE IN PERCENTAGE
NEW PATIENTS	Urgency 1	0.033	0.033	0.5%
	Urgency 2	0.173	0.173	0.1%
	Urgency 3	0.444	0.445	0.1%
	Urgency 4	0.302	0.301	0.4%
	Urgency 5	0.048	0.049	1.0%
CHECK-UP PATIENTS	CP	0.431	0.431	0.2%
	CPdoc	0.036	0.035	2.1%
	CPIBD	0.035	0.035	0.7%
	CPL	0.034	0.034	1.9%
	TC	0.367	0.367	0.0%
	VCP	0.073	0.073	0.1%
	Remainder	0.024	0.024	1.6%
PROGRAMS[13]	General	0.307	0.307	0.2%
	IBD	0.208	0.206	0.9%
	Liver	0.271	0.272	0.4%
	Nurse	0.214	0.214	0.0%

Table I.2 The differences between the data in the model and the historical data with regard to the proportions of new appointment, check-up appointment- and program durations (Confidential & 115,718 programs, Fax reports & X-care, 2014)

INPUT FACTOR	TYPE	MEAN-MODEL	MEAN-HISTORICAL DATA	DIFFERENCE IN PERCENTAGE
NEW PATIENTS	Urgency code 1 & 2	0.74	0.74	0.0%
	Urgency code 3 & 4 & 5	0.67	0.68	1.8%
CHECK-UP PATIENTS	CP	0.26	0.26	0.9%
	CPdoc	0.43	0.43	0.3%
	CPIBD	0.26	0.26	0.6%
	CPL	0.23	0.23	2.0%
	TC	0.10	0.10	0.5%

[13] The emergency programs are missing since we did not include these in the distribution functions for the number of programs. There is a difference of 0.3% between the amount of emergency programs in the model and the amount of emergency programs in the historical data. We assume this part of the input factor is acceptable.

	VCP	0.36	0.37	1.1%
	Remainder	0.19	0.19	0.2%
PROGRAMS	Emergency	3.33	3.28	1.5%
	General	2.33	2.24	4.1%
	IBD	2.31	2.36	2.1%
	Liver	2.42	2.33	3.5%
	Nurse	2.34	2.24	4.4%

Table I.3 The differences between the data in the model and the historical data with regard to the proportions of no-shows, per appointment type (Confidential, X-care, 2014)

INPUT FACTOR	APPOINTMENT TYPE	PROPORTION-MODEL	PROPORTION-HISTORICAL DATA	DIFFERENCE IN PERCENTAGE
NO-SHOWS	CP	0.056	0.055	1.9%
	CPdoc	0.034	0.034	1.2%
	CPIBD	0.048	0.049	2.1%
	CPL	0.072	0.070	3.2%
	NP	0.041	0.041	1.4%
	TC	0.011	0.011	2.5%
	VCP	0.094	0.093	0.4%
	REMAINDER	0.010	0.010	4.1%

Tables I.4 and I.5 show the outcomes of the AD-tests for the arrival pattern of the check-up patients for respectively Thursday and Friday.

Table I.4 Outcomes of the Anderson-Darling test for identifying the distribution of Thursday (Confidential, X-care, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL			WEIBULL		
LOGNORMAL	*Confidential*		GAMMA[14]	*Confidential*	
EXPONENTIAL					

Table I.5 Outcomes of the Anderson-Darling test for identifying the distribution of Friday (Confidential, X-care, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL			WEIBULL[15]		
LOGNORMAL	*Confidential*		GAMMA	*Confidential*	
EXPONENTIAL					

[14] *Confidential*
[15] *Confidential*

Appendix J- Additional calculations experiments

Tables J.1 until J.3 show the outcomes of the AD-tests for respectively Monday, Tuesday, and Wednesday. Figure J.1 shows the outcomes of the AD-tests and the graph fitting our data against the chosen distribution of Thursday. Table J.4 shows the outcomes of the AD-tests for Friday. Figure J.2 shows a graph of the new week factors for parameter P (programs) and an overview of the proportions of each included program type of the total number of programs is found in Figure J.3.

Table J.1 Outcomes of the Anderson-Darling test for identifying the distribution of Monday (2636 programs, X-care, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL[16]	0.660	0.080	WEIBULL	0.671	0.078
LOGNORMAL	0.939	0.016	GAMMA	0.807	0.039
EXPONENTIAL	14.393	<0.003			

Table J.2 Outcomes of the Anderson-Darling test for identifying the distribution of Tuesday (2636 programs, X-care, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL	0.493	0.208	WEIBULL	0.727	0.054
LOGNORMAL	0.565	0.136	GAMMA[17]	0.468	>0.250
EXPONENTIAL	14.502	<0.003			

Table J.3 Outcomes of the Anderson-Darling test for identifying the distribution of Wednesday for situation 2 (2636 programs, X-care, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL	0.722	0.056	WEIBULL	0.741	0.049
LOGNORMAL	0.506	0.193	GAMMA[18]	0.485	0.237
EXPONENTIAL	11.762	<0.003			

[16] *Confidential*
[17] *Confidential*
[18] *Confidential*

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL[19]	0.932	0.017	WEIBULL	1.203	<0.010
LOGNORMAL	1.099	0.006	GAMMA	0.978	0.015
EXPONENTIAL	14.489	<0.003			

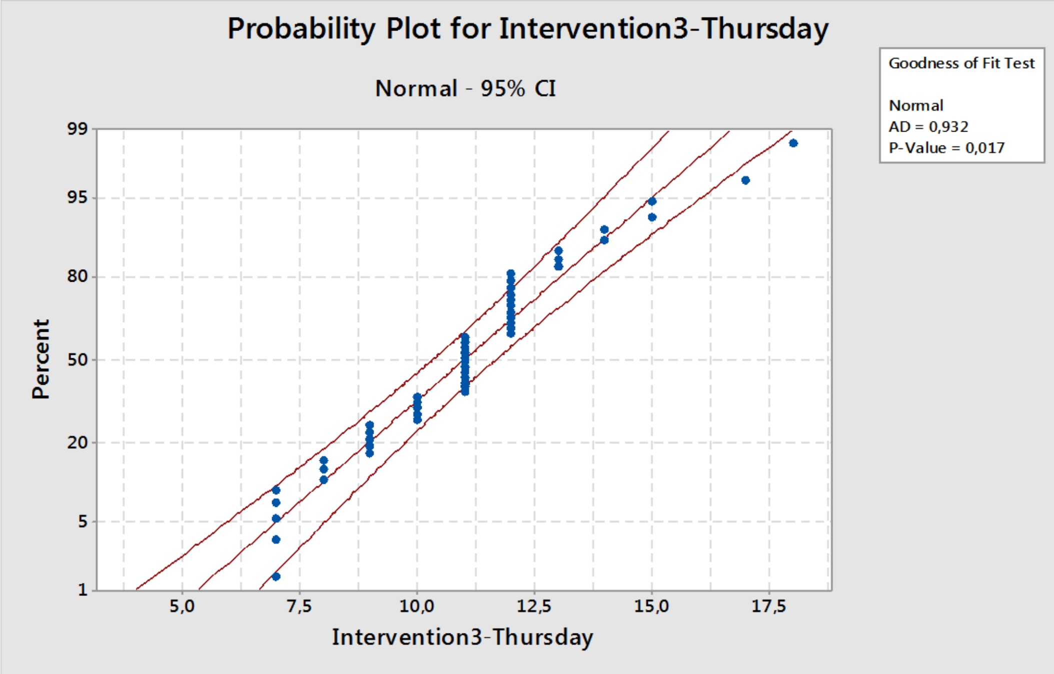


Figure J.1 Outcomes of the Anderson-Darling test for identifying the distribution of situation 2 for Thursday and the data from Thursdays fitted against the Normal distribution (2,636 programs, X-care, 2014)

Table J.4 Outcomes of the Anderson-Darling test for identifying the distribution of Friday for situation 2 (2,636 programs, X-care, 2014)

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL	0.688	0.068	WEIBULL[20]	0.611	0.108
LOGNORMAL	1.253	<0.005	GAMMA	1.018	0.012
EXPONENTIAL	12.753	<0.003			

[19] *Confidential*

[20] *Confidential*

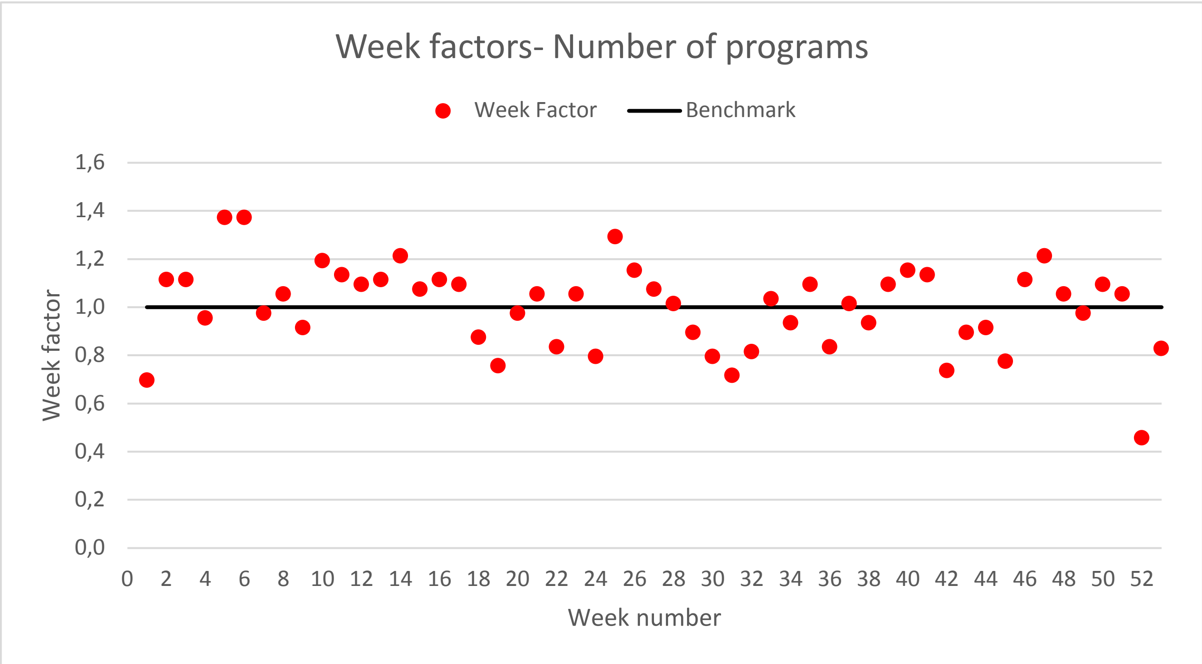


Figure J.2 The week factors with regard to the number of programs (2,636 programs, X-care, 2014)

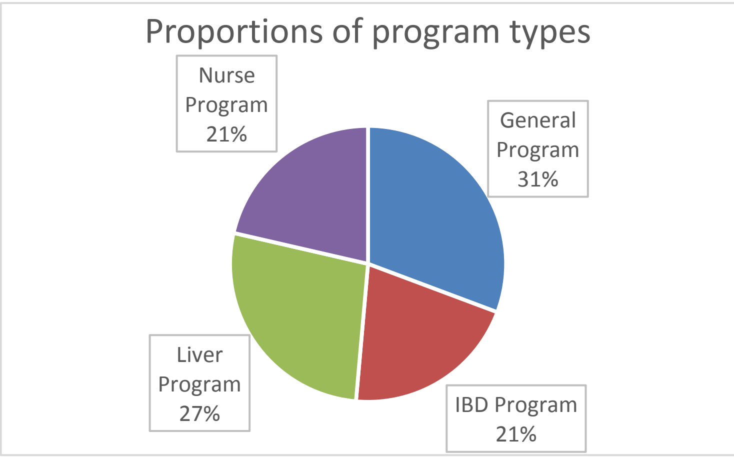


Figure J.3 Proportion of the separate program types within total number of programs for situation 2 (2,636 programs, X-care, 2014)

Figure J.7 shows the outcomes of the AD-tests and the graph fitting our data against the chosen distribution of all days merged into one sample (Experiment 5).

	AD-VALUE	P-VALUE		AD-VALUE	P-VALUE
NORMAL[21]	1.426	<0.005	WEIBULL	1.492	<0.010
LOGNORMAL	3.527	<0.005	GAMMA	2.362	<0.005
EXPONENTIAL	60.428	<0.003			

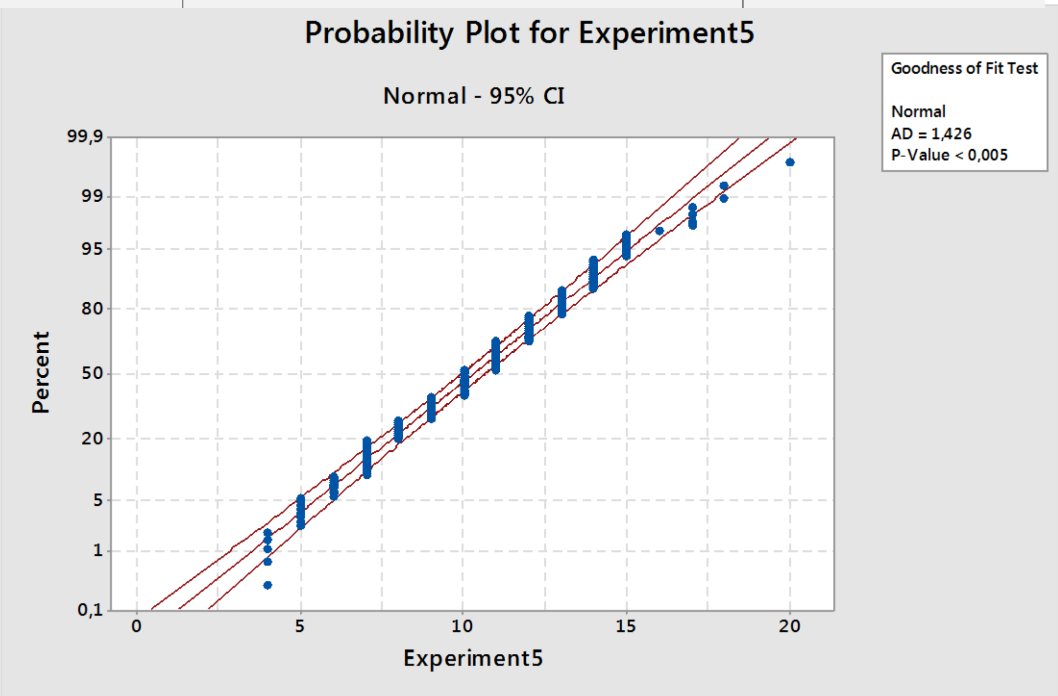


Figure J.7 Outcomes of the Anderson-Darling test for identifying the distribution of programs per day for experiment 5 and the programs per day fitted against the Normal distribution (2,636 programs, X-care, 2014)

[21] *Confidential*