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Coordinating supply and demand in Haga hospital outpatient planning: Towards a more service-oriented control structure

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COORDINATING SUPPLY AND DEMAND IN HAGA HOSPITAL OUTPATIENT PLANNING: TOWARDS A MORE SERVICE-ORIENTED CONTROL STRUCTURE

By

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Preface

This thesis report was written as my final work to obtain the degree of Master of Science in Mechanical Engineering. It describes a thesis assignment carried out at the Haga hospital, department of logistics, over a period of ten months. This report is written for the examination committee, the Haga hospital and the Delft University of Technology.

Excelling in your work is easier when you are surrounded by the right people, and I am grateful to a great many people: First I want to thank Alice Wielhouwer for her help and support during the past year. She has introduced me and guided me in the hospital, and she was always there for good support when I needed it. Next I want to thank all others in the department of logistics, specifically Tanja van Iterson and Arnoud van der Zalm. Tanja was always helpful and could pull the right strings if necessary. Arnoud provided me with many technical details during the assignment, the conversations with him taught me a lot about the context of healthcare processes and all its complexity. Moreover, I want to thank all planners, doctors and clinic managers from the different clinics I have observed. I want to thank them for their time and very cooperative attitude, without exception, towards me.

My TU supervisor Hans Veeke, who kept me on track and supported me during our fruitful discussions. And Dingena Schott for her support, enthusiasm and sharp commentary during the milestone sessions. I also want to thank my close friends and family for their support during this thesis period, especially my dad and sister whose advice I could count on, on numerous occasions.

Casper

EXECUTIVE SUMMARY

The Haga hospital in The Hague encounters several problems with their outpatient logistics. During the years, each outpatient clinic has developed its own method of planning, often based on experience and intuition. Many clinics face problems such as long waiting lists, patient waiting times and a general feeling of either working hard or being idle during consultation hours. These concerns are present for a while and since the hospital has adopted a new Hospital Information System (HIS) in June 2016, it feels now is the time to create a more structural approach for their outpatient planning, using the data and capabilities of the new HIS.

The Delft System's Approach is used to analyse patient appointment planning in five clinics: Gastroenterology, Ear-Nose- and Throat, Lung diseases, Gynaecology and Plastic surgery. Using the black box method the outpatient clinics are analysed as a system. Factors that are used to coordinate the request-, patient- and resources streams in the current situation are identified. The system requirements have been identified based on the three key stakeholders: Patient, doctor and hospital.

During the analysis, several problems were identified which can be summarized in the following three findings. 1. Long waiting lists lead to logistical issues in the clinics. Apart from the stress experienced by patients, long waiting lists result in higher no-show rates, the need for patient triaging by doctors and extra double bookings caused by (semi-) urgent patients. 2. The new HIS provides operational data that remains unused. Patient registration information and outpatient schedules are transferred to the data-warehouse. They could, but are not, used for reporting goals. 3. Doctors' requirements and annual budgets are the main factors determining the creation of schedules. Patient requirements are not yet used.

The latter is considered the most important finding. Looking from a system's perspective, the current control structure coordinates strongly based on financial stimuli, where patient requirements fall behind. The yearly production is used as a target, not as a capability to provide service. This has lead to the following research question:

"How can a control structure be designed for patient planning at the outpatient clinics in Haga, using the data from the HIS, that focuses on improving the patient-service level by the incorporation of patient requirements?"

First has been determined *what* needs to be controlled given the requirements, and then *how* it can be controlled on both operational and strategic level. The improvement of the control structure is therefore provided in three topics: 1. Function control, where the requirements are transformed into measurable Key Performance Indicators, and standards for KPI's are set. 2. Operational improvements, a set of identified improvements for all clinics that allow for enhanced performance on the KPI's. 3. Planning strategy, three planning strategies are found in literature and the preferred strategy is determined based on all stakeholders' requirements.

For function control, proposals have been made in areas where control was lacking. A Key Performance Indicator has been identified for every requirement, and a program is written in R that transforms raw data into measurement results of these KPI's. Based on analysis of historical results of these KPI's, general clinic standards are proposed for each of these KPI's. Finally, a reporting tool is developed where clinic managers can see their periodical performances in terms of the KPI's compared to the standards in a comprehensible dashboard, with the goal of improving this performance. This tool can be used by the hospital as well to compare clinics amongst each other.

To improve the clinics' performance in terms of the proposed indicators, a number of operational improvements are identified. First it is proposed to perform a systematic schedule screening by the planners three days ahead, to fill possible open slots on the last days. It is also advised to make adjustments to the registration processes, so that consult duration is measured accurately enough to be used for duration prediction, making data-supported slot length determination possible. It is advised to measure - in the HIS - the amount of urgent patients that arrive in the clinics, so that proposed proactive measures can be applied to prevent these extra appointments from mixing up the consultation hours. Finally is advised that schedule complexity is reduced by critically reviewing existing clinic ground schedules and eliminate appointment types that have no urge to be specific.

Three types of planning strategies have been found in literature: 1. traditional, 2. carve-out and 3. advanced access. Currently the Haga clinics use the traditional strategy. Based on the system requirements of all three stakeholders, a Multi Criteria Decision Analysis (MCDA) has been carried out. From the result, advanced access excelled as the preferred strategy. Given this outcome, it is advised to discuss the advanced access strategy with doctors and clinic managers as a serious alternative for the current planning strategies.

In practice, a major disadvantage of advanced access is to discover the minimum access time i.e. the access time where demand variation does not yet lead to chaotic consultation hours. One option is to go boldly under the minimum for a longer period of time to discover where the minimum is, but this is unacceptable for doctors. Therefore a simulation tool is built, to find the theoretical minimum buffer quantitatively. The simulation can be used as well to see what ground schedule adjustments can alter the theoretical minimum access time. The tool was verified and tested for the lung clinic, with current access time 25 days. It was concluded that the theoretical minimum access time for the current schedule is ten days. When the number of specific appointment types was reduced from six to two and the number of scheduled doctors per day is made constant, the theoretical access time could be reduced to four days minimum.

The simulation tool can be used as well for other purposes: To calculate the extra capacity needed to work down access time backlog and to test ground schedule tactics during doctor holidays and seasonal peaks, very common at for example the lung clinic.

Implementation of the new control structure and improvements is believed to lead to better performance, now considering the requirements of all stakeholders. It is anticipated that the MCDA and simulation tool help bring about a discussion about advanced access as a serious alternative for current planning strategy.

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Abbreviations

AIOS	Medical doctor under training (Arts In Opleiding tot Specialist)
ANIOS	Medical doctor not under training (Arts Niet In Opleiding tot Specialist)
CP	Check-up Patient
DB	Double Booking
DSA	Delft Systems Approach
ENT	Ear-, Nose- and Throat
GP	General Practitioner
HIS	Hospital Information System
KPI	Key Performance Indicator
MCDA	Multi Criteria Decision Analysis
NP	New Patient
OOR	Out Of Roster
OR	Operation Room
OS	Open Slot
PDL	Process Description Language
RVE	Business Unit (Resultaat Verantwoordelijke Eenheid)
ZD	ZorgDomein

1 INTRODUCTION

The Haga hospital is one of the largest hospitals in The Netherlands. It comprises a total of twenty outpatient clinics covering all well-known specialties from heart- to lung diseases and from urology to neurosurgery. Since two years the hospital has started project “Polihuis”. Until then, all outpatient clinics had been small islands that took care of their own logistics, both patient and means. The goal of the Polihuis project is to break with that system and to come to a more structured, standardized approach for outpatient logistics by means of a hospital-central department. In this way, logistics can be optimized and clinics can be compared to each other and hopefully learn from each other.

The current focus of the project is on the patient planning of the clinics. A general feeling of discontent of the patient planning exists within the hospital. For years, planning schedules have been made based on experience and intuition. Although there is little quantitative insight, there is the feeling that patients face long waiting times to come to the clinic and when in the waiting room. Doctors are complaining about facing either high peaks of patient numbers at some times, or lots of idle time at other times during their consultation hours.

Moreover, in the summer of 2016 a new hospital information system was implemented in Haga. Now that it’s fully functional, the hospital is interested to explore the possibilities of this new system: What data is gathered and what are the possibilities for practical use? It feels that this data could be valuable for patient planning and therefore feels now is the time to investigate how the hospital can come to a more structured approach of outpatient planning, ideally more satisfactory for patients, doctors and employees, using the data from the new hospital information system.

This research starts with the analysis of all logistical processes in the outpatient clinics by means of the Delft Systems Approach in chapter three. The main stakeholders and their requirements are analysed, and problems are identified. The main findings are summarized in chapter four, where the final research question is presented. The solution is presented in chapter five in three main topics: 1. Function control, where the highest level of KPI’s and standards are set. 2. General interventions, a set of interventions for all clinics that allow for improved steering on the standards. 3. Planning strategy, what planning strategies are found in literature and what is the preferred strategy based on stakeholders’ requirements. In chapter six, a simulation tool is added and tested that can be used by the clinic managers to assess the ground schedules. In chapter seven some valuable information is added for implementation purposes. In the last chapter the conclusions and recommendations are covered. The literature can be found in the bibliography, and additional details can be found in the seven appendices.

2 SYSTEM DESCRIPTION

The first part of this chapter will describe the Haga hospital in general, its main focus, activities and its organizational structure. The chapter will then elaborate on the planning process of the outpatient clinics by describing the creation of the schedule, the planning of the patients, the process of consultation and finally, the use of the software during these processes.

2.1 THE HAGA HOSPITAL

2.1.1 GENERAL INFORMATION

The Haga hospital is the largest hospital in the city of The Hague, and one of the four largest regular hospitals in The Netherlands in terms of first patient visits. The Haga hospital is situated at two locations: Sportlaan and Leyweg. Haga arose in 2004 from an administrative merger of three hospitals at different locations in The Hague: Leyenburg hospital, Rode Kruis hospital and the Juliana hospital for children. Since then, the three hospitals are under supervision of one managing board. In 2015, the Juliana hospital moved from its old location to the Leyweg, leaving the hospital on two locations shown in Figure 1.

The hospital has a total of 3569 employees. From this total, 199 are medical specialists and another 199 are residents (Annual report Haga, 2015). A medical specialist is a doctor who has completed an advanced education and clinical training in a specific area of medicine, and is also called a specialist. A resident is officially a doctor in practice, but is still under supervision of a specialist. With aforementioned number of employees, the hospital treated roughly 202.000 first patients at the outpatient clinics and performed just over 49.000 operations last year.

Haga has a continuous focus on carefulness, innovation and cooperation. Carefulness is obtained by constantly testing the patient-friendliness and quality of care to the norms of care-concept Planettree. To arrive at a top-level of care quality, on-going innovation is the norm for Haga. For the future Haga has chosen three top-clinical areas to make its mark on innovation: Heart- and vein centre, Mother- and child centre and a number of specific terrains in the field of oncology and haematology. Where possible, the hospital strives for cooperation in healthcare, it does so at the moment by:

- Focussing knowledge in the area of Neurosurgery, Cardiology and Radiotherapy with the Leidsch Universitair Medisch Centrum en HMC Hospital
- Cooperating with all hospitals in The Hague in the field of blood sampling, in the joint laboratory “Lab West”
- Bundling purchase of goods and logistics together with three other regional hospitals in the cooperation “Ziekenhuispartners XL”

FIGURE 1, HAGA HOSPITAL LOCATION LEYWEG (1), LOCATION SPORTLAAN (2)

FIGURE 2, THE HAGA HOSPITAL, LOCATION LEYWEG

The specialisms deliver treatment divided into inpatient- and outpatient care. "Inpatient" means that the procedure requires the patient to be admitted in the hospital and stay overnight, primarily so that he or she can be closely monitored during the procedure and afterwards during recovery. "Outpatient" means that the procedure does not require hospital admission. It officially means that the procedure is day-care, and that the patient can leave the outpatient clinic within the day he or she arrived.

In recent years, an increasing amount of therapeutic and small surgical procedures are moved from the inpatient to the outpatient clinics. This is beneficial for the hospital in terms of costs and bed capacity, and for the patients this can be convenient as they can now recover at home.

The Haga hospital is home to all well-known specialisms, ranging from cardiology to lung-diseases and from orthopaedics to neurology. In total there are 19 different large specialisms in the Haga hospital, listed in appendix B. The specialisms can be categorized in surgical- and diagnostic specialisms, the latter also known as internal specialisms. An example of a surgical specialism is the Ear-Nose-and-Throat (ENT). The week schedule of ENT-specialists is divided between consulting hours at the outpatient clinic and performing surgery in the Operation Room (OR). Diagnostic specialists do not perform surgeries but provide care with so-called non-invasive treatment. Their week schedule however often shows variation as well. Gastroenterologists for example perform colonoscopies when they are not having consulting hours.

It is of major importance that close cooperation exists between surgical and diagnostic specialisms. There exists continuous interaction between these fields; surgical patients frequently encounter internal issues, while 'internal' patients often require surgery as well.

In order to provide more background to the reader on the nature of the organization, another difference between the specialisms is mentioned. It concerns how the specialists have organized their practices from a financial point of view. First there are the specialists that are directly on the payroll of the hospital. Then there are the specialists that work independently and have organized themselves in a partnership (Dutch: maatschap). In the Haga hospital the specialists are, like on average in the Netherlands, roughly 50/50 divided between the two organizational structures; 104 are on the hospital payroll, 99 are in a partnership.

2.1.2 ORGANIZATIONAL STRUCTURE

To be able to control and steer the hospital towards its goals, the organization contains RVE's, which are Business Units (Dutch: Resultaat Verantwoordelijke Eenheden). An RVE is created per specialism, or per group of specialisms that often show overlapping production-resources and/or frequent cooperation between them. Within the Haga, the head of an RVE is called a sector manager, and the head of one specialism is called the head of unit. The goal of the RVE's individually is to achieve a yearly growth in revenue. The different specialisms in an RVE can be divided in the outpatient setting, the inpatient clinic and the research department that they contain. Also the Operating Room Complex is positioned in an RVE. To see an overview of the organizational structure see Figure 3. Specialists on the hospital payroll are under the supervision of the sector manager. Specialists that are working independently within an RVE are gathered in one or multiple partnerships.

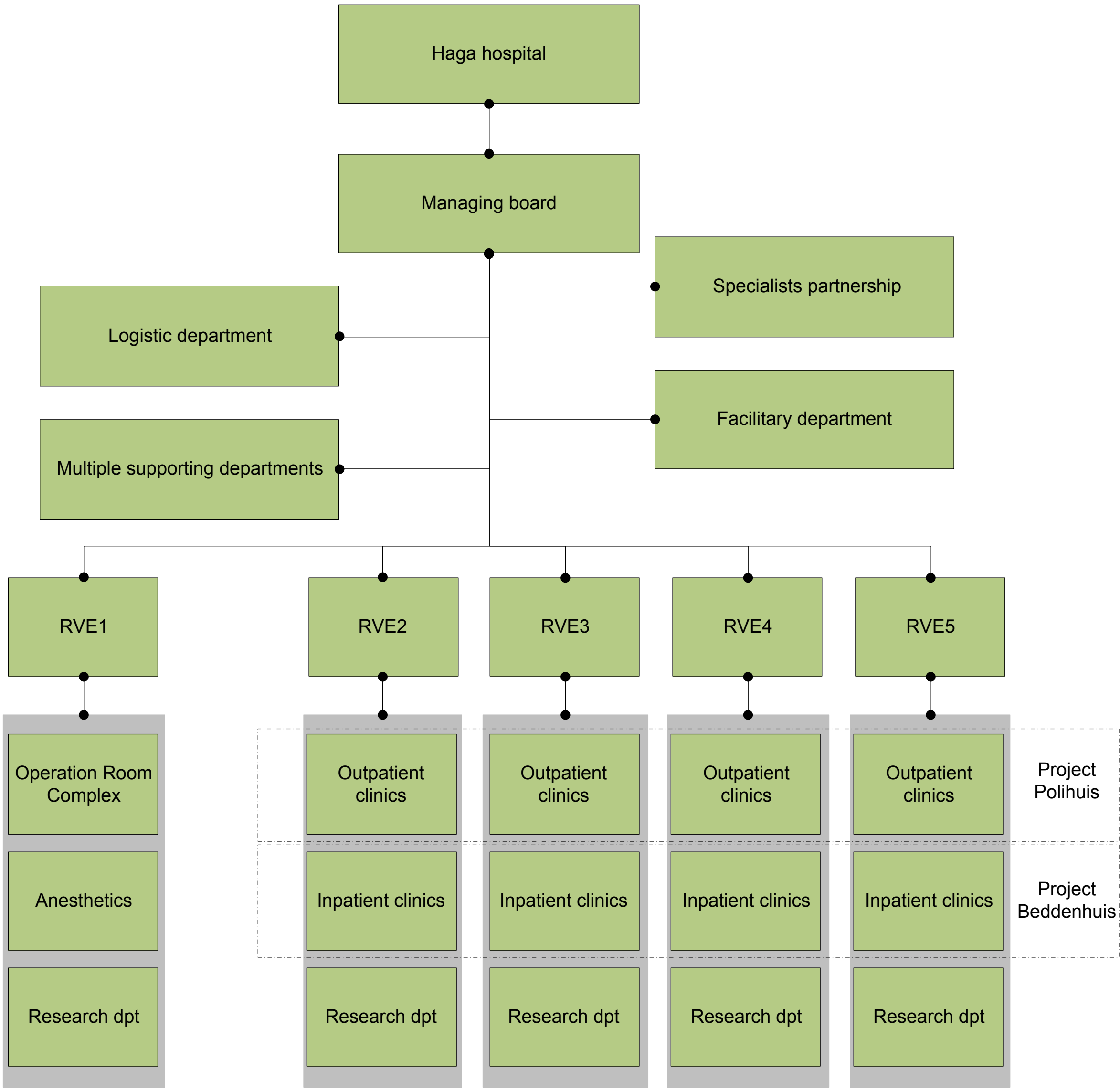

FIGURE 3, SIMPLIFIED ORGANIZATIONAL STRUCTURE HAGA HOSPITAL (SOURCE: HAGA ANUAL REPORT 2015)

Apart from the RVE's, there are various supporting departments in the hospital. In the light of significance for this research, three of them will be explained in further detail:

Planning, Control and Information

This department has the responsibility to check and inform the RVE's on their financial performances. It gathers all the data that involves the costs and revenues of both the outpatient and operations departments. Together with the Finance department they structure the Diagnosis and Treatment Combination costs of all patients, so that this eventually can be invoiced at the healthcare insurance companies. They also inform the specialisms monthly on how they are performing in terms of the production goal that has been agreed on at the beginning of the year. It is important to know that this production goal is defined in terms of the number of new patients for the outpatient clinics, and the number of operations in the operation room.

Bureau of Admission

A key task of this bureau is to schedule the OR's such that they are used as efficient as possible. This means that they schedule the specialists of different specialisms to the different OR's through the week. This Master schedule is the schedule where all further specialists' schedules are built on. The bureau of admission also assigns the beds to the different departments.

Logistics Company

The logistics company is the department that is responsible for logistics of both goods and patients. It is responsible for an efficient warehousing and in-time delivery of goods. Furthermore, it is responsible for the efficient and timely transport and care of the patients within the hospital. Since a couple of years, the logistic company has started two projects: Polihuis and Beddenhuis. The Beddenhuis focus lies on the clinic, the capacity and usage of hospital beds and the transportation of patients. Its main focus however is to maximize the time that nurses and doctors can provide care, by eliminating waste in their processes. The Polihuis focus lies on the efficiency of capacity usage in the outpatient clinics and to streamline all processes involving the outpatients in order for both patient and doctor to benefit. As can be seen from the organisational chart, the structure is organised vertically, whilst project Polihuis is organised horizontally over all outpatient clinics. As many of the specialisms have, overtime, created and adapted to a specific way of working, the goal of Polihuis is to standardize processes at the clinics where possible in order to benefit the patient.

Within the logistic company there is the impression that many of the outpatient clinics do not plan the specialists and patients efficiently. There is a tendency of largely varying waiting times for patients, empty appointment slots one time and many double bookings at other times. It was therefore the logistic company and project Polihuis that wanted to analyse the present ways of appointment planning at the clinics, and to design a standardized, more efficient way to organize the planning.

2.1.3 The outpatient clinic in short

As mentioned above, the definition of an outpatient clinic is a clinic where people are treated and leave the clinic before the end of the day. This also includes patients that come from the inpatient clinic to the outpatient clinic and afterwards return to the inpatient clinic. New patients are normally never directly seen by a specialist, but are always referred by a general practitioner or other specialist. In practice, an outpatient clinic provides three types of office hours, which are:

- Testing
- Consulting
- Small treatment

Testing at the clinics most often involves testing of organ and bodily functions. During consults the doctor informs the patient about his illness and possible treatments. With small treatment is meant small invasive procedures in a treatment room. The treatments sometimes require local anaesthesia but never require complete anaesthesia nor a room with pressure regulation. The physical clinics consist of a desk, a waiting room for patients, several consulting rooms and possibly testing and treatment rooms.

All clinics have a number of specialists varying from 5 to 15. Almost every clinic has a number of residents in training (Dutch: AIOS) and residents not in training (Dutch: ANIOS). Most clinics have either doctor-assistants or nurses to assist the specialists and residents in their jobs. Every clinic hosts a number of co-assistants every few weeks; these are basic-doctors in training in their bachelor phase.

Apart from that there are several administrative employees. All clinics have a couple of desk employees and phone assistants. These are also the people that plan the patients into the doctor's rosters. Moreover, every clinic has one head-of-planning, who constructs the appointment rosters and specialist's rosters of the specialists. Every clinic has a head-of-unit, who is responsible for the continuity of day-to-day business of the clinic.

2.2 PROCESS DESCRIPTION

In this section the process of the outpatient clinic will be illustrated. Existing differences between the observed clinics in these processes will be pointed out. This chapter will solely describe the processes as they give an impression to the reader, in chapter 3 the problems will be analysed in detail. First, the method of observing will be described to get insight in how the description was created.

2.2.1 METHOD OF OBSERVATION

Five outpatient clinics have been chosen to investigate. The description is based on an observing the outpatient clinics: Gynaecology, ear-nose- and throat, lung diseases, plastic surgery and gastroenterology clinics.

The number of five clinics is chosen because of the limited amount of time this research has to take place in. As mentioned before, main distinction in outpatient clinics can be made between surgical and diagnostic clinics, both of which are included. It is also expected that differences in responsibility may be present between specialisms with payroll- and partnership specialists, so both of these are in the observation set. The other most important criterion for the choice of clinics was the availability and willingness of employees for interviews and questions.

In order to obtain an insight in the processes from different perspectives, various employees per specialism have been incorporated. The analysis has been executed by observing and interviewing the following workforces:

- Head of planning
- Desk employee
- Nurse
- Specialist or specialist-in-training

The description is made based on four parts that form the process. These are 1. The creation of the appointment schedules. 2. The planning of the patients. 3. The process of a consult. 4. The utilization of software during the process.

2.2.2 CREATION OF THE SCHEDULE

For the creation of the outpatient schedule, a specialist's roster is used. The creation of this specialist's roster is different for the surgical and the observing clinics.

Specialist's roster

For the surgical specialisms a separate hospital-central department, the bureau of Admission creates an OR schedule. This schedule is created a year in advance, and involves all shifts i.e. mornings and afternoons) for all specialisms in the OR. Based on the OR-schedule, the surgical specialisms create a specialist's roster for their doctors. The specialists and residents often do this themselves based on their preferences. A doctor can be either scheduled for the outpatient clinic or for the OR. Compared to the outpatient clinic, the OR is a more expensive resource for the hospital. This means that the specialist's roster for doctors is currently optimized for the utilization of the ORs.

For the observing specialisms, a head planner of the clinic creates the specialist's roster based on specialists' preferences. Although these specialisms don't perform surgery, there are other procedures that these doctors perform such as testing and spectroscopies. The planning horizons for these observing specialist's rosters differ per outpatient clinic, mostly from half a year to a year ahead.

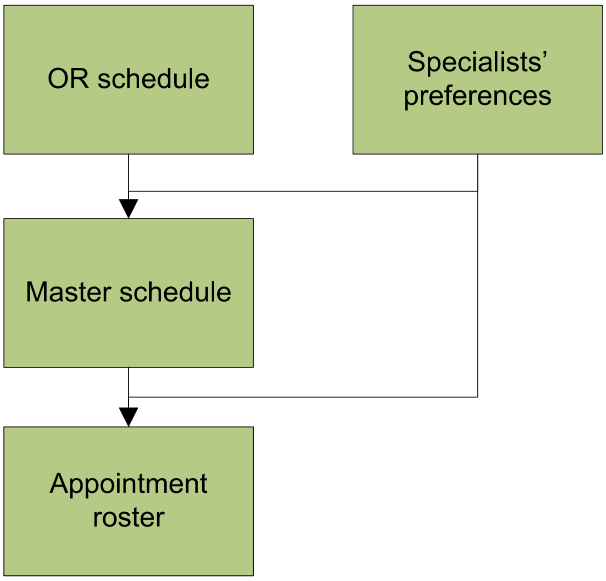

FIGURE 4, INPUT AND CREATION OF SCHEDULES

Appointment roster

Based on the specialist's roster an appointment roster for the consultations is created. The ENT roster is ready for a year ahead, which means that patients can already be scheduled one year from now. For gynaecology this is 7 months, for gastroenterology 3 months.

These empty appointment rosters contain various types of appointments, some of which designated for that specific slot. By far the most used appointment types at all clinics are New Patients and Control Patients.

It is important for the clinics to distinguish New and Control Patients because of the mentioned yearly production goal that needs to be achieved, which is expressed in terms of new patients treated. The definition of a new patient is that he or she has not been treated for this specific illness by the outpatient clinic for more than a year. Therefore when an arriving patient has not been treated by the clinic since a year or he has but arrives with a new illness to be treated, it is a new patient according to the definition.

Apart from the consulting appointments, every clinic works with Telephone Consults (TC). The patient is called for a small consult of 5 min of informative nature, most often to report results of a test. In all clinics, these TC's are booked in the doctors' schedules at the end of a shift.

2.2.3 PLANNING OF THE PATIENTS

Appointment requests

When the appointment roster is created, patients can be planned in the open slots. The request for an appointment can come from different four different sources:

1) The General Practitioner. 90% of all requests of the GP's are received in the software-program called ZorgDomein (ZD). ZD is a program in which all hospitals and most GP's in The Netherlands are registered, and share their medical information in. ZD contains standard fields where the GP fills in patients' general information, first diagnosis and possible urgency. In situations where a GP does not work with this system he sends a fax or handwritten letter.

2) Other specialism within the hospital. When a doctor of another specialism requests an appointment for his patient, this is done via an ICC (Dutch: Inter Collegiaal Consult).

3) Other hospital. Often referred by phone or fax.

4) The specialist. When the patient needs to come back for check-up, this is done via an "order'', sent to the planner.

Source	Document
General practitioner	-Zorgdomein (IT-system) -Fax -Handwritten
Other specialist	-ICC (IT-system)
Other hospital	-Fax -Handwritten
The specialist	-Order (IT-system)

TABLE 1, REFERRALS: SOURCES AND DOCUMENTS

All digital forms arrive in the planners work list. After the request is received, different clinics have a different policy. Lung-disease and gastroenterology have the policy to triage every appointment request. Triage means that the request is forwarded digitally, and then analysed and judged by a specialist. The specialist determines again in which timeframe the patient must be seen, and if necessary which specific doctor within the specialism needs to see the patient. This triaged form is sent back to the planner's work list.

The ENT, Gynaecology and Plastic clinics do not triage the patients. In case of a ZD, the patient has received the phone number of the clinic and the clinics wait until the patient calls them to make an appointment.

Patient planning

When the triage is finished or a patient calls/comes for an appointment, the patient needs to be planned. It rarely happens that a new patient wants to see a specific specialist, it sometimes happens that only a specific specialist can see the patient because of the patient's symptoms. It virtually always happens that a check-up patient needs to see the specialist that he or she had seen before.

The planner then uses the system's intelligent search function that looks for the filled in specialist and appointment type to find the open appointment slots according to the criteria and plans the patient. Sometimes the search function cannot find a slot within the desired timeframe. This happens when the patient needs to be seen within the access time period. The access time is defined as the time between the appointment request and the actual appointment.

Sometimes a patient needs to be planned sooner than access time allows. This happens in case of urgent patients, semi-urgent patients and check-up patients that need to be seen within the access time. Urgent and semi-urgent patients are referred, new patients. Generally speaking for outpatient clinics, urgent patients are viewed as patients that need a consult within one or two days. Semi-urgent patients can be viewed as patients that need to be seen within ten days or less. Other patients are considered elective patients.

2.2.4 GENERAL PROCESS OF A CONSULT

When the patient arrives in the clinic, he registers at a registration column. That is a digital device that scans the patients ticket barcode printed for the patient earlier in the central hallway. The column is shown in Figure 5. The system is now aware of the presence of the patient, who is directed to the waiting room. It is possible that the patient needs to undergo some tests before the specialist sees him. This is done based on the patient's characteristics and symptoms. For example at Gynaecology, a nurse in a special room always calls in pregnant patients first, to measure blood pressure, and return to the waiting room.

FIGURE 5, L: PATIENT IS CALLED UP VIA TV-SCREEN, R: PATIENT REGISTERS AT A COLUMN

On television screen, the patient can see and hear when he is expected by the specialist and in which room. The specialist does this by clicking the "call-up" button in the system.

A consult normally starts with questions, followed by a diagnosis and a treatment plan. The specialist or an assistant types these into the patient's file. This is mostly done during the consult, but some doctors find this inappropriate and type in their analysis directly after the consult. There is variability in the length of the consults because of the type of patients and their complaints. New patients usually take more time because the patient must be diagnosed. There also exist differences in the consultation length from doctor to doctor.

For the surgical specialisms the specialist sometimes provides treatment during the consult. This is done either in the consultation room or in a special treatment room. Examples are the echo-rooms for Gynaecology and the treatment rooms of the ENT-clinic. Because these treatments are not necessary for every patient, there are usually less treatment rooms than there are consultation rooms in a clinic. After the consult, the patient might need to come back for a check-up appointment. If so, the doctor has filled in a previous mentioned order to the desk. The patient goes to the desk employee to plan a new appointment.

2.2.5 SOFTWARE IN THE PROCESS

All previous described processes are supported by the general Hospital Information System-system (HIS), called Chipsoft HiX. Earlier mentioned ZD system is used for the file exchange with GP's. HiX has a ZD-viewer where all patient information can be watched, but the two systems are not compatible.

During the planning phase, the appointment roster is created in HiX. It is possible for planners to copy old rosters in HiX. In HiX, the planners have a work list where all ICC, orders and ZD request are stored. ICC and orders can be opened and ZD's can be viewed. The search tool in HiX looks for free slots according to the criteria filled in. The patient is booked in the system and the appointment is saved.

When the patient arrives and scans the barcode, HiX automatically shifts the patient's virtual status to "waiting room". When the doctor calls up the patient, the system shifts the status to "in consult". After the consult, the doctor dismisses the patient in the system and the patient's status shifts to "left". During the interviews it becomes evident that doctors do not always perform the last step, as a new consult needs to be prepared.

The system also contains Electrical Patient Documents (EPD). The doctor or his assistant fills in all significant medical information in this document. The system contains a few standard fields that can be used, but generally doctors type their findings, orders and ICC's manually in the system.

3 PROCESS ANALYSIS OF THE OUTPATIENT CLINIC

The processes as described in chapter 2 will be analysed with the Delft Systems Approach (Veeke et al, 2008), to identify and pinpoint the relevant issues that exist in the planning process of the clinics. The process of the outpatient clinic can be considered as a Black box, see Figure 6. The system boundaries are set around the clinic, which at this aggregation level can be considered any general outpatient clinic. The Main function of the system is to provide care to patients. On the input side patients enter the system, and on the output side treated patients leave the system. With treated here is meant given the best care to the knowledge of the system. From the environment and different stakeholders certain requirements are asked from the system. The environment of the outpatient clinic consists of the elements that exercise influence on the clinic, and these are established here.

The environment of the outpatient clinic involves the hospital, meaning the higher layers of management and departments that are closely related to the clinics, such as the OR-department and logistic department. Patients and doctors belong to the environment as important stakeholders. Other elements of the environment to be mentioned are employees, insurance companies and society in general. This research considers the hospital, patient and doctors as the most important elements in the environment and their requirements will be taken into the scope. The extent to which the system can fulfil the requirements of the environment is communicated to the environment as the performance of the system.

As this research addresses the outpatient planning, the pure medical requirements asked from the clinic are left out of the research scope. Medical requirements that have an influence on the planning processes will be taken into account. The described black box will be used to zoom in further to different aggregation levels so that shortcomings are identified that can lead to poor performances of the outpatient clinics.

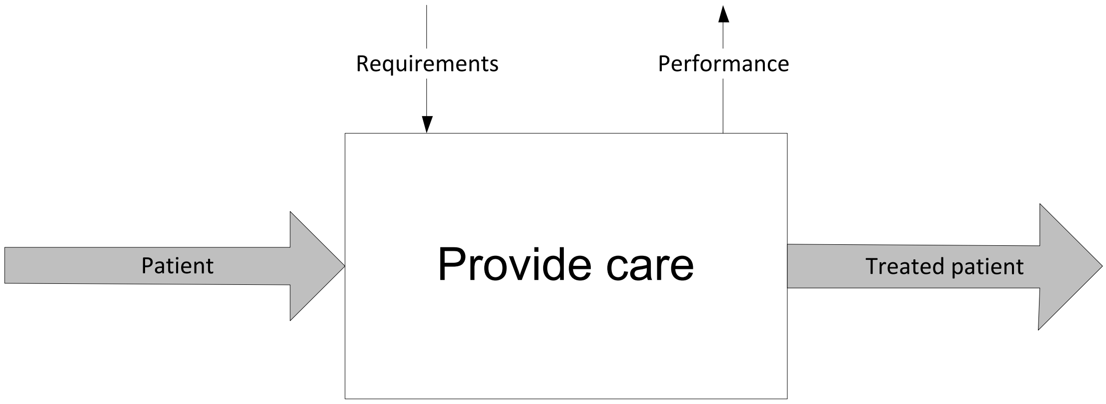

FIGURE 6, THE PROCESS OF THE OUTPATIENT CLINIC AS A BLACKBOX, AGGREGATION LEVEL 1

The goal of the outpatient planning is to tune and streamline different processes of healthcare. It aims to make sure that streams of patients and means are adjusted to each other and that doctor, patient, document and other resources meet each other in the right place, at the right time. Multiple aspects need to be considered, so the PROPER model (Veeke et al, 2008) will be used to analyse the system at the next aggregation layer.

The PROPER model recognises the multiple aspects relevant to the system. The elements in the aspect streams are transformed during the process. These relevant aspects are identified as the healthcare request, the patient and the resources.

The healthcare request is the referral and possible documentation of a first-line doctor or another specialist. During the process healthcare requests can be clarified through diagnosis, but the main function is to answer the healthcare request of the patient. The patient in need of care enters the system on a given day and time, and is treated during consultation hours at the clinic. The most important resource in the clinic is the doctor, which is arguably the most expensive and value adding resource. Other important resources are the rooms, employees and equipment. These resources are used during the main process with the function "provide care".

The coordinate function represented above the system is responsible for the coordination of the "Answer", "Treat", and "Use" functions by generating executable tasks from the healthcare requests and assigning the right – and right amount of – resources. This chapter will further analyse what the coordinating function does, in the current situation.

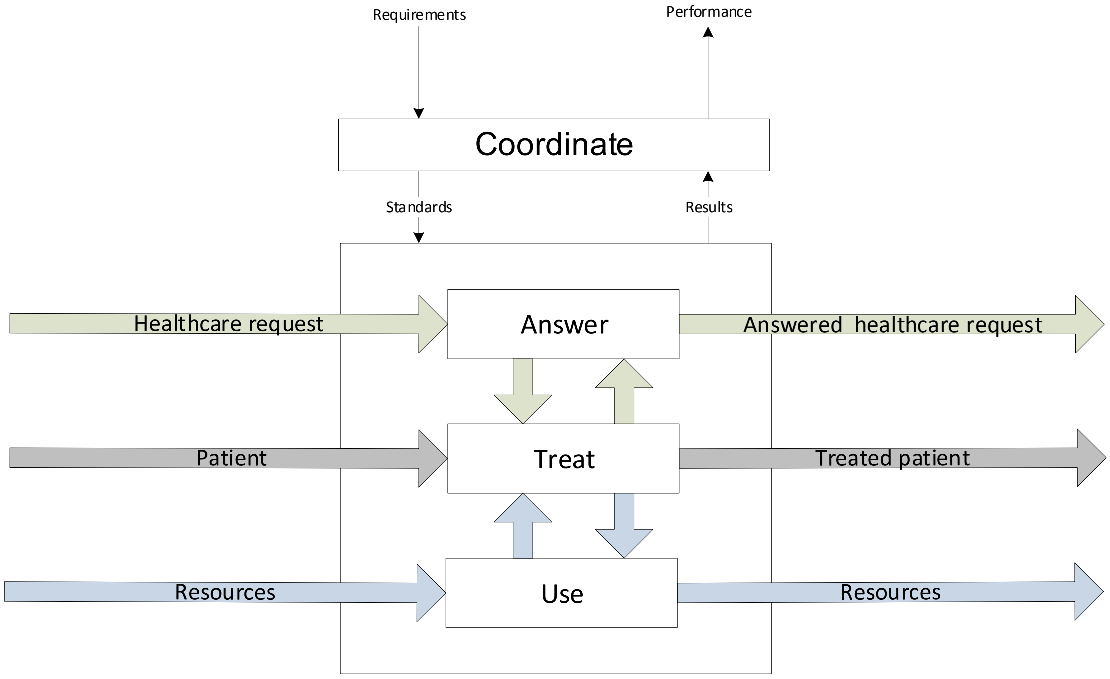

FIGURE 7, THE SYSTEM OF THE OUTPATIENT CLINIC WITH ASPECT STREAMS PRESENTED AS A PROPER MODEL, AGGREGATION LEVEL 2

Figure 8 zooms in further on the PROPER-model and the three aspect systems. It can be seen that a difference is made between the External Waiting Time (EWT) and the Internal Waiting Time (IWT). The EWT, also called access time, is the time between an appointment is made and the date of appointment. The IWT is the time between the time of appointment and the actual moment when the patient is called in, and is situated in the patient stream. In the next part the requirements will be established for each of the three aspect-streams, based on the stakeholders needs.

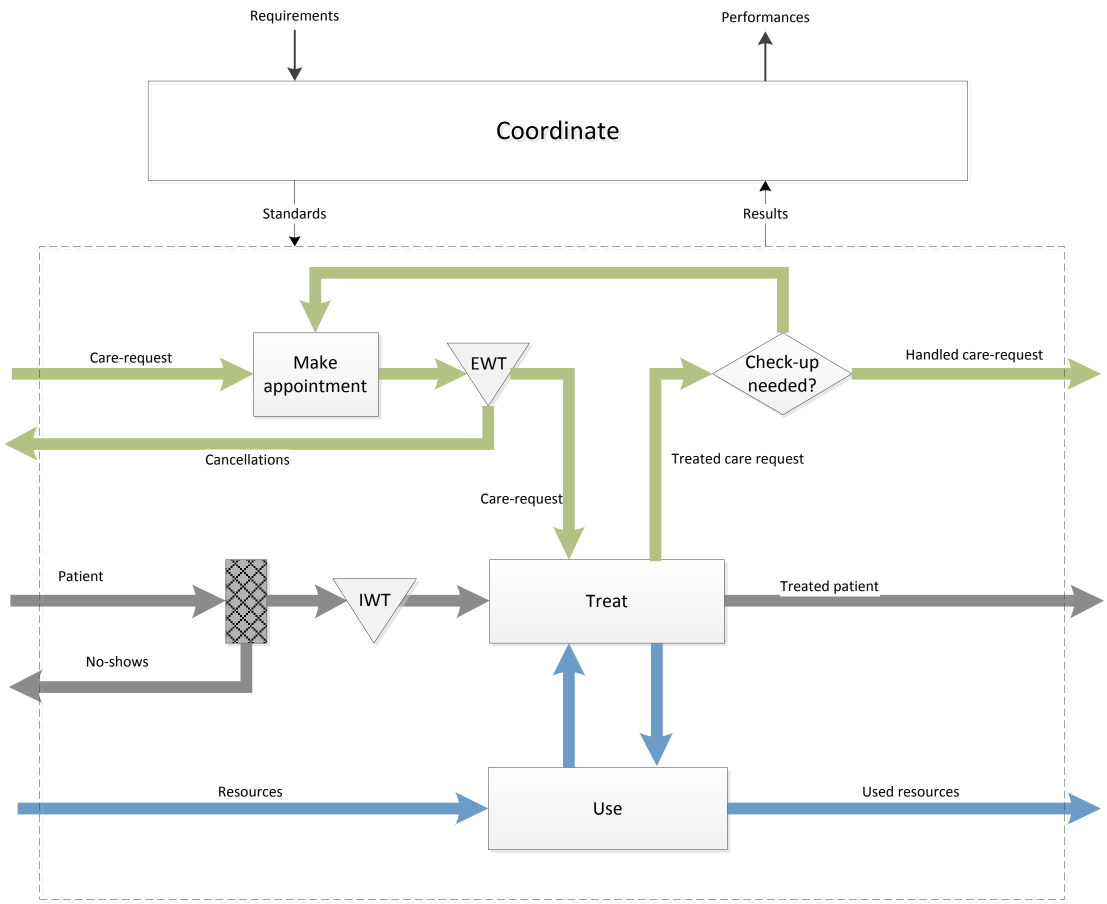

FIGURE 8, PROPER MODEL OF OUTPATIENT CLINIC, AGGREGATION LEVEL 3

3.1 REQUIREMENTS

To analyse what is being coordinated in the current situation, we first need to know what we need from the system. This is established by analysing the requirements. As mentioned above, we take the three most important stakeholders into account in this research. Based on interviews with the stakeholders and literature research (Moayyedi, Moeke), a list of important requirements for the system is created which can be seen in Table 2.

The hospital provides the necessary means such as rooms, equipment, nurses and other staff. They make central agreements with the insurance companies about production and are the employer of the doctors. For the hospital it is important that these means are used as efficient as possible. In case of payroll specialist, these specialists belong to the staff. As the OR is a more expensive department, the hospital needs the outpatient planning to follow the OR planning. Furthermore, the hospital has agreed on the production goal with insurance companies and therefore needs the production, in terms of new patients, to be close to this goal.

Doctor

Doctors are the most valuable resource in terms of costs and specific knowledge. The majority is working in a partnership construction, hired by the hospital. They make production agreements with the hospital based on the insurance contracts that the hospital agreed upon, so for these doctors it is important to achieve a production close to the yearly goal. The doctor has many more requirements from the hospital as a system. He needs to conduct research to improve the quality of treatments, he needs to perform operations on patients at the OR and attend patients in the inpatient clinic. He also attends congresses to share and gain knowledge on treatments. For these reasons, an important requirement for the doctor from the outpatient setting is flexibility in the planning to fulfil his other requirements.

The doctor also requires as less overtime as possible, both at the level of extra (unplanned) working days as daily overtime during the consultation sessions. Partnership specialists also need their time to be spent as efficient as possible, which is true to a lesser extent for payroll specialists.

Patient

The patient is the client of the clinic and main end-user of the system. It is the product that needs to be transformed by the system and therefore its interest is of major value to the system. When a patient is referred to an outpatient clinic, he is concerned and often stressed about his health. He therefore needs to see a doctor as soon as possible and requires minimal access time. When the patient has made an appointment, it happens that the appointment is cancelled by the hospital due to circumstances such as changes in rosters or the doctor being required elsewhere. It is in the patient's interest that this happens as seldom as possible.

When the patient arrives he requires that he is called in timely by the doctor within a certain timeframe, as he has made an appointment with the clinic. When the patient is in for consultation, he needs to feel that he has sufficient amount of time with the doctor to ask questions and obtain all information necessary for him.

Stakeholder	Requirements
Hospital	Yearly production goal
	OR-requirements must be met
	Maximal utilization of staff and means
	Maximal utilization of doctors (payroll specialists)
Doctor	Flexibility for leave
	Yearly production goal (partnership specialists)
	Minimal overtime (working days)
	Minimal overtime (extra work-hours)
	Maximal utilization of doctors (partnership specialists)
Patient	Minimal access time
	Minimal appointment reschedules
	Sufficient time with doctor for consult
	Minimal internal waiting time in waiting room

TABLE 2, IDENTIFIED REQUIREMENTS PER STAKEHOLDER

Some of the requirements established per stakeholder overlap. They are arranged together and sorted per aspect system according to Figure 7. This can be seen in Table 3.

Aspect system	Requirements
Answer	Yearly production goal
	OR-requirements
	Flexibility for leave doctors
	Minimal overtime (working days)
	Minimal cancellations
	Minimal access time
Treat	Minimal overtime (working hours)
	Minimal internal waiting time
Use	Maximal utilization of doctors
	Maximal utilization of staff and means

TABLE 3, IDENTIFIED REQUIREMENTS ARRANGED PER ASPECT PROCESS

In further analysis will be zoomed in on the separate aspect streams, and see what is being coordinated by the coordinating function, with the identified system requirements in mind.

3.2 CARE REQUEST STREAM

The care request stream is shown in Figure 9. When a healthcare request comes in via one of the sources described in section 2.2.3, the request goes for triage.

The triage process differs from clinic to clinic. Some clinics pile the requests in buffers for the triage specialist on duty. He performs the triage and the patients are planned and sent a letter with information on when they are expected. Other clinics pile the requests in a buffer, and wait until the patient calls. Based on information in the request, the planner makes an appointment with the patient. In this case the planner performs the "triage". Other clinics use hybrid systems that can be categorized between the two mentioned processes.

The appointment roster determines when there are slots available for the making of an appointment, and the appointment is saved into the roster after it has been made. The appointment roster is based on the specialist's roster, which determines when which specialist is available for consultation hours.

Finding 1: Doctors' requirements determine the rosters

The specialist's roster is composed based on doctor's requirements, mainly his other job requirements and 100% utilization of doctors. This means that access time and cancellations initiated by hospital are not deemed as important during schedule creation. It also means that the financial targets get priority, such as the production goal, which is explained in the next part.

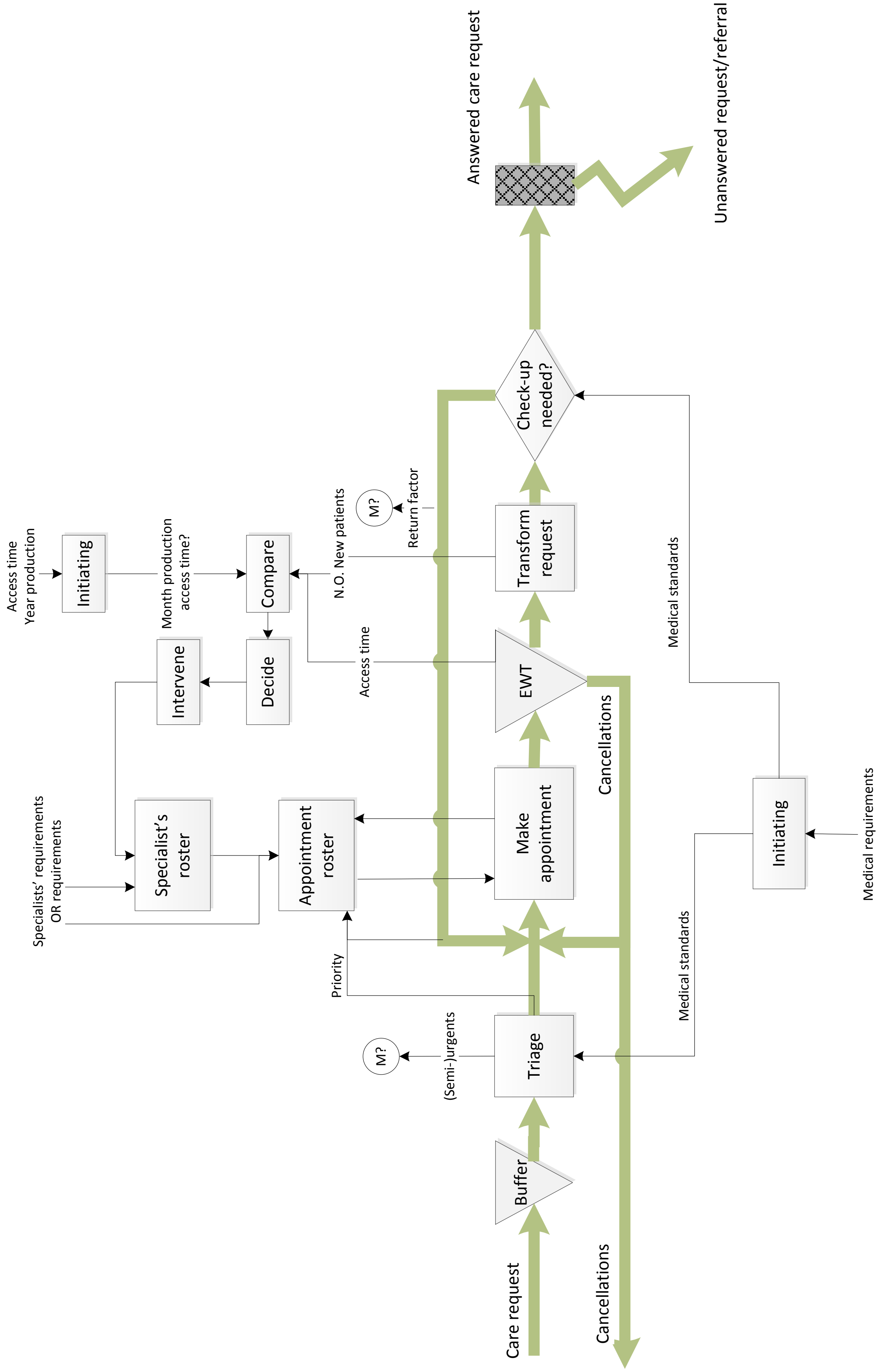

FIGURE 9, HEALTH CARE REQUEST STREAM, AGGREGATION LEVEL 4

Every month, the production of the clinics is evaluated. In month X, it is then held against the yearly production times X divided by 12. It does not frequently happen that it comes to a direct intervention based on these figures, as often a lag in schedule is causes by doctors being on holiday. This creates a lag based on the average production but will be made up for. Intervention based on the access time is also possible. When access times get to a high level as perceived by them, the partnership will occasionally decide to add extra capacity to the clinic to manage the situation. This means that the clinics do not actively control the access time.

Finding 2: Production is used as a target, not as a capability to deliver service

It can be concluded that control is applied fully to achieve the production target and marginal for access time. The production has an evaluating and initiating function with clear norms that can be - however is not always - acted upon. The access time has a clear norm called the Treeknorm. The Treeknorm states that 80% of patients must be seen within 3 weeks, and 100% within 4 weeks. However in the current situation there are no consequences for violating the Treeknorm, so it is never acted upon. This can be seen as a sign that, despite the non-profit nature of the hospital, financial targets are considered more important to steer on than the patient requirements.

After the doctor has concluded that no further treatment can be provided by his clinic, the healthcare request is not necessarily answered. It is possible that the patient cannot be treated or must be referred to a different clinic.

During the analysis, observations have been made on the blueprint of the appointment rosters and the length of the access times. First we feel the need to explain the general concept of supply and demand.

Theory of supply and demand

Variation	Long term (>week)	Short term (<week)
Demand	Reschedules Cancellations Weekly fluctuation Seasonal fluctuation	(Semi-)urgent No-shows Cancellations Reschedules Daily fluctuation
	Check-up patients	
Capacity	Roster changes	Sick-leave Unplanned meetings
	Holidays Congresses	Planned meetings

TABLE 4, IDENTIFIED VARIATION SOURCES IN SUPPLY AND DEMAND

If it were not for several different variations in the streams of supply and demand, capacity could be attuned to the existing demand flawlessly. The system however is subject to constant variations. These variations can be divided into short-term and long-term deviations, with the cut-off point placed roughly at one week. Moreover, variation can be divided into planned and unplanned variation. The different causes of variation in the system can be seen in Table 4.

The demand varies in the long term, as there is a natural variance in the number of requests that comes in on a weekly basis. Moreover, there is a variation that can be attributed to the seasonal influence. The lung-disease clinic for example experiences an increase in demand in spring time, when air-pollen causes breathing difficulties in allergic patients. An extra variation exists when patients cancel or reschedule their appointment.

In the short term the demand can vary through cancellations and rescheduling of appointments as well, however this becomes more problematic as it can be a challenge to fill up the slots if cancellations come in last minute, for example when the patient calls in sick. The most extreme form is when a patient does not show up at all for an appointment. Another form of variation is the number of urgent and semi-urgent patients that arrive and need to be planned on short notice. The number of requests fluctuate on a daily basis, however trends can be visible on daily basis such as a higher demand on Mondays for most clinics.

Although most clinics have a quite consistent specialist's roster throughout the weeks, the capacity is subject to substantial variation as well. A doctor on holiday or congress creates a temporary stop in supply for a patient group. The same variation on a small scale is true for meetings planned during the sessions. These variations are controllable and can be planned. Roster changes due to unplanned causes however occur on a regular basis. These can be due to OR-schedule changes or congresses and meetings planned late. Another last minute variation that occurs is when the doctor calls in sick, and patients need to be rescheduled. An example of demand and supply variation can be seen in Figure 10.

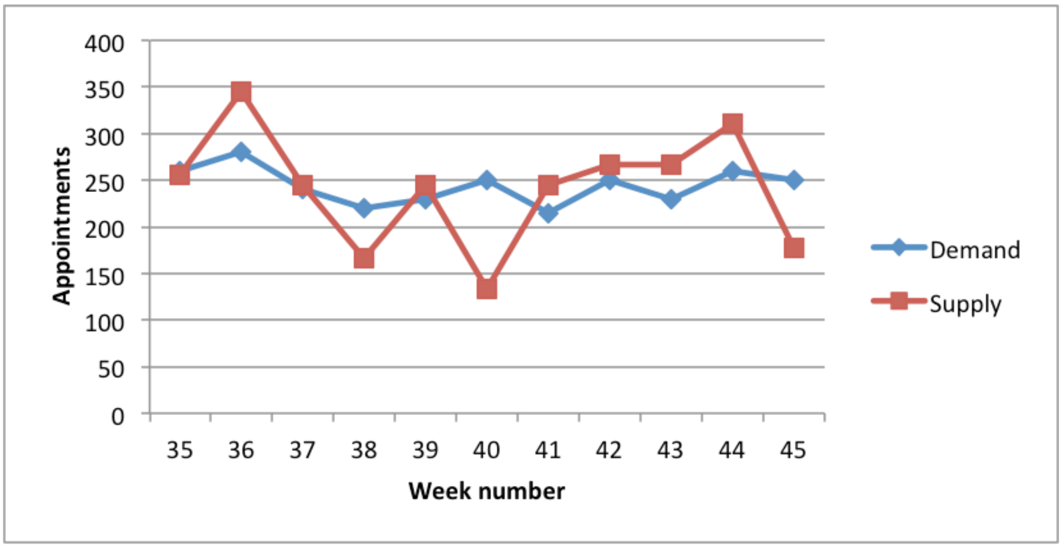

FIGURE 10, EXAMPLE OF DEMAND AND SUPPLY VARIATION OF ENT-CLINIC, 2016

Finding 3: Access time is used as buffer, but creates extra logistic work

The access times of the different clinics are shown in Table 5, shown by the third next available appointment. The access time is the delay between health care request and the first consult. For patients, this period can be stressful as they are dealing with a health-related issue.

The access times have some other disadvantages as well. The longer the time between the request and the appointment, the higher the likelihood that a patient will cancel or reschedule their appointment, or not show up. This means a higher risk of open slots in the roster, and more work for the staff to reschedule appointments. Another disadvantage is that patients that need to be seen on shorter notice, such as semi-urgent and check-up patients, need to be double-booked if the roster is full several weeks ahead. This leads to discussions between staff and doctors and in case of a double booking, to extra IWT and overtime for the doctor. Moreover, when a doctor's roster is changed and patients need to be rescheduled, a longer waiting list means rescheduling of more patients. This leads to more inconvenience for patients and extra work for staff.

The delay in access can have three different causes (Van der Voorde, 2013):

- Demand is larger than supply
- Uncertainty in supply
- Uncertainty in demand

For gastroenterology, at least part of the access time is caused by a higher demand than supply. All clinics in the surrounding area of the hospital have an equally high access time, as with population screening on colorectal cancer has significantly increased demands in the past year.

For the other clinics, the access time has been approximately the same level for a significant time, at least one year. This means that supply and demand are balanced, and the access times are used as a safety buffer to cope with the addressed uncertainty in supply and demand. However, we also concluded that the clinics do not actively steer on the access time. It is therefore highly likely that the access times can theoretically be significantly lower for the patient, given that there is a temporary extra capacity released to reduce the backlog. The better supply and demand can be matched and uncertainty can be avoided, the lower this theoretical access time is.

Outpatient clinic	Access time according to TNAA (01-03-2017) in weeks
ENT	3
Gastroenterology	12+
Gynaecology	7
Lung-diseases	4
Plastic surgery	3

TABLE 5, ACCESS TIMES OF THE 5 INVESTIGATED CLINICS

Finding 4: Many and dedicated appointment types create extra waiting lists

All clinics work with an empty blueprint an appointment roster. The blueprint consists of slots for certain appointment types with a period a multiple of 5 minutes. The number of different appointment types varies per clinic and goes up to 58 different appointment types. Not all appointment types created are in fact used. Some clinics use flexible slots. This means that all types of appointment that require the slot-time can be used. Other clinics use dedicated slots, which means that only a specific appointment type can be booked for that slot.

The large number of appointment types increases the complexity of the planning, and dedicated slots increase the number of patient queues. For example when a system uses 16 dedicated appointment types, it has in fact created 16 different patient queues, each with their own access time. As the relative uncertainty of these smaller queues is higher, this system creates extra access time to be sure that the appointment slots are filled. The number of types and flexibility is shown in Table 6.

Appointment roster	N.O. Appointment types	Flexible/dedicated
ENT	12	Flexible
Gastroenterology	59	Flexible
Gynaecology	29	Dedicated
Lung-diseases	6	Dedicated
Plastic surgery	16	Dedicated

TABLE 6, APPOINTMENT TYPES AND FLEXIBILITY OF APPOINTMENT ROSTER BLUEPRINTS, PER CLINIC

3.3 PATIENT STREAM

The patient arrives at the hospital and registers at the first column, where he is sent to the outpatient clinic. He receives a ticket with a number. At the second column he registers with the ticket, which sends a signal to the doctor that the patient is in the waiting room. When the doctor is ready to treat the patient, he will use a call-in button in his computer, the patient will see his number on a large screen and walks in for treatment. When necessary, the patient will make a check-up appointment at the desk.

It happens that a patient does not show up or cancels within 24 hours. In this case, it is checked whether the patient's reason for cancellation is valid. There are no standards; the planner decides the validity of the reason. If the reason is considered invalid, an invoice for a fine is sent to the patient.

Finding 5: Registrations are not used for measurements

The moment of registration, the moment of call-in and the end-time of consult are all measured in the system. The end-time of the consult however is not registered flawlessly, as doctors regularly forget to press the exit button. The start-time is registered almost flawlessly as it is needed to call in the patient. The start-time of the consult is compared to the appointment time of the patient, and subtracting results in the IWT in the waiting room. The waiting time per doctor is displayed on a screen in the waiting area so that the patient is informed about the expected waiting time. These registrations however are not used in the current situation for reporting purposes or creation of the schedules.

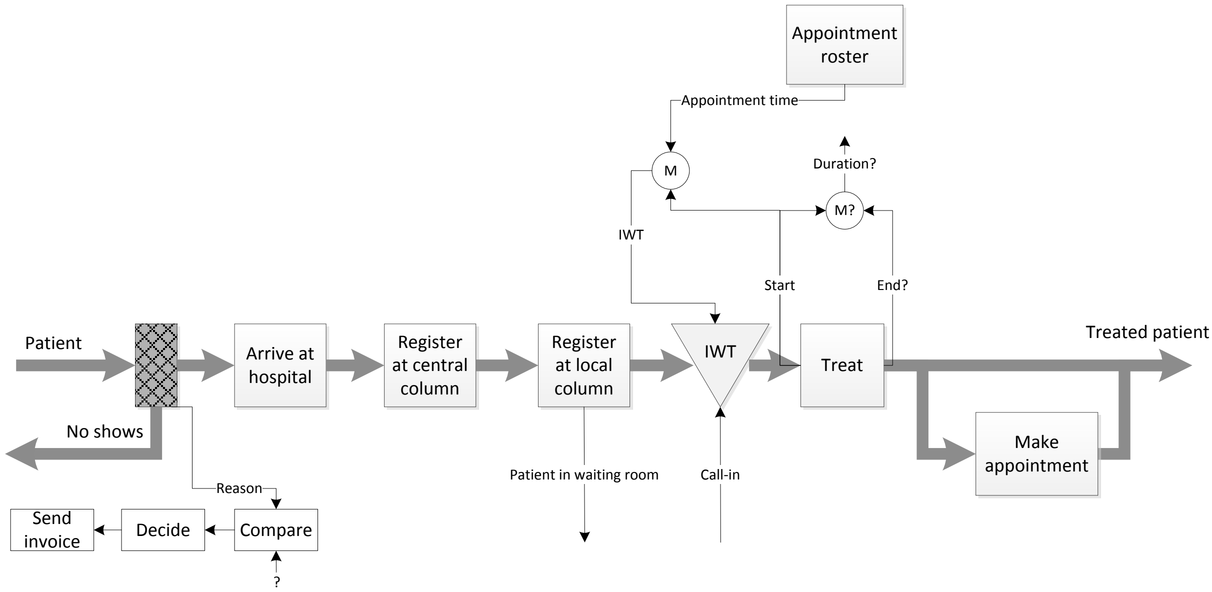

FIGURE 11, PATIENT PROCESS, AGGREGATION LEVEL 4

3.4 RESOURCES STREAM

The resources can be divided into rooms, staff and doctors. The rooms can be divided in consult rooms and treatment rooms for surgical specialisms. Treatment rooms are expensive rooms and have priority when it comes to optimal utilization for the hospital. Staff can be divided into nurses, doctor's assistants and desk employees. Further differentiation of functions exists within the hospital but this will not be elaborated on for the sake of simplicity.

The doctor is the leading capacity and his schedule initiates the scheduling of all other resources. The amount of staff depends on the number of doctors having consults. In discussion with staff and doctors, the hospital decides on a yearly basis the amount of staff needed per consult session. This is evaluated yearly with discussion and a questionnaire on the work pressure experienced. The high-level resources stream controlled for staff utilization is shown in Figure 12.

Finding 6: No measurements for doctor utilization

On a daily level it is desired to let the doctor, being the most expensive resource, be used maximally. At the moment the doctors make decisions about the appointment schedule with the aim of 100% utilization. However, there are no measurements that are used to check the utilization of doctors apart from their own experience. The zoomed-in process of the doctor is shown in Figure 13.

The utilization of rooms is not specifically measured in the current system. By investigating the flexibility of rooms this parameter might be improved. This is considered as a strategic adjustment and is not included in the scope of this research. Treatment rooms have a very specific character per clinic and therefore will not be included in the research either.

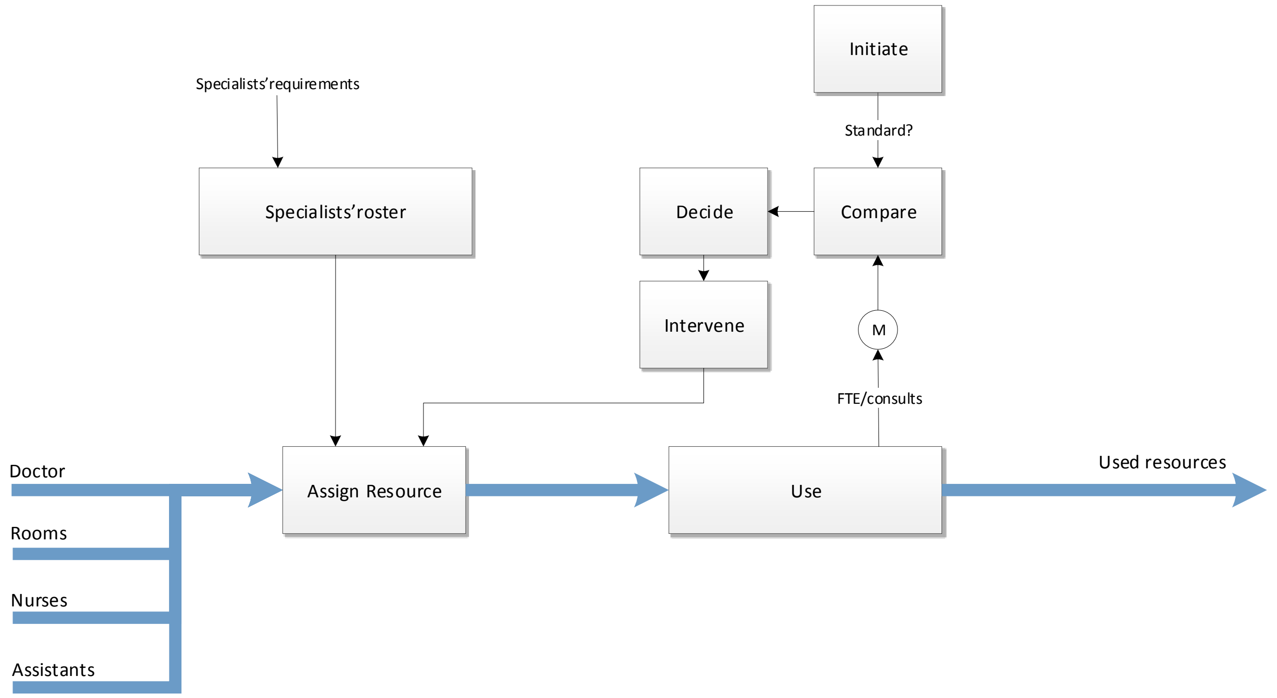

FIGURE 12, RESOURCE PROCESS, AGGREGATION LEVEL 4

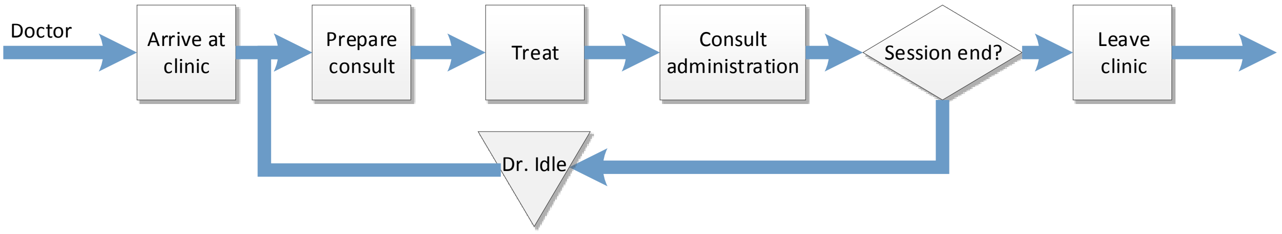

FIGURE 13, DOCTOR PROCESS, AGGREGATION LEVEL 5

3.5 Conclusion: Lack of patient requirements in coordination

When we look back at Figure 6, we can now conclude that the coordination in the current situation is mainly based on hospital and doctor requirements. Veeke et al (2008) state that in order to control a system four conditions are demanded: The system must have a goal, the goal must be achievable, it must be possible to influence the systems behaviour, and the result of change in behaviour must be known. For proper function control are needed a KPI, standard, measurement and evaluation of those measurements. The current coordination for the identified requirements is shown in Table 7.

The green cells indicate there is a clear control, in red are the parameters that are not controlled for in the current situation. The yellow cells indicate that there is no clear measurement or evaluation, but the hospital has strict rules that are to be obeyed.

	Requirement	KPI	Standard	Measurement	Evaluation
Hospital	**Yearly production goal**	Number of new patients	Contractual agreement	Appointment roster HiX	Yearly negotiations
	OR-requirements	-	OR-schedule	-	-
	Utilization of staff	Staff/session	Clinic specific	Completed schedule	Yearly discussion
Patient	**Cancellations**	?	?	Cancellations in HiX	?
	Access time	TNAA	?	TNAA	?
	Sufficient time with doctor	?	?	?	?
	Internal waiting time	?	?	?	?
Doctor	**Utilization of doctors**	?	?	?	?
	Yearly production goal	Number of new patients	Contractual agreement	Appointment roster HiX	Yearly negotiations
	Overtime	?	?	?	?
	Flexibility for leave doctors	Leave announcement period	3 months and 6 months	-	-

TABLE 7, CURRENT FUNCTION CONTROL IN THE THREE PROCESSES, BASED ON IDENTIFIED REQUIREMENTS

The OR-requirements are generally followed. The number of cancellations by the hospital is measured in the system but these measurements are not reported and no standard exists. The flexibility for leave of doctors is controlled by the rule of requesting leave within a certain time frame.

The requirements for the patient stream are the IWT and sufficient amount of time with the doctor. The sufficient amount of waiting time can be difficult to determine, as it is a subjective measurement. However it is not tried to measure it at this moment. The internal waiting time is measured in the system by taking the difference between appointment time and start-time of consult. Measurements are not reported however, and there is no norm to compare the results with. The finding in the resources stream is that no measurements are currently performed on the operational utilization of the doctors and no KPI is set so that it can be controlled.

It can be concluded that control is not present for the patient requirements Access time, Cancellations, Sufficient time with doctor and Internal waiting time. Also for the doctor requirements Overtime and Utilization there exists no function control.

4 PROBLEM STATEMENT

In this chapter the final problem statement is defined based on the analysis of the current system in chapter 3. First chapter 3 is summarized and literature is used to back up the statements, which lead to the problem statement. Then the solution approach is presented based on a set of research questions.

Focus on financial steering

It is concluded that the system for outpatient logistics has a strong focus on financial control. This is due to doctors determining the input for both the specialist- and the appointment roster. Though situations might differ per doctor and per clinic, this leads to a general situation where doctor requirements have priority. The main steering is focused on achieving maximum utilization, flexibility for the doctor to do his other tasks – paragraph 3.1 - and reaching the yearly production goal, a requirement the doctor shares with the hospital through financial contracts. In other areas, financial figures are steered upon as well: The costs for staff are steered upon accurately and OR-requirements are leading because of OR cost.

The consequence of a strong financial focus is that patient requirements lose out, specifically considering the scheduling. In this situation waiting lists are used as a safety buffer to reach 100% utilization of doctors and appointments are double booked, which leads to extra internal waiting time for patients. OR scheduling in the lead can cause the rescheduling of outpatients. The yearly production is used as a target, instead of a capability to provide service. Not every clinic witnesses every one of these circumstances but many do, and the steering on pure financial targets gives rise to them.

New IT system registers operational data that remains unused

Since June 2016, the hospital has implemented a new HIS. During the first several weeks to months, the doctors and staff have gradually found their way to work with the system in a satisfactory way. Management however has not yet found the way to optimally use operational data from the system.

Operational data in particular is registered in the new system. This data concerns the doctors' schedules and no-shows. It also concerns the time of arrival at the clinic, time of call-in and time of exit of the patient in the doctor's office. This data is stored in the HIS and all cumulative data of a working day are transferred overnight to the hospital's data warehouse. The data is raw and needs to be processed, and it can be necessary to create registration guidelines and standards. Nonetheless it has the potential to provide useful information for measurement and reporting purposes for the management that is lacking in the current situation.

Waiting list results in logistic issues

Waiting lists of 3 to 7 weeks are the most common for the clinics. Often waiting lists are not a consequence of larger demand than supply, but rather of a lack of steering on access time as mentioned earlier. Too short waiting lists are not in the doctor's interest, as there is a risk of very full or empty schedules due to demand variation. A long waiting list however results in several issues as well.

Full schedules lead to double bookings for (semi-) urgent and follow-up patients that need to be seen in time for medical reasons. Waiting lists also lead to more no-shows and therefore empty slots, as the risk for patients not showing up tends to grow when the time between making the appointment and the appointment date grows. Waiting lists also result in extra tasks for doctor and staff. In case that a doctor cancels his consults for a day, the planners must reschedule patients. The smaller the waiting list, the less appointments that need to be rescheduled. Triage based on urgency is needed in case of a waiting list. Doctors spend valuable time assessing all referrals to see if they need to be seen sooner than the waiting list allows. Often extra calls and discussion with General Practitioners is involved.

Van der Voorde (2013) and Murray (2003) propose a solution by steering on access time. Their theory is that if supply and demand is in balance, a long access time is not a necessary practice. By redesign of the schedules and control, and actively steering on the access time for patients, they believe that the negative logistic effects of access times can be mitigated.

Literature: Service orientation vs. financial orientation

We concluded that, given the requirements of the different stakeholders, current control structure is strongly aimed at the financial targets when compared to the targets of service. Seen from a doctor's perspective, the developed situation is understandable. The next question is; how desired or undesired is this situation for the total system? To answer this question, relevant literature has been studied.

In 1987, Kaplan and Norton invented the widely used Balanced Scorecard (BSC). The BSC is an evaluation tool that can be used by managers that deal with a set of complex business goals. According to their theory, management steering perspective can be divided into four quadrants: Finance, customer, internal processes and innovation. Kaplan and Norton conclude that, even for for-profit companies, reliance on financial measures alone is insufficient for managing complex and ever-changing business situations.

In the 00's, researchers have applied the BSC in healthcare organizations. Pink (2001), Gumbus (2003) and Kocaculah (2007) all empirically researched the use of the BSC in the non-profit healthcare sector. The authors all observe the general developments in healthcare that creates more focus on financial measures in the BSC: Pressure on budget systems, controlling governmental measures, increasing power of insurance companies and a need for mutual comparisons between hospitals.

In spite of external developments in the industry, all authors stress the importance of balancing the BSC over all four quadrants. They thereby underline the non-profit character by stating that the financial goal is to achieve Return Of Investment (ROI), not profit. Gumbus and Kocaculah criticize financial measurements for being narrow, one-dimensional and encouraging short-term decision-making. Aidemark (2009) concludes that a too strong orientation on finance leads to the undesired situation of neglecting service-oriented measures, which violates the role of the hospital in society. Atkinson (2006) and Bouter (2009) go even further by stating that success of hospitals should be measured not by financial figures in the first place, but by the effectiveness of delivering service to citizens. Bouter states that the mission of the hospital should be guiding in the composition of performance measures. In its mission, the Haga hospital shows strong belief in service orientation, stating that patient satisfaction is always a number one priority.

Generally, the writers agree on the fact that changes in the healthcare environment have lead to more pressure on financial performances. The overall opinion however is that given the non-profit character and the societal mission of hospitals, the performance measurement focus of the BSC should be divided between all four quadrants, with financial solidity as an important condition. Thereby balancing orientation on service and finance.

Problem statement and research question

Main conclusion is that coordination of the system has its emphasis on the financial and production targets. In literature it is found that in a healthcare organization, service and financial orientation must be in balance to achieve a desired situation. Hence, there is a need for stronger steering on patients requirements and therefore make the shift towards a more service-oriented system. The strong feeling exists that this can be achieved with the current information system. Moreover the waiting lists lead to extra logistical issues, which are believed to partially resolve with reduced access times.

This leads to the following research question:

"How can a control structure be designed for patient planning at the outpatient clinics in Haga, using the HIS, that focuses on improving the patient-service level by the incorporation of patient requirements?"

This research question can be divided in several sub-questions, which can be divided in several sub-questions once more. These questions are answered in the following sections. First it is determined *what* parameters must be controlled and then it is determined *how* these can be controlled, by identifying performance-enhancing improvements both on operational and strategic level.

How can the function control of the planning process be designed in areas where it is currently lacking, so that performance can be measured?

What Key Performance Indicators are suitable to reflect the identified requirements?

How can these KPI's be measured using the current Hospital Information System?

What standards are recommended for the identified KPI's?

What evaluation period is recommended for each of the KPI's?

Which operational improvements can be identified that lead to better performance?

Which general operational issues in the current situation can be identified that lead to bad planning performance in the clinics?

What general improvements can be identified for these issues?

Which strategic improvements can be identified that lead to better performance?

What planning strategies can be identified in literature?

How can these planning strategies be compared using all stakeholders' requirements?

What planning strategy is preferred for the Haga clinics?

5 Control structure improvement

The aim in this chapter is to improve the coordinating control in the areas where it lacks currently. This improvement is achieved in three ways: The creation of the control structure, general interventions and planning strategy.

First, a control structure is developed to exert so-called function control (Veeke et al, 2008). According to Veeke, the functioning of the system must be protected in the long term: Requirements need to be converted into standards, which are measurable. The standards are compared to the measured results, which leads to the system's performance. Deviations must be tracked and analysed, and if necessary the standard must be adapted.

After the function control has been established, a number of operational is proposed that can help to achieve those standards. The improvements proposed here are only the ones that are generally applicable on all clinics. In the last section of this chapter, the possible planning strategies are lined out and valued.

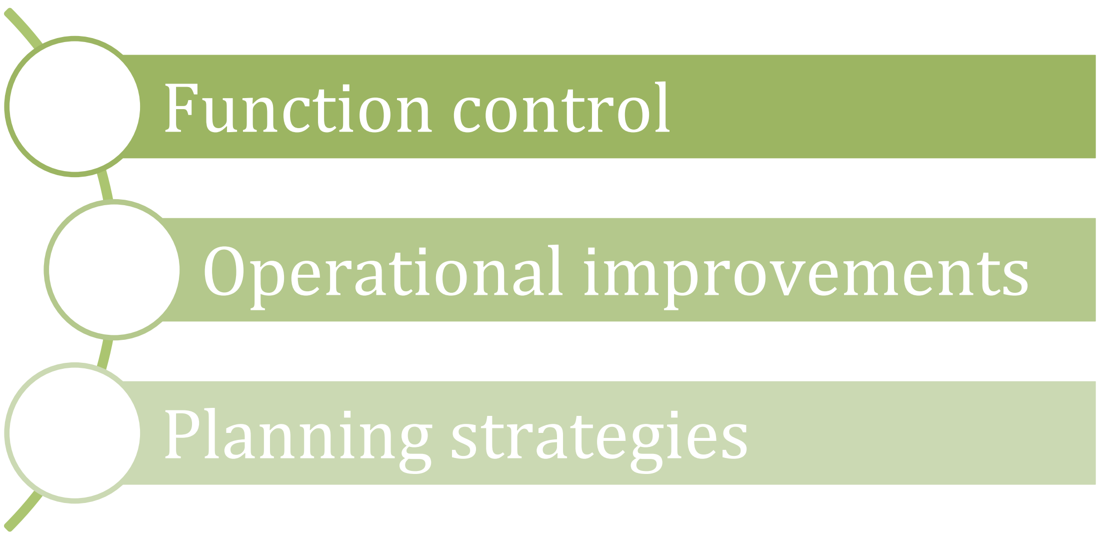

FIGURE 14, THREE WAYS TO IMPROVE CURRENT CONTROL

5.1 Function control

To apply function control, we need to look back to Table 7. The aim of this section is to fill the red-coloured cells, extracted and shown in Table 8. Proposals for KPI's, standards, measurement- and evaluation method are given. These are determined based on data analysis of the hospital data-warehouse, literature resources and experiences from practice. RStudio and Excel were used to perform the data analysis and create reporting, both programs are available for use for the hospital without additional costs. Per requirement, the conditions for function control will be determined

Requirement	KPI	Standard	Measurement	Evaluation
Overtime (working days)	?	?	?	?
Cancellations	?	?	Cancellations in HiX	?
Access time	TNAA	?	TNAA	?
Overtime (working hours)	?	?	?	?
Internal waiting time	?	?	?	?
Utilization of doctors	?	?	?	?
Sufficient time with doctor	?	?	?	?

TABLE 8, STARTING POINT: EXTRACTED TABLE OF COORDINATION LACKING

Access time

Access time is currently measured already. The head of unit is responsible for this and the KPI that is used is measuring the Third Next Available Appointment (TNAA) method as indicator for access time. This method assumes the first- and second available appointments are not reliable enough, because they can produce false positive results for the access time in case of coincidental appointment cancellations at the time of measurement. In Appendix D it is determined whether this assumption is justified, and the conclusion is that that is the case: The Third Next Available Appointment is a reliable measure for access time and is therefore chosen as KPI.

Currently, the purpose of this measurement however is solely to inform the patient and GP in ZorgDomein for the access time that they can expect. It is not used to steer upon. The Treeknorm is not meant as a goal to achieve, rather as an absolute maximum for every clinic in the Netherlands (Van der Voorde, 2013), as we concluded earlier. This makes the Treeknorm meaningless.

To actually set an access time as a goal, it is concluded this should be clinic-specific. An access time standard depends mainly on three factors: Demand variation, capacity variation and schedule complexity. Specifically the latter two differ between clinics. For example surgical specialties may experience grave weekly variations in capacity because of doctor allocation to the OR, where observing specialties have a more consistent supply. Some specialties have many specific appointment types, where special equipment and nurses are required. Other clinics have less complex rosters, and therefore the access time standard may be lower.

To arrive at the clinic-specific access time goal, it is necessary to take these characteristics into account. This will be further elaborated on in Chapter 6. The evaluation of the measurements compared to the goal can be done on a yearly basis, comparing the average deviation of the monthly TNAA to the goal.

Rescheduling

When an appointment is rescheduled in HiX, it asks whether it is patient- or hospital initiated. For this patient requirement, we are only interested in rescheduling initiated by the hospital. The data can be retrieved via "appointment mutations", which are collectable in the data warehouse as an Excel file. The KPI determined is the percentage of rescheduling in a period, of all appointments in that same period, denoted as:

$$KPI = \frac{N.O.Reschedulings}{N.O.Appointments} * 100\% \quad (1)$$

To set a standard, it is useful to take into account the historical data. The percentage of rescheduling of the five clinics analysed are presented in Figure 15. The main reasons are given: "Doctor is sick", "Last-minute congresses/meetings", "OR-schedule change" and "Patients planned on uncertain resident roster".

First, it is recommended to add these four standard reasons in HiX to be able to quantify the reasons for cancellation. Second, of these three reasons only "Doctor is sick" is not manageable. Plastic surgery – a specialty that deals with OR - shows that with obeying strict rules for doctor cancellations and not planning patients on yet uncertain rosters, it is possible to achieve a percentage around 5%. This is only 1% above the absence through sickness. This percentage is therefore established as the standard for the clinics. It is recommended to evaluate the deviations on a 3 monthly basis.

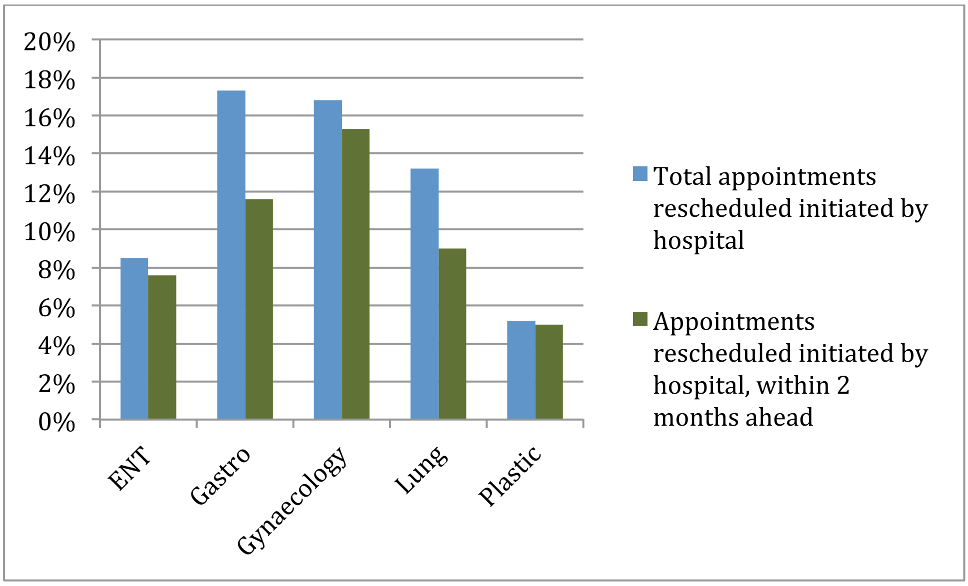

FIGURE 15, APPOINTMENTS RESCHEDULED JUNE 2016-FEBRUARI 2017

Sufficient time with doctor

Sufficient time with the doctor is a very subjective observation. To express this into a KPI, it is concluded that a survey is needed to measure the sufficiency of doctor-patient time with a grade between 1 and 10. The measurement can be carried out in the current Feedback-Radar system, an IT-based program used by the Quality and Policy department. The measurement can be carried out as part of a larger patient survey.

A new standard is difficult to propose here, as patients may value doctor-time very differently, but a more than sufficient 7 is suggested as a start for the first evaluation. This evaluation is recommended to take place as soon as possible, to possibly adjust consultation times in case of very low grades. Afterwards, it is recommended to evaluate the patient grades on a yearly basis to keep track.

Utilization and overtime of doctors

It is not possible to continuously monitor the doctor's activities during consultation hours. The percentage of unplanned Open Slots (OS) in the schedule however can be considered a valuable estimate of unused capacity. Double bookings (DB) can partially compensate for the OS, when situated before an open slot. It has to be taken into account however that this is at the expense of patients waiting longer. A DB situated after an OS results in unused capacity, as well as overtime. Out Of Roster bookings (OOR) are a measure for doctor overtime as well.

The combination of percentages OS, OOR and DB in the roster is proposed as the KPI's for doctor utilization and overtime. A tool in R is built to measure these figures from raw schedule data. Start-, end- and lunchtime of sessions can be configured per clinic. For the exact definition of OS, OOR and DB is referred to Appendix C. The results in the past months are shown in Figure 16. Gastroenterology data was considered unfit to use, as appointment durations were not filled in correctly.

An OS is often the result of a no-show or late cancellation. It is difficult to fill late cancellations, specifically for triaging specialties, as no new patients can be planned in unless they have just been triaged. Other causes leading to OS are highly specific appointment types that are not used, or simply overlooking empty slots. DB and OOR are often the result of not anticipating on the stream of (semi-)urgent patients or check-ups that need to be seen within a short period. In the next section, it will be explained how OS, OOR and DB can be reduced.

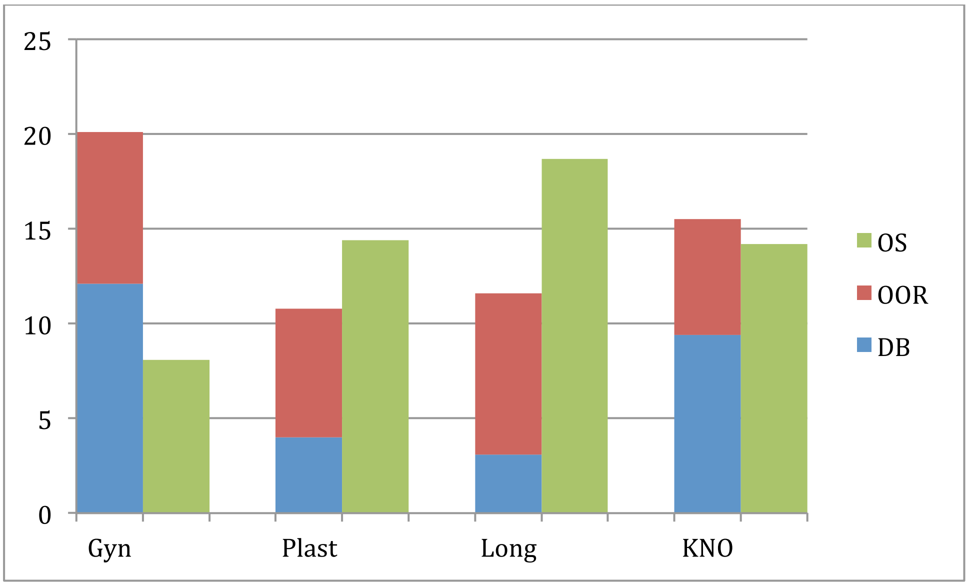

FIGURE 16, PERCENTAGE OF OPEN SLOTS, OUT OF ROSTER- AND DOUBLEBOOKINGS IN DIFFERENT CLINICS MARCH-JUNE 2017

The goal for OS, OOR and DB is to be as low as possible, however a clinic will always face no-shows and variation in urgent patients. No-shows in the current system are between 4 and 6 %. Given the current percentages of OS in Figure 16, 8% is proposed as the standard for OS, which would already imply a very significant reduction for most clinics. To partially neutralize the effect of OS on the utilization, it is recommended to achieve a DB percentage of half the OS percentage, 4% of the appointments. Another 4% is advised as the standard for OOR bookings, keeping in mind that the goal remains to strive for 0%. It is recommended to evaluate the results every three months and to evaluate the initially set standards after one year of working with them.

Internal waiting time

Although there is discussion in literature (Vissers, 1979) on the definition of internal patient waiting time, it is chosen to not take into account waiting time between patient arrival and actual appointment time. For the aim of setting standards, the hospital cannot be hold accountable for patient's early arrivals. The waiting time is therefore determined as the difference between appointment time and patient call-in. Since the columns are online in Haga, this is measured accurately as doctors call in their patients via the system. Data of appointment times and call-ins is transferred to the data warehouse and has been processed in R to the histogram seen in Figure 17.

FIGURE 17, 90TH PERCENTILE WAITING TIME ENT CLINIC MARCH-JUNE 2017

Given the long-tailed nature of these histograms, the average waiting time is not considered representable for the experienced waiting time by the patient. From Appendix D it can be concluded that the 90th percentile is a good KPI for the patient waiting time, thereby following Cayirli et al (2006).

Current KPI's can be seen in Figure 18. 90th percentiles of 40 minutes are no exception and at gastroenterology, 10% of the patients wait longer than 50 minutes. In literature, it is difficult to find standards for the waiting time. The British NHS sets a maximum of 20 minutes for 100% of the patients. Taken into account the current results, a goal of 90% in 30 minutes is proposed as a standard to start with. It is recommended to evaluate these KPI-deviations every three months, and to evaluate the standard after a year whether it should be set sharper.

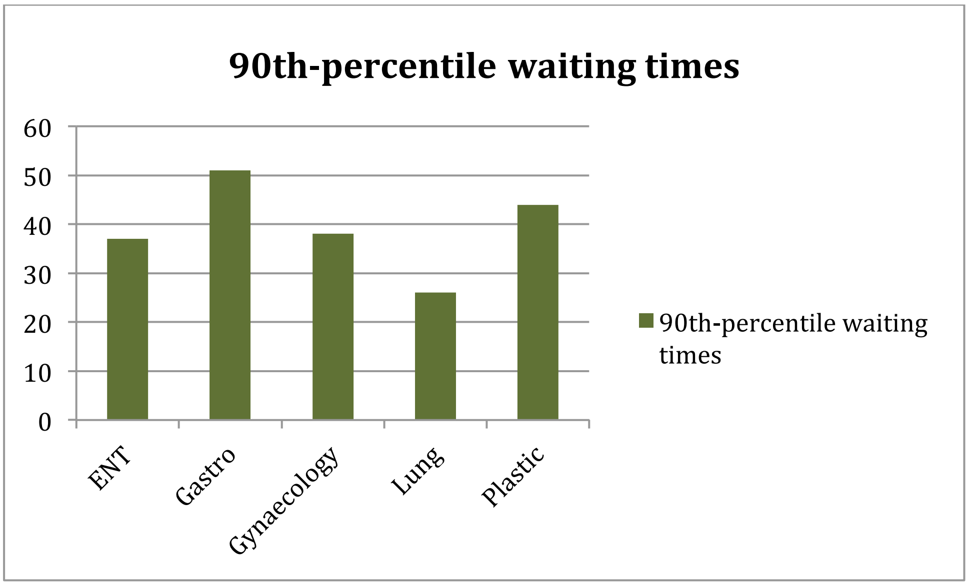

FIGURE 18, 90TH PERCENTILE WAITING TIMES IN MINUTES, MARCH-JUNE 2017

Overwork (extra days)

Overwork in days can be necessary in case of diversion from production goal or the access time. In reaction to lagging on the access time goal, extra (part of) days can be scheduled. In most situations, where the yearly schedules are accurately based on the real demand, the extra working days can be compensated by dropped (part of) days when the access time is very low. In this case, the extra days can therefore be seen as a measure of flexibility. The KPI is the amount of executed sessions, which equals half a day, that were not incorporated in the original roster three months ahead.

This can be measured by comparing the roster of three months ago to the achieved schedule over the same period. The set standard will be the result of negotiations between hospital and doctors. The proposed amount is five sessions every three months as a maximum. In chapter 6 it is researched what the effect of this degree of flexibility is on the access time. The measurement and evaluation period are recommended once per three months.

The control structure of the function control is now complete. Every requirement is now measurable so that results can be evaluated. The resulting structure is shown in Table 9.

Requirement	KPI	Standard*	Measurement	Evaluation
Overtime (working days)	Extra sessions/3 months	5	Compare initial and achieved roster	Three months
Cancellations	% appts rescheduled by hospital	5	Appointment mutation analysis	Three months
Access time	TNAA	Per clinic	TNAA by unit head	One month
Overtime(hours) & Utilization of doctors	% OS	8	Agenda analysis	Three months
	% DB	4		
	% OOR	4		
Internal waiting time	90th percentile minutes	30	Appointment analysis	Three months
Sufficient time with doctor	Patient grade	7	Feedback Radar	One year

TABLE 9, COMPLETED CONTROL STRUCTURE FOR FUNCTION CONTROL PER REQUIREMENT

* The standards given in the table are based on historical data, experiences and estimations. In this section it is pointed out per requirement how the standard must be interpreted and in what period an evaluation of this standard is recommended.

5.2 OPERATIONAL IMPROVEMENTS

In the previous section the control structure has been established for function control for the clinics' planning. The following question is how these set standards can be achieved. Every clinic has its own weak spots regarding the requirements, for which tailored solutions need to be found. The control structure helps them to gain insight in these weak spots, but this report will not provide specific solutions for every single clinic. There are however some general improvements on operational level that every clinic can use to enhance their current performance. These improvements give a better grip on disturbances such as empty slots and urgent patients. They are pointed out in this section. In terms of DSA, these apply either process control or lower echelon function control.

5.2.1 ADAPT MEASUREMENTS FOR CONSULT DURATION

In the current situation, the doctors determine the planned duration of consults. These durations are based on experience, feeling and personal preferences. It can be very valuable, also from a doctor's perspective, to access insight in the realised time that consults have taken over a period of time. Both from the duration as well as the variation per appointment type and patient type, better-founded decisions can be taken about the planned consult duration. This can ultimately lead to more efficient use of doctors and shorter waiting times for the patients. The measurements to come to this data are already in place using the system as described in section 3.3, and an example of the result is shown in Figure 19. Here we see the realised durations over a 6-month period of 10-minute planned appointments, where the difference between new and check-up patients is indicated.

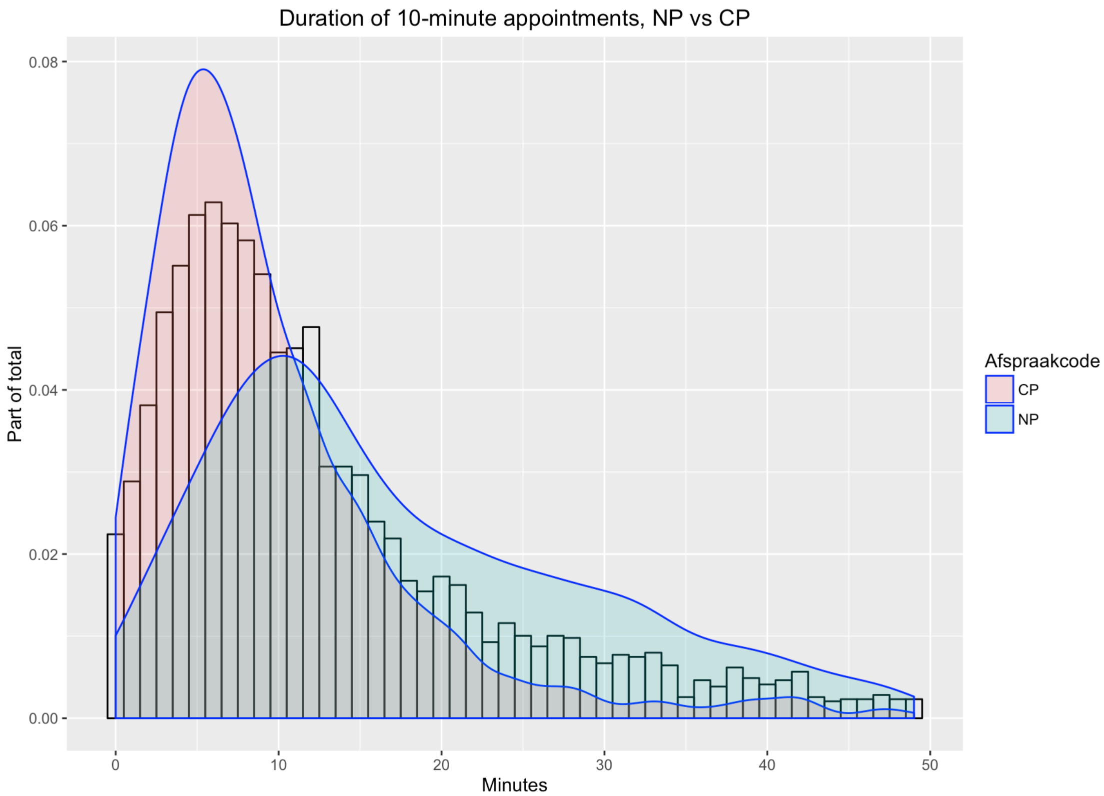

FIGURE 19, DURATIONS OF 10-MINUTE APPOINTMENTS IN ENT-CLINIC, FEB 2017 - AUG 2017

There are two particular complications in the current situation that make the data too unreliable to use, and these need to be resolved. First, doctors have a direct motivation to press "Call In" in HiX for their patients, but they often forget to press the button "Leave" after consultation. At the end of the day or at lunch break, these patients leave the consult in HiX automatically when the doctor logs out. This leads to falsely long realised durations.

Second, in every clinic there are co-assistants – or trainees – at work. Sometimes when new patients are called in they are seen first by a co-assistant, and afterwards go to the regular doctor for further treatment. This way, the consults appear to be longer than the doctor has been used for in reality.

To solve the first issue, it is recommended that HiX automatically stops the previous consult as soon as he calls in the patient for the next consult. The second issue can be resolved by giving the co-assistants account the possibility to call in the patient. This way the system registers the time spent with the co-assistant and doctor separately, and the actual time spent with the doctor can be used for the making of the planning. By implemented these changes the data can be considered reliable enough to be used for planning purposes.

5.2.2 EMMENTHALER SCREENING

Currently the planners use the HiX' automatic search function for planning. The advantage of this system is that planners fill in three fields and the first available appointments that meet the criteria are shown. This saves the planners a great deal of searching and scrolling through the doctors' schedule. The disadvantage is that specific slots for other purposes can remain unused, because HiX does not take them into account. Also, it can happen that when HiX searches for slots of 30 minutes, empty spots of 25 minutes in the agenda remain unused.

To counter these drawbacks, it is recommended to use the so-called Emmenthaler screening method. The idea is that clinic planners start every day by checking three days ahead for possible forgotten empty spots in the schedules and fill them during the day, thereby optimally using agenda space. This improvement is already used by some clinics, but is recommended for all.

5.2.3 URGENT PATIENTS MEASUREMENT

Urgent patients can seriously disrupt consultation hours, as most clinics' planners add the patients unsystematically in the consultation hours. Urgent patients are not automatically registered. Planners have the possibility in HiX to mark a patient as "urgent", but rarely do this consistently because there is no incentive for them to do so. As a result, not a single clinic has insight in the amount and fluctuation of urgent patients.

First, it is recommended for every clinic to consistently mark patients in HiX as "urgent" if they need to be seen by a doctor within one day. It is recommended to do so for at least 3 months to generate a considerable amount of data. Second, it is recommended that this data will be used to save some schedule time for urgent patients. It is recommended to save this time at the end of the session, so the impact on the session is as small as possible. A good tactic can be to appoint one doctor every day that has schedule space freed up to deal with the urgent patients.

5.2.4 RULES FOR SPECIFIC APPOINTMENT TYPES

In section 3.2 it is concluded that in the investigated clinics there is an overuse of predefined appointment types, which leads to inflexibility. To oppose this entirely, the theoretically most flexible schedule is made up of all blocks of 5 minutes that can be used as part of every appointment and appointment type. The HiX system however does not support such a flexible schedule, so there are always fixed appointments.

To prevent unnecessary predefined appointment types, it is recommended to only use specific appointment types in case of:

- Specific duration of the appointment
- Specific assistants or nurses that have to attend the appointment
- Specific and scarce materials and/or rooms needed for the appointment

It is recommended that during the creation of schedule redundant appointment types are removed, and historical data on the number of past appointment types is used to determine the amount of specific appointment types needed per week. It is also recommended that when a specific appointment type is not used X days ahead, a special function in HiX is used that frees up the specific appointment slot, so it can be used for all appointment types. This, in combination with the Emmenthaler screening might prevent a significant amount of empty slots in the clinics.

5.3 PLANNING STRATEGIES

According to Murray et al., three different planning strategies can be distinguished in primary care and specialty clinics. These are the traditional, carve-out and advanced access strategy. The next section will elaborate on the different strategies, after which a multiple criteria analysis is used to choose the favourable strategy.

Traditional strategy: Meet urgent demand now and meet non-urgent demand later

In most clinics in the Haga, this is the current strategy used for planning. There is a rough categorization of elective, semi-urgent and urgent patients that need to be seen. In the traditional strategy, the appointment roster is fully booked. Delays and access time are the result of –usually temporary- mismatches between demand and supply. After a more urgent referral enters it needs to be double-booked in the roster, often accompanied with discussion with nurses and doctor.

Carve-out strategy: Predict urgent demand and reserve time to meet it

A slightly more complex strategy is the carve-out strategy. Because of the pressure that results from the traditional strategy, some clinics choose to save slots that are needed for (semi-) urgent patients. When the slot is not used for such a patient with for example 2 days before the appointment, the slot falls open for elective patients so that no gaps are left in the schedule.

Although this strategy has advantages when compared to the traditional method, it has certain drawbacks as well. Often carve-out is applied by reserving more capacity than is strictly necessary for average semi-urgent demand, which creates an even higher access time for elective patients. Moreover, practice of carve-out learns that informal systems might develop to "steal" slots that are reserved for urgent patients, often under pressure of a large waiting list.

Advanced access strategy: Do today's work today

Murray describes the advanced access model as doing todays work today. For most specialty clinics this description needs to be adjusted to "do this week's work this week". This strategy attempts to eliminate the delay in access as much as possible. It thereby assumes that capacity and demand are equal, as without this assumption not a single appointment strategy works.

As opposed to the other two strategies, advanced access method can be described as a pull method instead of a push method. Where the other strategies protect today's capacity by pushing demand into the future, advanced access protects the future's capacity by pulling demand to the present. Van der Voorde et al state that most clinics have a stable waiting list, thus demand and supply are equal. The main difference between short and long waiting lists lies in the backlog of the clinics. For the Haga clinics this seems to be the case, with the exception of gastroenterology where supply cannot keep up with demand and waiting lists grow gradually. The essence of advanced access is to work down this backlog and actively steer on access time.

5.4 MULTI CRITERIA DECISION ANALYSIS

To choose the best suitable strategy for the Haga clinics, a multi criteria decision analysis is carried out according to the method of Saaty (1990). First a number of selection criteria are chosen, which then are assigned weights according to their importance. Then the strategies are evaluated based on the criteria, finally resulting in a selected strategy.

For the criteria, the requirements are used that have been established in chapter 3. Only the requirements that are assumed to be affected by strategy selection are chosen as criteria. These criteria are the production goal, overtime (working days and working hours), cancellations, access time, internal waiting time and utilization of doctors. With the criteria selected, the next step is to assign weights on the different criteria. This is done by a pairwise comparison method, carried out by each of the three stakeholders. In the research 30 patients have participated, 5 hospital employees and 3 doctors. Two of the hospital employees work at the planning department, one as sector manager, one as unit head and one as logistical manager. The doctors were from the lung, ENT and gastroenterology specialisms, unfortunately no more doctors were available for this research.

The result is the weighted criteria per stakeholder, as shown in Table 10. The final weighted criteria are the averages of these three, thereby assuming that all three stakeholders' requirements are equal.

Criterion	Hospital	Patient	Doctor	Average weight
Production goal	0,22	0,03	0,26	0,17
Cancellations	0,21	0,27	0,03	0,17
Internal waiting time	0,23	0,32	0,03	0,17
Utilization of doctors	0,15	0,30	0,03	0,16
Access time	0,12	0,03	0,29	0,15
Overtime (WD)	0,07	0,03	0,19	0,09
Overtime (WH)	0,05	0,03	0,19	0,09
Total	1	1	1	1
Average consistency ratio	0,10	0,11	0,08	-

TABLE 10, WEIGHT FACTOR ASSIGNMENT

Also shown in the table are the consistency ratios. This ratio is a statistically reliable estimate of the stakeholder's consistency throughout the completion of the pairwise comparisons. Saaty advises a consistency ratio of less than 0.1 for guaranteed consistency, and until 0.15 can still be deemed permissible. All questionnaires with a higher inconsistency than 0.15 were rejected. Therefore four patient questionnaires were not taken into this result.

The next step is to evaluate the three strategies based on these selection criteria. First, it is explained per criterion how it is expected the different concepts will perform. Then an evaluation table is constructed.

Production goal

In both the carve-out and the traditional system it is possible to steer on the production goal. In practice this is not always done precisely, but by creating schedules that should reach this target. If through diseases or holidays the production lags, it is occasionally corrected. The current system therefore performs high on reaching the production target because it is possible, however the schedules' flexibility is not high enough to achieve the maximum reward.

With advanced access it is more difficult to steer accurately on reaching the target. The target is set yearly based on the expected demand, and is therefore used as a capability instead of a goal. If the real demand exceeds or falls behind the expected value, then it is not possible to steer on the production goal. If yearly production estimations are made well-informed, chances on significant mismatch between expected and realized demand are small.

Cancellations

Because of reasons mentioned, it is always possible that appointments need to be cancelled and rescheduled due to roster changes. In Figure 15, the current amount of cancellations is shown with the traditional strategy. The amount of roster changes is not influenced by the different strategies, however the number of appointments affected is. It is believed that with the carve-out strategy the amount of cancellations will approximately be equal. The number of appointments made in the future is, however spread more widely, the same.

For advanced access the number of appointment cancellations will be lower, as new patients are only planned in the very near future. This can be quantified as follows: The ratio of new patients to check-ups in the hospital is roughly 1:2. Then it holds that with a short access time, the number of appointments in the future 6 weeks will be approximately 2/3 of the appointments in the traditional system. The amount of cancellations will then drop by one-third on average with advanced access. This is positive from a patient perspective, but also saves extra work for the planners.

Access time

The current strategy is barely aimed at a low access time, as violation of the Treeknorm is not acted upon. In the carve-out system however, the consequence for the access time will be worse. By reserving empty slots for urgent patients, the waiting list will become even longer than in the current situation. The advanced access method has its aim in reducing the waiting list as far as possible and is therefore most positive for the access time.

Internal waiting time

The traditional strategy faces the most problems with patient waiting time due to the double bookings that can be expected. The main reason to use carve-out is to prevent these otherwise necessary extra bookings and to create a more fluent consult session. Advanced access prevents these double bookings from being necessary, by shortening the access time level so that semi-urgent and check-ups can still be booked in a free slot.

Doctor utilization

The most crucial factor for doctor utilization is the amount of no-shows or late cancellations. A patient can forget an appointment or decide he does not want to go. It is also possible that the disease has faded. The chances for this to happen can be imagined smaller if the patient calls and gets an appointment in 5 days, instead of 5 weeks. The risk for a no-show is also proven in literature to be significantly smaller as the time between making of the appointment and the appointment reduces (Sharp et al, 2001). Advanced access therefore contributes more to doctor utilization than the traditional and carve-out strategy. Because carve-out leads to longer access times, risks for no-shows are even higher.

Apart from this mechanism, it is expected that no triage will be needed in case of advanced access strategy. Referrals that go for triage normally wait 1 to 5 days before a doctor judges them. It is anticipated that with advanced access, an appointment is already available in that time frame. This saves doctors a significant amount of time, otherwise spent on a task that adds no further value.

Overtime (working days)

The traditional strategy and carve-out strategy only use extra sessions in rare occasions to compensate, as the production goal is the standard and fluctuations in demand are buffered by the access time. The advanced access strategy aims to steer actively on the access time, which means that it can necessary occasionally to add flexibility to the schedule in order to react to demand fluctuations. This means that sessions can be dropped when demand is low, and extra sessions are planned in case of high demand. The severity of demand fluctuation determines the need to do this.

Overtime (working hours)

Similarly to the internal waiting time, the overtime is influenced strongly by the amount of appointments that are double booked. Similarly, and for the same reasons, the traditional method is outperformed by the carve-out and advanced access methods.

The next step is to construct an evaluation table, shown in Table 11. Based on the performance of the strategies on the criterion – as elaborated above – a qualitative score between 0 and 1 is awarded to the concept. To assure that every criterion is weighted according the weight factor, the awarded scores are normalized per criterion. Then the normalized score is then multiplied by the criterion's weight factor, and all these weighted scores are added per strategy. This results in a final weighted score.

Criterion	Weight factor	Traditional	Carve-out	Advanced Access
Production goal	0,17	0,8	0,8	0,4
Cancellations	0,17	0,4	0,4	0,6
Internal waiting time	0,17	0,4	0,8	0,8
Utilization of doctors	0,16	0,6	0,4	0,8
Access time	0,15	0,4	0,2	0,8
Overtime (WD)	0,09	0,8	0,8	0,4
Overtime (WH)	0,09	0,4	0,8	0,8
Normalized weighted score	-	0,30	0,31	0,39

TABLE 11, STRATEGY EVALUATION TABLE WITH SCORES AND NORMALIZED WEIGHTED ENDSCORES

To assure the robustness of the strategy selection in case of small deviation of the weight factors, a sensitivity analysis is carried out. The weighted scores are evaluated in case of a positive and negative deviation 0.1 of the weight factors. For all these scenarios, advanced access is the preferred outcome.

A highly unsuitable fourth strategy is added to the MCDA. Such a strategy is expected to score low in the end result, and the MCDA model can be verified by checking whether this expectation is correct. The walk-in strategy is chosen as the unsuitable strategy. Walk-in strategy means that no schedule is used and patients can walk in when it suits them. This is considered unsuitable as very high peaks and low lows can be expected in terms of workload and crowdedness; such a system has been tried in outpatient clinics worldwide but was has not been maintainable. In Appendix F it is shown that this walk-in strategy scores lowest in the MCDA by some margin. This means that the MCDA produced the expected result.

Based on the outcome of the multi-criteria analysis, the advanced access method turns out as the preferred method. For the actual implementation for this strategy however there can be practical issues. A clinic needs to find its minimum access time where it does not suffer empty slots and double bookings due to patient variation. Van der Voorde (2013), who performed the in-vivo study of advanced access in Dutch hospitals, illustrates this. In his qualitative study he comes to the conclusion that to know the minimum access time, a clinic needs to go boldly under the minimum for a longer period of time. This is unacceptable for most doctors. With smaller buffers other questions arise as well for doctors and managers: What should be done in case of seasonal fluctuations or holiday periods in order to keep a low access and prevent chaotic consultation hours.

These uncertainties and lack of quantitative knowledge can become an obstacle for implementation of advanced access. It is therefore concluded it would be very useful to have a tool that can simulate the planning of patients. Therefore in chapter 6 such a simulation tool is built and finally used in an experiment for the lung diseases clinic.

6 SIMULATION

Van der Voorde (2013) states that in order to determine the optimal access time for an outpatient clinic, it is necessary to go below the optimum for a substantial amount of time thereby experiencing a significant increase of double bookings in busy periods and empty slots in quiet periods. This in-vivo experiment is unacceptable for doctors and clinic managers. Therefore a model is built to give insight into the dynamics of patient planning and determine a minimal access time.

Deterministic models could give a first insight. However, many stochastic factors are present in the system that cannot be neglected – such as arrival variation, doctor availability, check-up patients and the willingness of patients to accept an offered appointment. This level of complexity is cannot be captured by deterministic models. With Discrete Process Simulation, these stochastic factors can be incorporated and can be tested for their influence. Therefore it is chosen to make a simulation tool in Delphi TOMAS (Veeke & Ottjes). The structure of TOMAS provides a solid basis for other students to elaborate on in the future.

6.1 GOAL OF THE SIMULATION

To determine to what extend advanced access is an option for a specific outpatient clinic, a simulation tool has been built. The goal is to determine the amount of double bookings and empty slots per day given a maximum allowed access time for new patients (i.e. the number of days between the patient's call and his appointment).

This tool simulates patients that call the clinic for an appointment, which is then planned in the doctors' schedules. With this tool, all specific characteristics of the clinic and its schedules, appointment types and patient types can be simulated.

The goal of this tool is to give clinic managers insight in the effects of a short access time under patient arrival variance, and to support them to determine a minimum access time for their specific clinic. Moreover, it can support managers to see what specific measures can help to lower the minimum access time, such as making the rosters/doctors more flexible. It can be used as well to determine the extra capacity temporarily needed to get rid of the backlog in a clinic. This model can support tactical decision-making during seasonal fluctuations and holidays periods quantitatively as well.

6.2 DATA AND ASSUMPTIONS

Historical data can be used to modify the model's clinic characteristics. For the current model shown below, data of the Lung Clinic in the Haga hospital has been used. The number of doctors per shift has been scheduled as realistic as possible as during a regular working week. The amount of patients calling per day – in the period June 2016 to June 2017 - is used to determine the average and variance. Differences per weekday are not taken into account.

For the planning algorithm, it is assumed that the patient is offered the first available appointment in the schedule, suiting his specific doctor and appointment type. The Check-up Patient/New patient balance is determined based on the Lung clinic data. One specific doctor always sees check-up patients. Based on the data, 50% of the check-up patients is planned 2 weeks ahead, 25% 4 weeks ahead and 25% 8 weeks ahead.

It is assumed that not all patients will accept an offered appointment slot, due to their personal schedule. This might affect the simulation results. Therefore an approximation will be used based on the scheduler's experience, and a sensitivity analysis will be done to see how the system reacts to change in this value. As stated earlier, there is no data available for the amount of urgent patients. Therefore, an estimate will be used for the percentage of urgent patients, combined with a sensitivity analysis.

In this simulation model it is chosen that a patient will leave in the system after he has been planned. Therefore at the creation of the patient, it is randomly determined whether it is a new or check-up patient. For the sole purpose of patient scheduling, this simplification is legit as we are not interested in the patient's course of treatment.

6.3 OUTPUT AND PERFORMANCE INDICATORS

The output parameters of interest will be watched from both hospital and patient perspective. In order to have a smooth consultation session it is vital that both empty slots and double bookings are as low as possible. The lower these parameters the more beneficial it will be for doctor utilization, doctor overtime and patient waiting time. For the patient also the average access time is used as parameter:

- The average number of double bookings per day
- The average number of empty slots per day
- Average access time

In accordance with the hospital's head planner, it is decided that only the average number of double bookings/empty slots are not a KPI easily to grasp for people involved. A better KPI is the amount (or %) of time that the number of overbookings exceeds a certain threshold. For example, once in 20 days a doctor has more than 4 double bookings. Therefore the following KPI's are used as output:

- N.O. Exceedances of critical threshold empty slots
- N.O. Exceedances of critical threshold double bookings

6.4 MODEL PARAMETERS TO BE VARIED

The most important parameter to be varied will be:

- The allowed access time for new patients. This parameter will be used as a rule; every new patient must be offered an appointment within the allowed access time. If the new patient does not accept this, he can be planned later.

- The second parameter is the schedule flexibility, expressed in the number of specific appointment types a clinic has
- The third parameter is the doctor flexibility, expressed in the number of specific patient types the doctor treats

These parameters have been chosen to keep a clear overview. Of course it is possible to test the sensitivity of the system to other parameters such as daily arrival variance of patients, patient acceptance rate and the balance between new and check-up patients.

6.5 PROCESS DESCRIPTION

The simulation is built using a set of elements that will be described here. In Figure 20 a representation is shown of the basics of the simulation model. In Figure 21 a more detailed schematic view shows the basic logics of the planning algorithm.

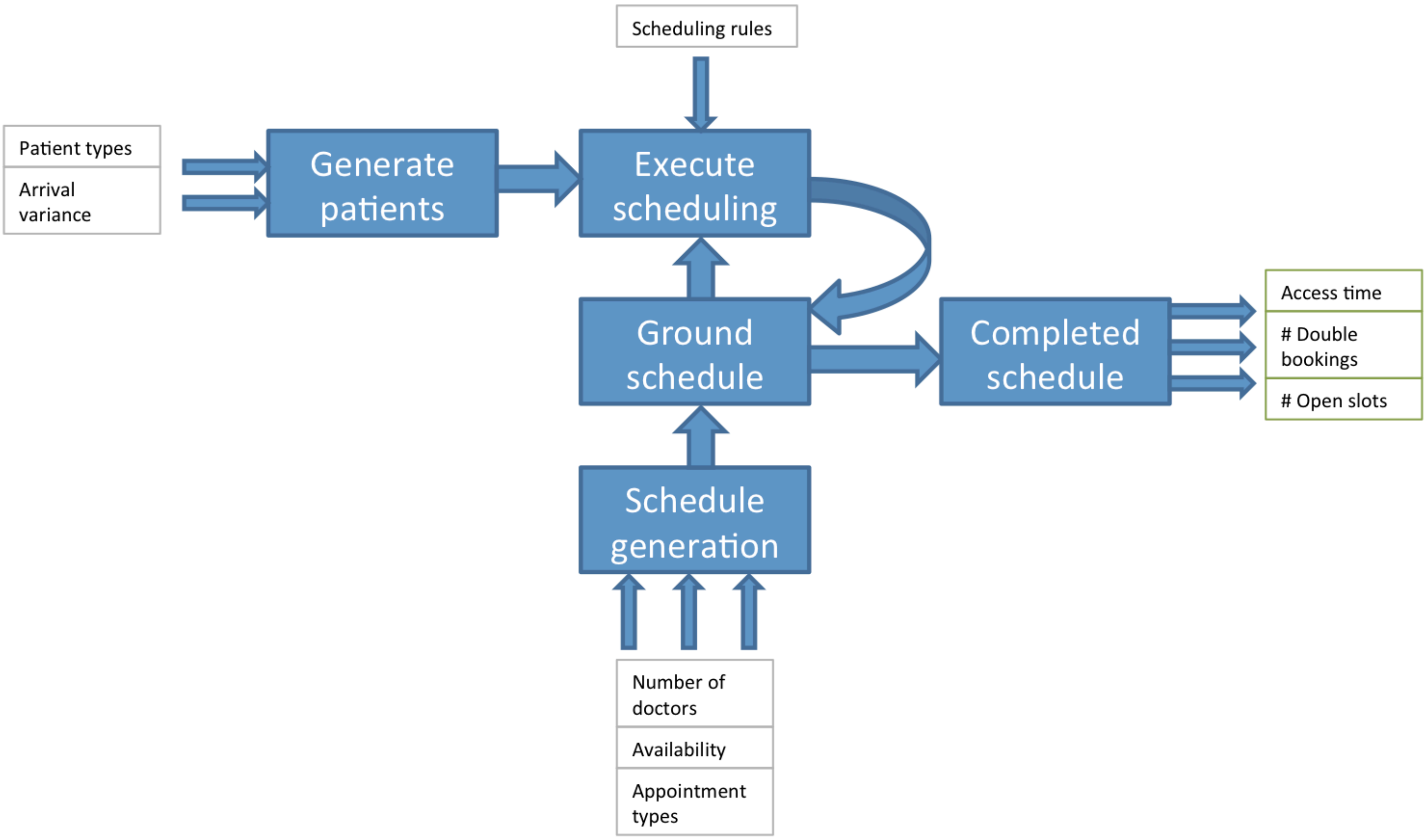

FIGURE 20, SCHEMATIC REPRESENTATION OF THE SIMULATION MODEL

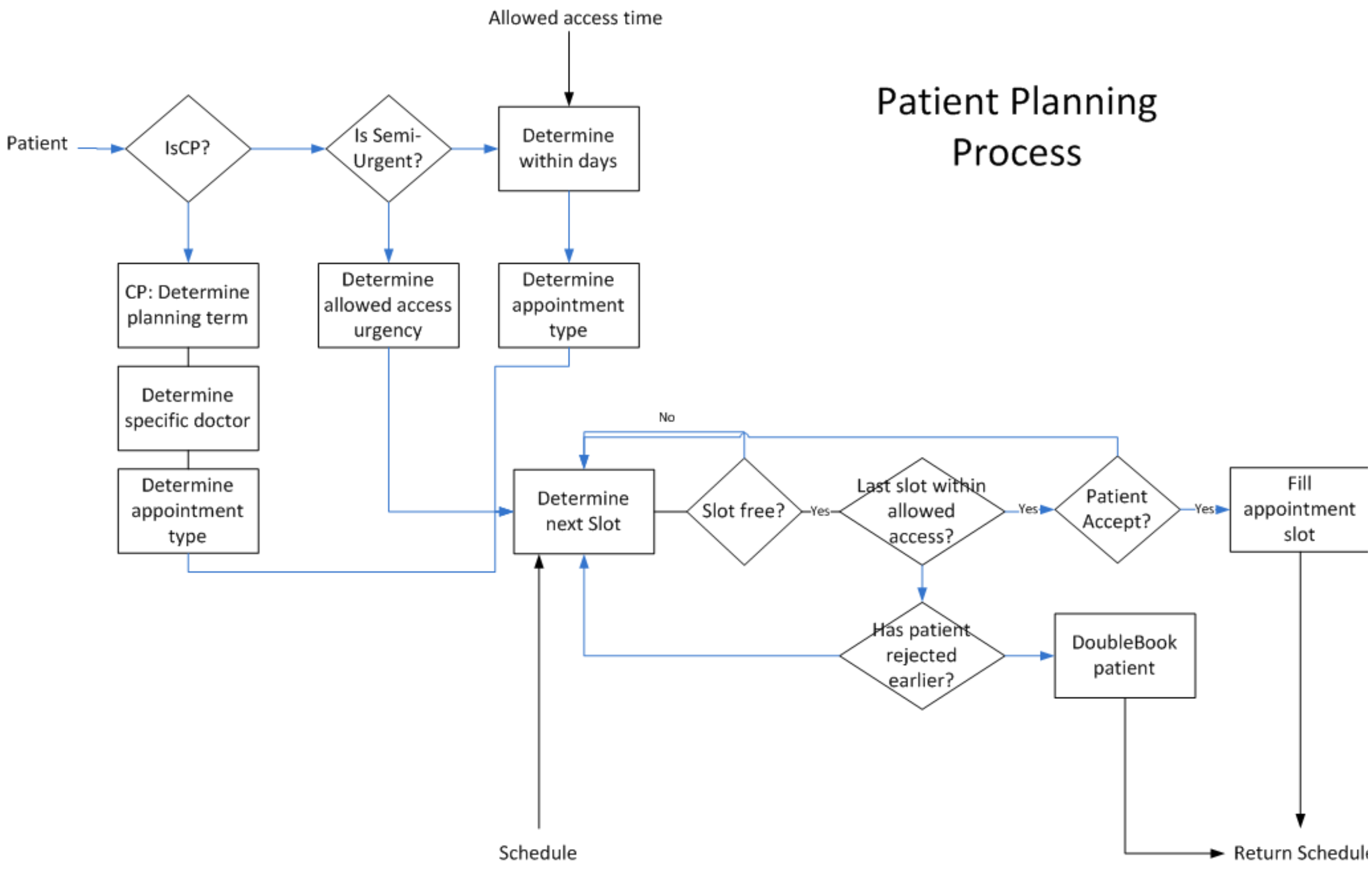

FIGURE 21, PATIENT-PLANNING LOGICS OF THE MODEL

Patient Generator

The patient generator creates a daily amount of patients. This daily amount fluctuates with a variation that has been derived from the lung department, but can be altered in the form.

With the creation of the patient, it is also determined which patient type the patient has based on a uniform distribution. Moreover it is determined whether the patient is a new patient or a check-up patient, based on the inserted CP factor – standard 0.6 for lung department based on historical data.

In case the patient is a check-up patient, his own doctor is determined by a uniform distribution. For the check-up patient it is determined in which timeframe he needs to be seen, this is done by a uniform distribution. By means of a random generator, a percentage of new patients is assigned as an urgent patient, which needs to be seen in a short timeframe. Regular new patients must be planned within the allowed access time. The patient is then put in to a queue waiting to be planned.

Patient Planner

The planner plans the patient in the weekly doctors' schedule. For new patients, it starts checking the schedule from the day after the patient calls. For check-up patients, it starts at the start of the timeframe that was determined earlier.

The planning algorithm then checks whether a timeslot is free. If not, it checks the next doctor etc. If the timeslot is not available for any doctor it checks the next timeslot etc. If applicable, the algorithm also checks whether the appointment slot is with the patient's specific doctor and specific patient type. If a timeslot is available, the timeslot is offered to the patient. A random generator determines whether the patient accepts or rejects the timeslot.

If the patient accepts the timeslot, this timeslot is assigned "occupied". Then this doctor is assigned as the doctor of the patient. The patient is removed from the patient queue, and the next patient is planned.

If the patient could not be planned within the timeframe he must be planned and he has not rejected an offered timeslot, he is then added to the schedule via a double booking on the last day he is allowed to be booked.

General section

In the general section all variables are set and the doctors' schedule is created. This is done based on the number of doctors, their shift times in the week and the number of appointments per shift.

6.6 CONCEPTUAL MODEL

PatientgeneratorClass	SimElement
ArrivalTimeDistr	TNormalDistribution
PatientType	TUniformDistribution
IsCP	TUniformDistribution
DoctorDistr	TUniformdistribution
NewPatient	PatientClass
Process	Method
PatientClass	SimElement
PatientType	Value
IsCP	Value
FromTime	Value
WithinTime	Value
MyDoctor	DoctorClass
ScheduleCreationClass	SimElement
NODoctors	Value
AppointmentType	TUniformDistribution
Process	Method

<u>PatientPlannerClass</u>	SimElement
MyPatient	PatientClass
MyPatientType	Value
MyAppointmentType	Value
MyIsCP	Value
MyDoctor	Value
PoliSchedule	Array of Array of Array of Integers
AppointmentAccept	TUniformDistribution
Process	Method

<u>DoctorClass</u>	SimElement

6.7 PROCESS DESCRIPTION LANGUAGE

PatientGenerator Process

Repeat
Advance (Sample(InterArrivalTimeDistr))
NewPatient.Create
NewPatient.Planned = False
NewPatient.Reject = False
Determine (CP or NP)
If CP
NewPatient.CPNP = CP
If NP
NewPatient.CPNP = NP
Determine (PatientType)
NewPatient.PatientType = Sample(PatientTypeDistr)

If CP
NewPatient.Doctor = Sample(DoctorDistr)
NewPatient.FromTime = Sample(CPTimeDist)
NewPatient.WithinTime = 6
If NP
NewPatient.MyDoctor = AllDoctor
NewPatient.FromTime = TNow+1
Determine (Semi-urgent or Regular)
If Semi-urgent
NewPatient.WithinTime = Sample(WithinTimeDistr)
If Regular
NewPatient.WithinTime = AllowedAT
NewPatient.Enter (PatientQ)

Patient Planning Process

```
Repeat
  While PatientQ.Length = 0 do Standby

        MyPatient = PatientQ.FirstElement
        MyDoctor = Mypatient.Doctor
        MyFromTime = Mypatient.FromTime
        MyWithinTime = Mypatient.WithinTime
        MyPatientType = MyPatient.PatientType


For (MyFromTime to PoliSchedule.End)
        For (All appointment slots)
                For (MyDoctor)
                Check
                Is the slot empty? Yes then
                Is the appointmentType = PatientType? Yes then
                Does the patient accept appointment? Yes then
                        Patient.Planned = True
                        Slot = Booked
                If (Tnow – FromTime = WithinTime) and (slot = last slot of the day) and
                (patient has not yet rejected appointment) then
                        Patient.Planned = True
                        Slot = Overbooked
MyPatient.Leave(PatientQ)
MyPatient.Destroy
```

General section

```
  Read (number of Doctors)
  Read (number of Appointment Types)
  Read(Working days per doctor)

        For  (number of doctors)
        Create 3D Array
        For (number of days)
                If workingday
                Appointment.Work = True
                Else
                Appointment.Work = False
        For (Number of appointments)
        Appointment.Type = Sample(AppTypeDistr)
```

The Delphi form that is used can be seen in Figure 22. All main input parameters can be entered in the input fields. In the memo on the right side the resulting schedule of a doctor can be seen, with used and unused slots. In the other memo's the average access time, double bookings and empty slots are represented, as well as the number of exceedances of the threshold values as described in the output parameters section.

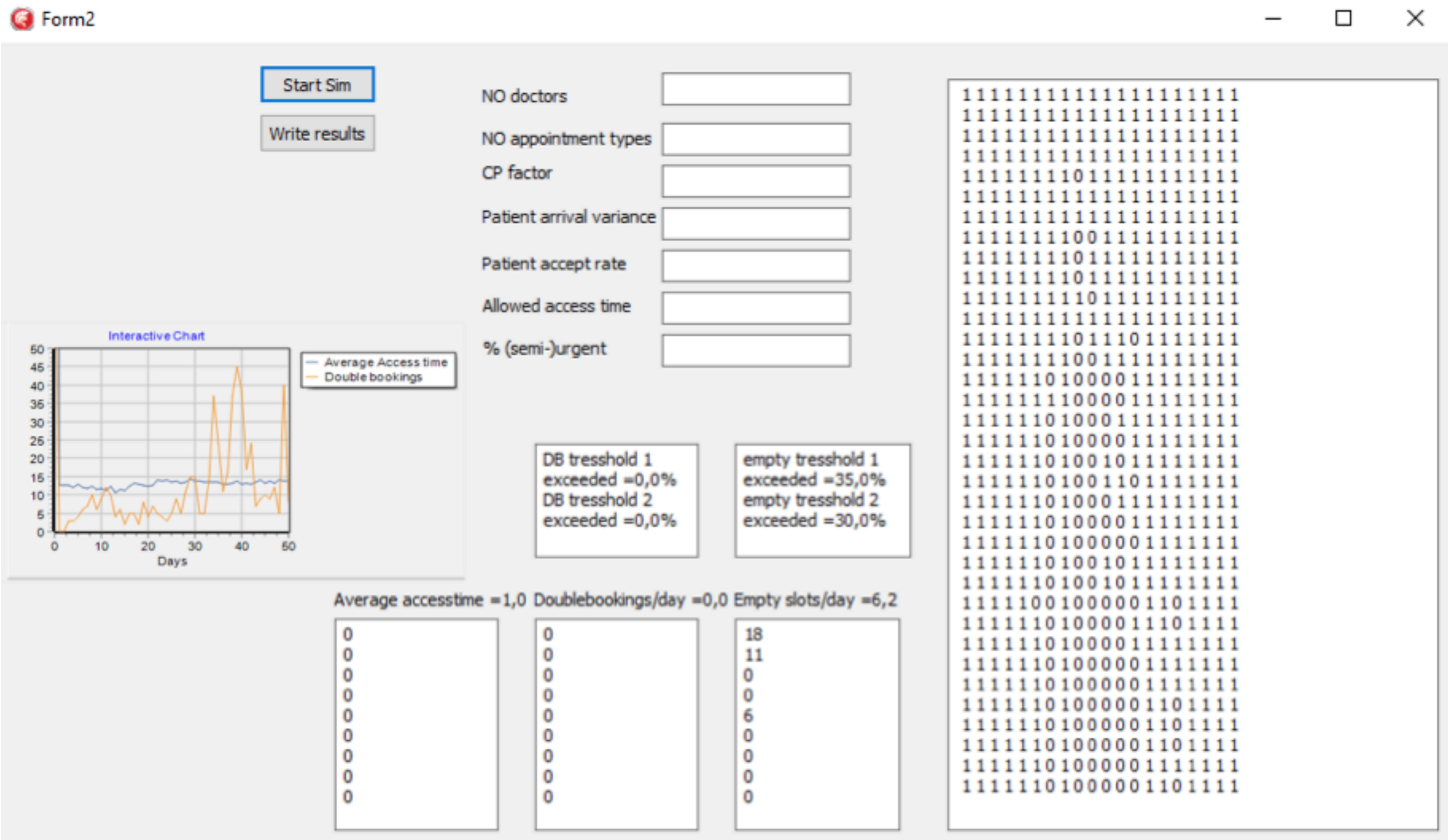

FIGURE 22, SIMULATION FORM OF THE DELPHI MODEL

6.8 MODEL VERIFICATION

The model is verified in four different ways: Expert discussion on PDL, simulation with trace function, Little's formula calculations and sensitivity test runs.

First all model steps have been run through with the head of the general planning department. This is done based on the Process Description Language, where all steps are written down comprehensively, and the schematic models in Figure 20 and Figure 21. Together with him it is determined which process elements are vital to reflect the real situation and missing elements have been added.

For verification goals, Delphi TOMAS contains a built-in trace feature that allows for the program to run step by step whilst describing every action of the model. This trace function is used in combination with the visualization of the appointment schedule as shown on the right hand of in Figure 22. Running the planning on the simplest settings creates the possibility to check for every patient if and where he has been planned in the schedule. For the simplest settings it is expected that every patient is planned in the next available empty slot. This is correctly verified using the Trace function in combination with visualization.

Next, the simulation model has been verified by comparing test run outcomes to outcomes of numeric calculations. In order to keep a good understanding of the results, most settings are set to simple values. We start with an empty schedule, the number of patients that is created daily is 36 on average for all runs and we run with an infinite capacity of daily doctors.

The patient is in the system from the day he is created until the day he has his appointment. The time he spends in the system is the throughput time. According to Little's formula, the average number of patients in the system must be equal to the average throughput time multiplied by the average arrival rate of patients according to:

$$N = \lambda * D \tag{2}$$

AcceptanceRate	CP Rate	Throughput Time	**Expected # Patient In System (Little's formula)**	**Real # Patient In System**	STD (10 runs)
1	0	1	**36**	**36**	0
0,5	0	1	**36**	**36**	0
0,2	0	1	**36**	**36**	0
0,1	0	1	**36**	**36,2**	0,12
0,05	0	1,2	**43,2**	**42,8**	0,35
0,02	0	1,9	**68,4**	**69,4**	0,5
0,01	0	3,3	**118,8**	**118,4**	0,88
0,05	0,1	2,5	**90**	**89,9**	0,69
0,05	0,2	3,8	**136,8**	**137,2**	1,04
0,05	0,3	5	**180**	**181,6**	1,27
0,05	0,4	6,4	**230,4**	**230,1**	1,48
0,05	0,5	7,6	**273,6**	**275,4**	1,43
0,05	0,6	8,9	**321,4**	**320,3**	1,57
0,05	0,7	10,3	**370,8**	**371,4**	1,6
0,05	0,8	11,6	**417,6**	**419,4**	1,81
0,05	0,9	12,9	**464,4**	**463,6**	1,95

TABLE 12, VERIFICATION THROUGH LITTLE'S LAW

We would expect the simulation to work well if the results of multiple settings correspond to this formula. To test multiple settings, both CP rate and Acceptance rate have been varied to create variation. Every run has been executed for 10.000 days. For every setting, these runs have been repeated ten times with a different seed.

For the first setting, patients accept all offered appointments and all patients are new patients i.e. want to be seen as soon as possible. Given the settings and infinite capacity, the system is expected to plan all patients the next day. This results in a throughput time of one day and 36 patients in the system on average, as seen in Table 12. For this first simple setting, we can verify that the simulation results match the logics. Sixteen settings have been tested with varying CP rate and acceptance rate. Of these sixteen runs, twelve times the expected average patients in system fall within the standard error of the real number of patients. Four times the result falls outside the standard deviation for 10 runs, but within two times the standard deviation. From this it is concluded that the simulation works according to the expectations of Little's formula.

The model has also been verified by executing several sensitivity runs whether the model responds in an expected way.

Next step in the verification is to test the output for the sensitivity for other variables, whilst keeping the other variables constant, and see if these are according to the expectations. First, the simple output of double bookings and empty slots per day is shown in Figure 23. Results of the next verification step can be seen in appendix E.

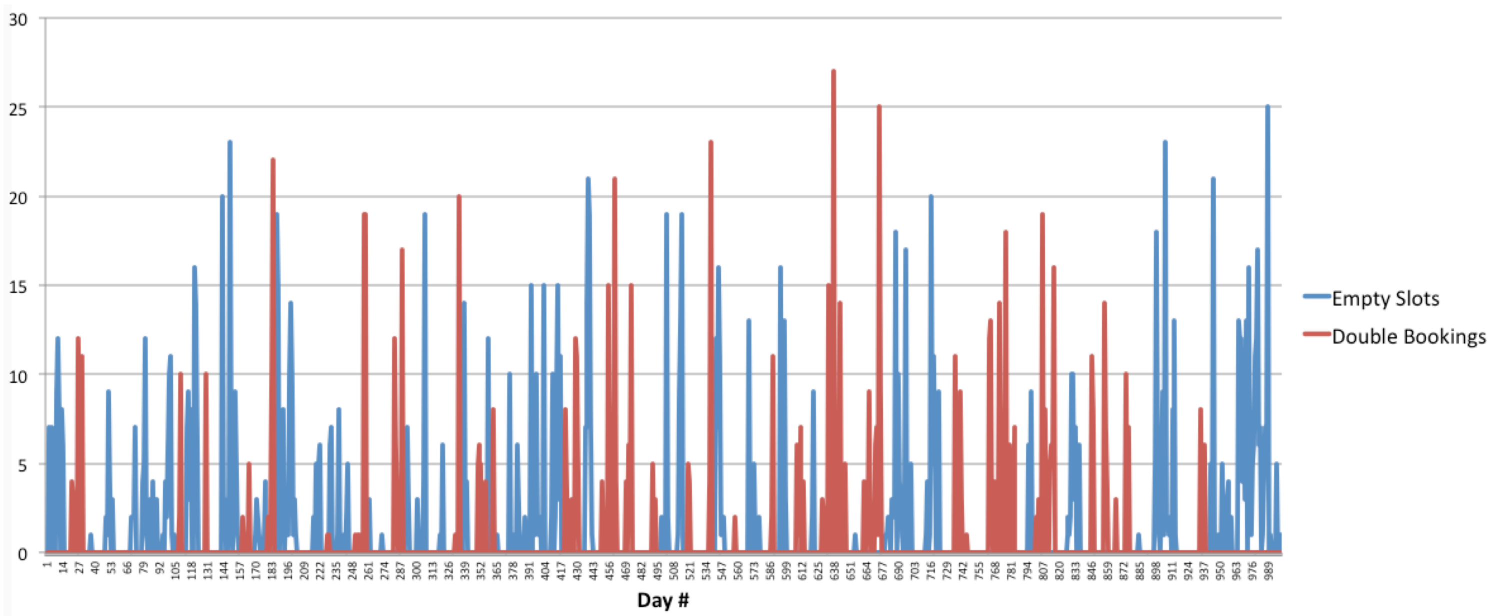

FIGURE 23, OUTPUT: DOUBLEBOOKINGS AND EMPTY SLOTS PER DAY (RUN 1000 DAYS)

6.9 Experiments

To demonstrate possible application of the simulation, the model is used for the lung clinic. First, the sensitivity runs are carried out for two parameters that were estimated in the experiment. The results of the sensitivity runs are found in Appendix E. The % of (semi-) urgent patients is estimated at 15 %, and the ratio of which patients accept an offered appointment is estimated on 0,6. These estimations are made based on interviews with the planners of the lung department. The number of patients per day calling is assumed normally distributed, based on a detailed assessment shown in the last part of Appendix E.

In the experiments it will be tested what the shortest allowable access time is in the current situation at the clinic, and what happens to this theoretical minimal access time when certain configurations are changed. This experiment is mainly done to give doctors insight in the possibility of shorter access. Therefore, the main outcome parameters are determined together with the doctors as follows:

Two thresholds have been defined for double bookings, two for empty slots. They can be seen in Table 13, together with the other basic settings that are based on the lung department's data. The first threshold should be rare and cannot be exceeded more than once in 10 days or 10%. The second threshold should be highly rare and cannot be exceeded more than once in 33 days, or 3%. If for a configuration this is true for all four thresholds, then the configuration is considered feasible.

Basic settings	
N.O. doctors	7
N.O. Patients per day	120
% (semi-) urgents	15
Patient acceptrate	0,4
CP factor	0,62
% No-shows	6
Days runtime	5000
DB1 Threshold	3 per shift
DB2 Threshold	6 per shift
Empty1 Threshold	2 per shift
Empty2 Threshold	4 per shift

TABLE 13, BASIC CONFIGURATIONS OF THE MODEL DURING THE EXPERIMENT

As stated earlier, the allowed access time is defined as the time in which every new patient should be offered an appointment at least once.

At the moment, the schedule of the lung department contains six different appointment types that are frequently used, mainly for administrative reasons. One configuration is to change this to only two appointment types namely half-hour appointments and 15-minute appointments, thereby aiming to make the schedule more flexible. This is setting 2 in Table 14.

Moreover, in the current situation the doctors' schedule is a fixed weekly roster with doctors working 6 shifts per week on average in the outpatient clinic. These doctors are, such as in every clinic, very unequally divided over the days. Some days only one doctor has consulting hours, other days five doctors. This creates a fluctuating supply. This experiment will test a configuration where the same amount of doctors works in the clinic every day of the week, thereby creating a stable supply pattern. This is setting 3 in Table 14. A combination of setting 2 and 3 is configured in setting 4. Setting 1 reflects the current situation.

Settings varied	Setting 1 (Current)	Setting 2	Setting 3	Setting 4
N.O. Appointment types	6	2	6	2
Daily supply	Variable	Variable	Stable	Stable

TABLE 14, VARIABLE CONFIGURATIONS OF THE MODEL DURING THE EXPERIMENT

The runs in the experiment are done for 5000 days. To assure no start-up- or termination effects, the first – and last 500 days are not taken into the results.

To do the experiment, it needs to be determined how many runs are needed for reliable results. This is done by a conducting a random trial experiment with ten runs, or N_0 = 10, every time with a different seed for the random generator. For this trial of 10 runs, the result of DB1 was 35,4 on average, with a standard deviation of 1,64. With these figures for 90%-confidence level, the order of magnitude of runs N required can be estimated according to:

$$0{,}5 * \epsilon * \mu > t_{N-1,\frac{\alpha}{2}} * \sigma/\sqrt{N} \qquad (3)$$

With on the left side the confidence interval desired and on the right side the 90%-confidence interval according to the trial run. With $\epsilon = 0{,}1 = \alpha$, respectively the allowed error margin and confidence level. With σ the standard deviation of 1,64 and N = N_0 = 10 and μ = 35,4. With these figures, t can be determined via literature as $t_{9,0.05}$ = 1,812 (Dekking & Kraaikamp, 2007 p433). Now based on formula 3 the ratio can be determined as:

$$R = \frac{0{,}5 * \epsilon * \mu}{t_{N-1,\frac{\alpha}{2}} * \sigma/\sqrt{N}} = \frac{0{,}5 * 0{,}1 * 35{,}4}{1{,}812 * 1{,}64/\sqrt{10}} = 1{,}88 > 1$$

This means the 90%-confidence interval is smaller than the desired interval. The ratio R is 1,88. Based on this estimation it means that we are on the safe side, in the right order of magnitude for N. Therefore, we take N = 10 as the number of runs for every configuration.

6.9.1 Results

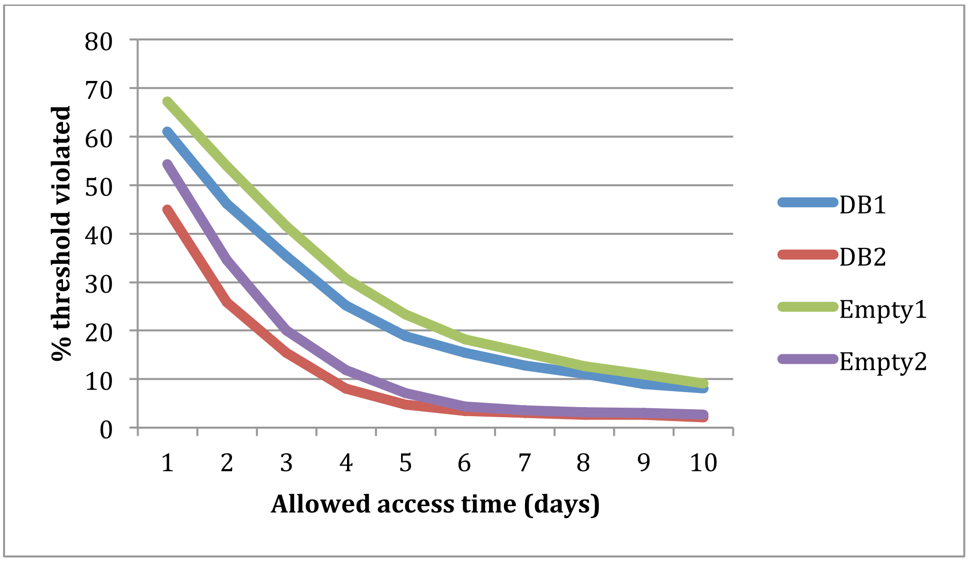

FIGURE 24, RESULTS SETTING 1

Allowed accesstime	DB1	DB2	Empty1	Empty2
1	61	45	67,2	54,3
2	46,2	25,9	53,9	34,5
3	35,4	15,5	41,6	20,1
4	25,2	8	30,7	11,9
5	18,9	4,8	23,4	7,1
6	15,4	3,4	18,2	4,4
7	12,8	3	15,5	3,6
8	11,1	2,7	12,7	3,2
9	9	2,6	10,9	3
10	8,1	2,1	9,1	2,7

TABLE 15, RESULTS OF SETTING 1 IN % OF DAYS WHERE THRESHOLDS WERE VIOLATED

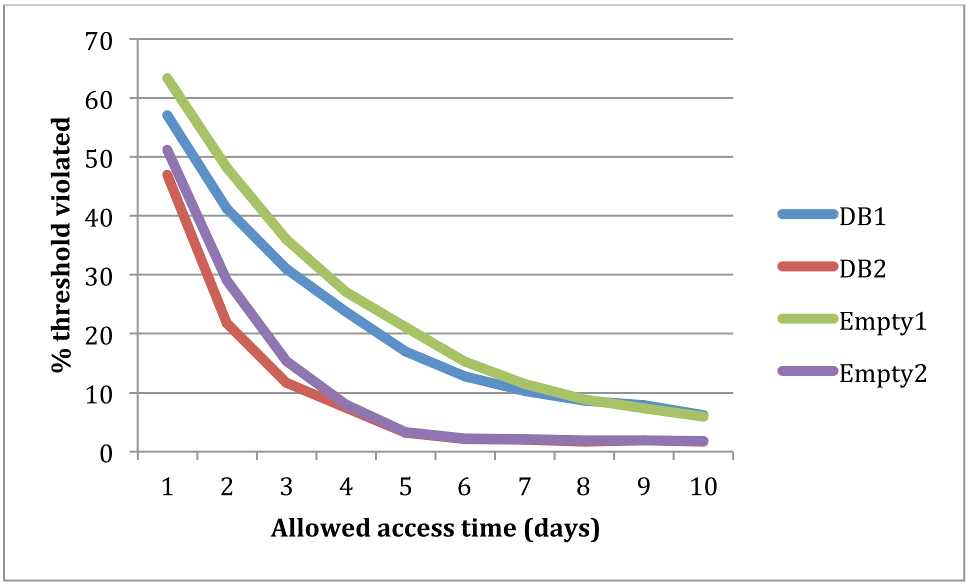

FIGURE 25, RESULTS SETTING 2

Allowed access	DB1	DB2	Empty1	Empty2
1	57,1	47	63,4	51,2
2	41,2	21,8	48,2	29,1
3	31	11,7	36	15,4
4	23,8	7,5	27,1	8
5	17	3,2	21,1	3,3
6	12,8	2,1	15,3	2,2
7	10,3	2	11,5	2,1
8	8,6	1,7	8,9	1,9
9	7,9	1,9	7,3	1,9
10	6,2	1,7	5,9	1,8

TABLE 16, RESULTS OF SETTING 2 IN % OF DAYS WHERE THRESHOLDS WERE VIOLATED

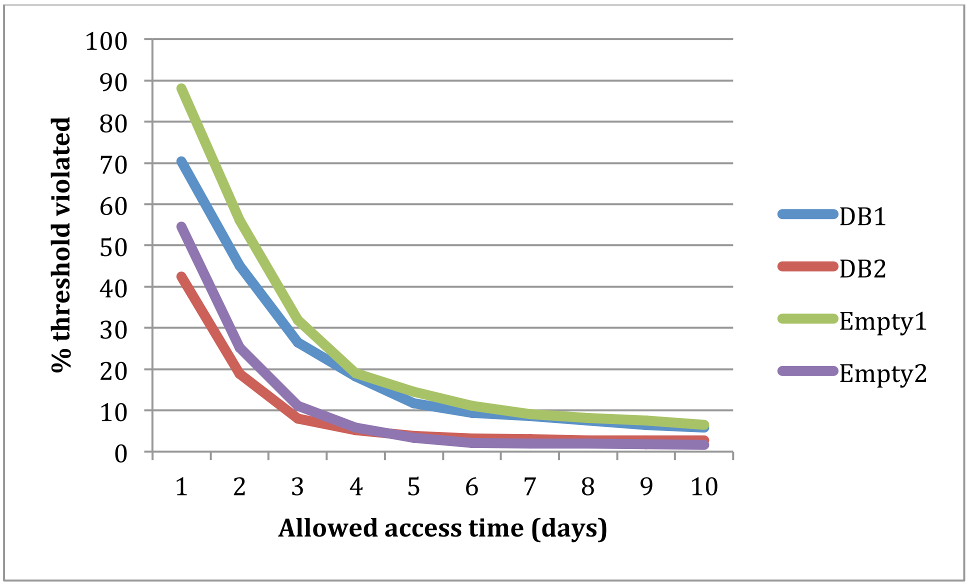

FIGURE 26, RESULTS SETTING 3

Allowed access	DB1	DB2	Empty1	Empty2
1	70,4	42,4	88,1	54,6
2	45,1	18,8	56,1	25,2
3	26,5	8	31,9	11,1
4	18,2	5,2	19	5,8
5	11,8	3,8	14,5	3,4
6	9,4	3,2	11,1	2,1
7	8,7	3	9,1	1,9
8	7,6	2,8	8,2	1,9
9	6,5	2,7	7,5	1,8
10	5,8	2,7	6,5	1,6

TABLE 17, RESULTS OF SETTING 3 IN % OF DAYS WHERE THRESHOLDS WERE VIOLATED

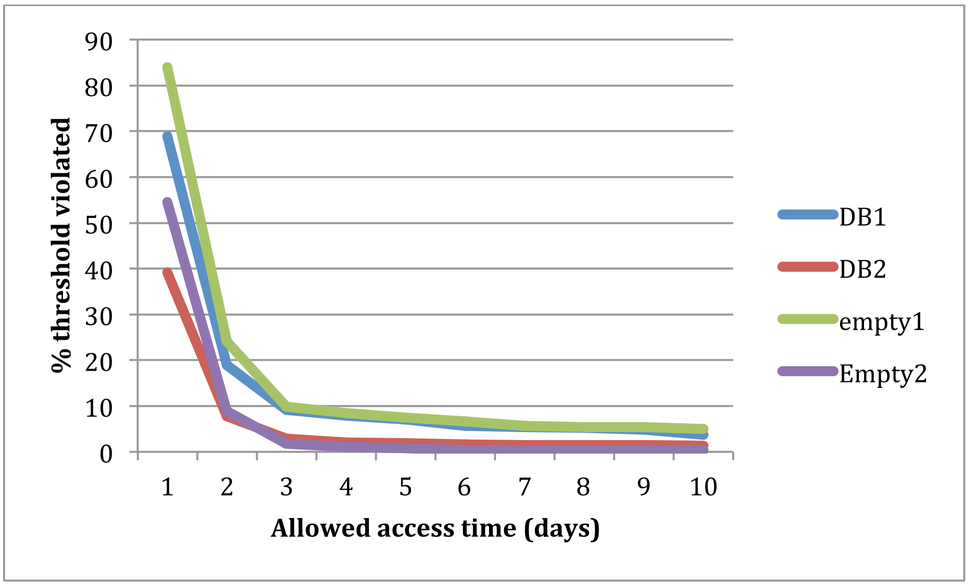

FIGURE 27, RESULTS SETTING 4

Allowed accesstime	DB1	DB2	empty1	Empty2
1	69	39,2	84	54,6
2	18,9	7,8	24,1	12,2
3	9,1	2,7	9,8	2,9
4	7,9	2,1	8,4	2,5
5	7	1,9	7,5	2,3
6	5,7	1,6	6,7	2,2
7	5,4	1,5	5,7	2,1
8	5,2	1,5	5,4	1,9
9	4,8	1,5	5,4	1,8
10	3,7	1,3	5	1,7

TABLE 18, RESULTS OF SETTING 4 IN % OF DAYS WHERE THRESHOLDS WERE VIOLATED

6.9.2 CONCLUSIONS

From the results in Table 15 it can be seen that under current circumstances, acceptable conditions are present when the allowed access time is not less then ten working days or two weeks. For setting 2, it can be shown that evenly divided doctor rosters can help shorten the minimal theoretical access time to eight days as can be seen in Table 16 . Reducing the number of specific appointment types leads to even better results, the minimum theoretical access time being seven days. See Table 17. A combination of the two in setting 4 leads to a significant drop of minimum theoretical access time to four days. Four days are chosen here instead of three, because for two critical elements in Table 18 the limit falls within the confidence interval as set previously.

The conclusion is that the minimum access time that the lung clinic can steer on can significantly be reduced by two planning adaptations. After this result, doctors can decide what changes they are willing and able to make to achieve lower access time. It can be concluded from this experiment that the model can be a helpful tool for doctors to provide quantitative insight in planning applications.

6.9.3 FURTHER APPLICATIONS AND POSSIBLE EXTENSION

The model can be used for different purposes in the future: It can be used to determine the temporary capacity increase in order to work down the backlog of patients. It can be used to determine the effect of seasonal variance in demand on access times. Moreover, it can be used to assess the effect of doctors going on holiday or longer-term leave, and to see what can be done to reduce these effects.

The TOMAS model is based on objects such as doctor and patient, thereby created in a structure that allows for extension. A possible and logical extension in the future would be to simulate the arrivals, treatments and desk activities in the clinics. Given the very different characteristics every clinic has, it is recommended to concentrate such an extension on a specific clinic rather than attempt to make a general model.

7 IMPLEMENTATION

In chapter 5 possible solutions have been presented for the lack of control and patient orientation discovered. Some solutions are short-term implementable, others can be seen as solutions for in the further future. In this chapter it is briefly discussed how the solutions could be implemented and what the current limitations for the solutions are.

7.1 CONTROL STRUCTURE

The control structure is ready to be implemented directly without any adjustments. It needs to be stressed that the standards chosen are based on theoretical estimations. In practice it is advised to evaluate the standards one year after implementation with logistic management, unit head and clinic's doctors. If necessary they can be changed to a more suitable or challengeable value.

For easy implementation a reporting tool is created in Rstudio, as shown in Figure 28. On an easy readable dashboard it is possible for managers to see the results of the reporting period compared to the standards. In addition, extra information can be plotted such as the consultations times and patient waiting times to obtain more insight.

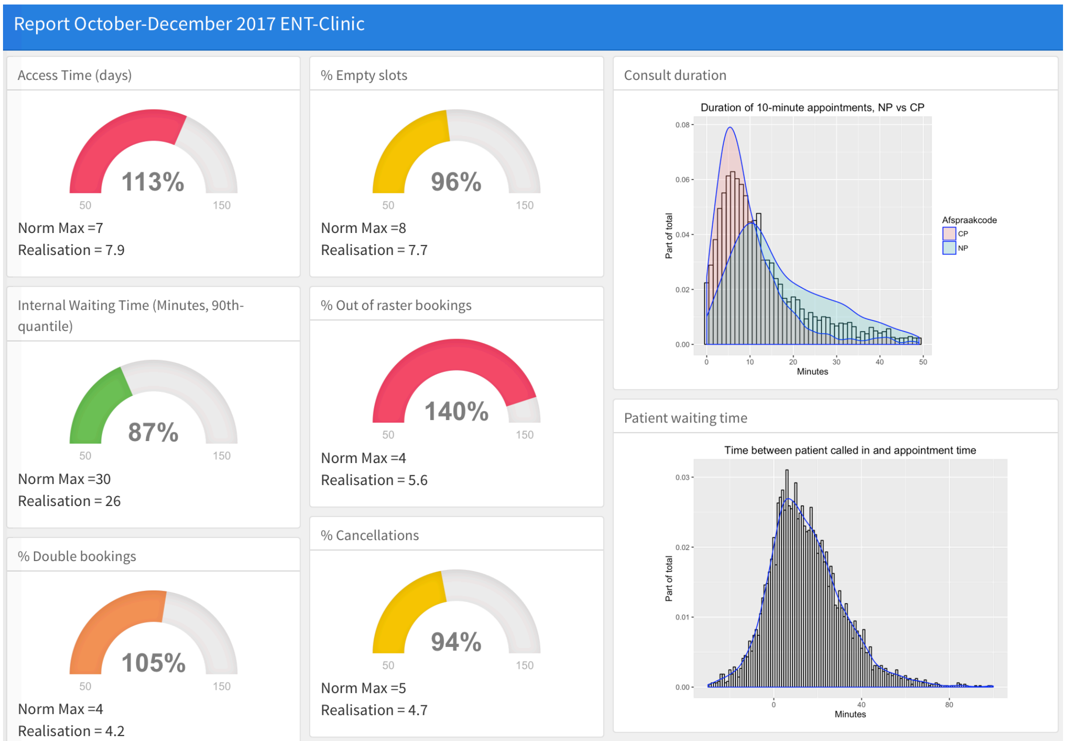

FIGURE 28, REPORTING TOOL DASHBOARD WITH KPI GAUGES

The control structure is used to coordinate and steer on the newly developed KPI's. Based on the analysis in chapter 3, it is of importance that planning staff and doctors are closely involved in this process. Because of their daily practice and experience, they have good insight in improvement directions, making their input very valuable.

It is recommended to first use the control structure solely as an information tool, with the employees' intrinsic motivation as the drive to achieve results. In a later stadium, it is also possible to use the results as a financial stimulus for the clinics to help strengthen the value of these otherwise non-financial parameters.

7.2 OPERATIONAL IMPROVEMENTS

The implementation for the improvements can be done as soon as there is consensus within the clinics about them. Doctors need to decide which appointment types are still necessary in the schedule in compliance with 5.2.4. Planners can directly start with the measurement of urgent patients. Based on the results after three months the doctors can decide how much space is reserved for urgent patients. The automatic freeing of specific appointment types is an already working function in HiX that can be used immediately. The adjustments in HiX for consult duration need to be discussed with a HiX consultant.

7.3 ADVANCED ACCESS

In section 5.4, advanced access exceeded as the best strategy considering the stakeholders' requirements. It is advised that management and doctors discuss advanced access as a serious option for future planning, given the advantages mentioned in this report. For the benefit of the discussion some limitations and considerations about the implementation of advanced access are addressed here.

As mentioned during the analysis, advanced access only works in situations where supply and demand are equal. In case of gastroenterology, there is a serious excess of demand nationally. This leads to steadily increasing access times, more than 14 weeks currently. For this situation, advanced access cannot provide a solution, only a balance of demand and supply can.

In addition, it must be noted that there is a risk of the suction effect. Every hospital has its own dedicated adherence area. When the aimed access time gain is exceptionally high however, it is possible that doctors from other adherence areas send their patients to a hospital with lower access times. Based on his 3-year in-vivo study, Van der Voorde concludes that this effect is negligible and advanced access is sustainable. In Appendix G, we use his data to show the effects in fourteen hospitals. It is advised to always take into account the possibility of suction effect when the access time gain is over four weeks. In case the hospital decides to move on to implementation of advanced access, it is advised to organize this one clinic at a time to avoid the overstraining of capacities further upstream, such as the operation room department.

8 CONCLUSION AND RECOMMENDATIONS

8.1 CONCLUSIONS

The Haga hospital initiated this research because it encountered several problems with their outpatient clinic planning. During the analysis it became clear that the current control structure is incomplete, and is mainly financially oriented as opposed to service-oriented. In chapter 4, the research question therefore is defined as:

"How can a control structure be designed for patient planning at the outpatient clinics in Haga using the HIS, that focuses on improving the patient-service level by the incorporation of patient requirements"

This research question is answered by answering the defined sub-questions. First it is determined which parameters are needed for the required performance and how to measure them, then it is determined how to improve these defined performance parameters.

"How can the function control of the planning process be designed in areas where it is currently lacking, so that performance can be measured?"

This question has been answered by developing function control for the outpatient clinics for the lacking requirements: For every requirement there has been defined: 1. A Key Performance Indicator, 2. A standard that it must reach, 3. A way of measuring the result of the KPI, 4. An evaluation period. This has all been designed so that it can be used in the current environment and with current Hospital Information System. In Rstudio a program is written that uses the raw data in the HIS and compares the calculated KPI's to the standards. A reporting tool is built that can be used to evaluate monthly achievements of the different clinics. This can be used to periodically evaluate results, and act when standards are not met. It can also be used by the hospital to compare the clinics to each other.

"Which operational improvements can be identified that lead to better performance?"

Now that the performance is defined and can be measured, the next step for a good control structure is to have means to achieve good performance. Therefore four operational improvements are proposed that can be helpful for all clinics to achieve a better results on the defined KPI's. Every clinic has its own specific planning challenges to address, but the mentioned improvements can be applied to every clinic. It is advised to:

1. use flexible appointment slots. Three rules of exception are proposed for when a specific appointment type is allowed. This decreases the complexity of the schedule and the number of hidden queues in the system, preventing empty slots for some

appointment types and long access time for others 2. that the planners screen the schedule daily for empty slots that are missed by the HiX searching algorithm, it is advised to do this three days ahead so that there is enough time to fill them. This increases the efficient use of schedule space. 3. measure the number of urgent patients to get insight in the average and variation, and use this to plan slots dedicated for urgent patients. This can decrease the amount of last-minute double bookings 4. adapt the consult duration measurements in a specific way to realise more reliable data results. This data was not necessary for the defined KPI measurements, but when this data comes from more reliable measurements it can be used in the future for more accurate prediction of consult length. This in turn can decrease waiting time and improve doctor utilization.

"Which strategic improvements can be identified that lead to better performance?"

The last step for good control is to assess which planning strategy to use in the clinics, based on the earlier identified requirements of the three stakeholders. In literature, three global planning strategies for outpatient clinics have been distinguished: Traditional, carve-out and advanced access. With the use of a multi-criteria decision analysis, these strategies have been compared: Criteria have been determined using stakeholders' requirements, and mutual comparison by all stakeholders led to weighted criteria used to assess the strategies. The conclusion of the MCDA is that the advanced access strategy is the preferred planning method.

Finally, a simulation tool has been built that can help managers and doctors gain quantitative insight in how to achieve advanced access. It can be used to estimate the amount of capacity needed to reduce the access time over a time period, and to estimate what the theoretical minimum access time is that can be achieved by the clinic - given variation in patient arrivals. It can also be used to see what changes can be made to the schedule to realise a lower theoretical minimum access time. The simulation tool has been used for the lung clinic. From the results it can be concluded that the minimum access time in the current situation is ten days. When the number of specific appointment types is reduced from six to two, the minimum access time is only seven days. In addition, if the supply is made constant i.e. if the same amount of doctors work every day, the minimum access time is only four days. From this practical example it can be concluded that this simulation model can be a useful tool for managers to get insight in the possibility of advanced access and the effect that their schedule has.

With the proposed KPI reporting, operational improvements and planning strategy it is believed that an improved control structure is developed based on both financial and service-oriented requirements. The simulation tool can be used for quantitative support for planning strategy decisions of clinic managers and doctors.

8.2 Recommendations

This research can be extended on a number of terrains; the most important ones are mentioned.

Clinic-specific research

At the ENT-clinic the treatment rooms pose a significant problem for the patient waiting time in the clinic. At the gastroenterology it seems that a shortage of nurses causes many cancellations. From this research, the next step is to investigate clinic-specific root problems for lack of good results. The results from KPI analysis and reporting tool from this research form a good starting point for such in-clinic research.

Repeat of MCDA with more doctors

The MCDA in this report is done with only three doctors, as no other doctors were available for the analysis. Of the 200 specialists in the hospital three is obviously not significant, but given the availability in the timeframe the best possible result. Doctors are an important factor in the decision making process in the hospital. In order for the result to have better support it is therefore advised to repeat the analysis with the developed framework, but for at least 80 doctors so the result can be qualified as significant.

Suction effect of clinics with extensive access time

For clinics that have a possible access time gain of four weeks or more, it is advised to assess the potential suction effect. This can be described as the willingness of patients to be directed to a different hospital for access time reasons, and can be investigated with a questionnaire. If the suction effect is expected to be too large, a possibility is to investigate a regional advanced access strategy for example with the Reinier-Haga group.

Simulation model extension

The simulation developed in this research is a discrete event simulation, containing objects such as patients and doctors. It is used for day-to-day planning and scheduling and does not include minute-to-minute simulation of in-clinic processes. Because of the discrete event structure, the model can be extended to this floor-level simulation. It can then be used for assessing the effects on parameters at this lower level, and to perform bottleneck analyses. Because of the major differences in rooms, staff and logistics at different clinics however it is strongly recommended to make such an extension clinic-specific. A solution for one clinic does not necessarily work for another.

Prediction of consult-lengths

One of the operational improvements was the adjustment of clocking patients in- and out of the consult room for more reliable measurements. This adjustment is only the first step. The next step is to use patient-, doctor- and appointment type- data to predict the duration of a consult more accurately. A patient's age, doctor's preferences and the appointment type's procedures can significantly influence the duration of the appointment. It is advised to investigate to what extent the resulting measurements can be used to predict the consult duration accurately. In that case duration variation can be reduced, which can lead to both increased doctor utilization as well as reduced waiting time for the patient.

Coupling of ZorgDomein and HiX

This recommendation is an extent of the previous one. For all new patients, personal data is available in ZorgDomein such as the GP's diagnosis and health record. The hospital can only see a picture of this ZD form, but does not actually have access to the data. This ZD information, in combination with the patient registration data in HiX can lead to very valuable data. With the combination of age, diagnosis and historic health records for example it can be predicted much more precisely what the consult duration would be. It is therefore advised to investigate the possibilities of coupling the ZD and HiX data.

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Coordinating supply and demand in Haga hospital outpatient planning: Towards a more service-oriented approach

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Abstract – The Haga hospital in The Hague demands a more structured approach for their patient planning in outpatient clinics. Five clinics have been observed and analysed using the Delft Systems Approach and system requirements were established using three main stakeholders: Patient, Doctor and Hospital. Main conclusion is that current coordination lacks for many requirements; the main focus lies on financial-, not service parameters. A control structure is proposed considering all system requirements. The structure consists of new KPI's and standards, and a number of interventions for every clinic that allow for more accurate KPI steering. An MCDA is used to determine the preferred planning strategy, and a simulation tool is added to assist clinic managers in making ground schedules

Index terms – Delft Systems Approach, KPI's, outpatient planning, control structure, simulation, Haga group

I. Introduction

The patient logistics area is in a state of continuous development, ranging from research in emergency departments to inpatient- and outpatient clinics. The first pioneer in the area of outpatient planning was Bailey (1952)[1], who studied queues and waiting times using simulation. Since then, many studies followed focusing on waiting times, arrival times, no show rates and the prediction of service times. For a comprehensive review of studies see Cayirly et al (2003) [2]. On a more strategic level, Murray et al (2003) [3] provides a good insight. In case of a quantitative approach, most studies use either queuing theory or a simulation tool, or a combination of both.

The Haga hospital is one of the largest hospitals in The Netherlands. It comprises a total of twenty outpatient clinics covering all well-known specialties from heart- to lung diseases and from urology to neurosurgery. Since two years the hospital has started project "Polihuis". Until then, all outpatient clinics had been isolated islands that took care of their own logistics, both patient and means. The goal of the Polihuis project is to break with that system and to come to a more structured, standardized approach for outpatient logistics by means of a hospital-central department. In this way, logistics can be optimized and clinics can be compared to each other and hopefully learn from each other.

The current focus of the project is on the patient planning of the clinics. A general feeling of discontent of the patient planning exists within the hospital. For years, planning schedules have been made based on experience and intuition. Although there is little quantitative insight, there is the feeling that patients face long waiting times to come to the clinic and when in the waiting room. Doctors are complaining about facing either high peaks of patient numbers at some times, or lots of idle time at other times during their consultation hours.
Moreover, in the summer of 2016 a new hospital information system was implemented in Haga. Now that it's fully functional, the hospital is interested to explore the possibilities of this new

system: What data is gathered and what are the possibilities for practical use? It feels that this data could be valuable for patient planning and therefore feels now is the time to investigate how the hospital can come to a more structured approach of outpatient planning, ideally more satisfactory for patients, doctors and employees, using the data from the new hospital information system.

II. Methods

The process and current control structure of the Haga outpatient clinics are analysed using the Delft Systems Approach (DSA) [4]. As this research addresses the outpatient planning, the pure medical requirements asked from the clinic are left out of the research scope. Medical requirements that have an influence on the planning processes will be taken into account. The main question this analysis needs to answer is how the current processes and planning in the outpatient clinics are controlled.

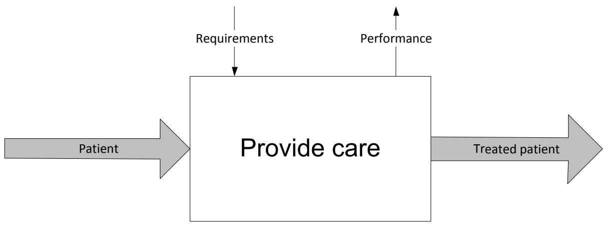

Figure 1, DSA at the first aggregation level

Using DSA's black box approach, on the first aggregation level the outpatient clinic is identified as a system with its main function: Treating patients. See Figure 1. On the second aggregation level the Process-Performance (PROPER) model is used to identify three relevant aspects: A healthcare request from the GP that needs to be answered, a patient that needs to be treated, and the resources that need to be used during the process. Resources are the doctor, nurses, rooms and equipment needed for a consult. These three main processes are coordinated by the current control structure, as can be seen in Figure 2. This current coordination is analysed, but first the system requirements are identified.

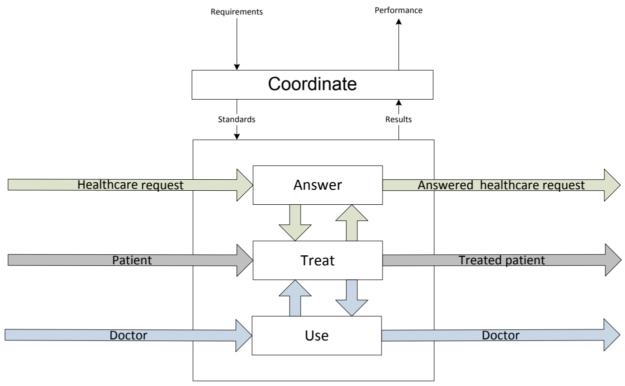

Figure 2, DSA at the second aggregation level: PROPER model

The outpatient clinic involves three main stakeholders: Hospital, doctor and patient. Requirements have been established based on these stakeholders. The direct requirements for the hospital are:

- Production goal
- Operation Room (OR) requirements
- Maximal utilization of staff and means

For the doctor these are:

- Production goal
- Flexibility for leave
- Minimal overtime
- Maximal utilization

For the patient these are:

- Minimal access time
- Minimal waiting time in waiting room
- Sufficient consult time with doctor
- Minimal rescheduling of appointments

An analysis of the current control structure is made; to investigate to what extent the identified requirements are controlled for in the as-is situation. In the Answer-process, the schedules are created. The outpatient doctors' schedules are mainly based on the schedules of the OR, and on the current production achieved compared to the expected production. These financial parameters largely determine the doctors' schedule. Another finding is that the access times are mainly used as a buffer, to prevent fluctuation of health request to lead to empty appointment slots. These long access times however lead to logistical issues as well. Apart from the stress experienced by patients, long waiting lists result in higher no-show rates, the need for patient triaging by

doctors and extra double bookings caused by (semi-) urgent patients.
In the Treat-process, the new HiX system is used in combination with the registration columns. This generates very useful raw data for a control structure about times of patient arrivals, patient departures and agenda data. This data currently remains unused however.

In the Use-process, the main focus of control is on the optimal utilization of staff. Doctor rosters automatically indicate the amount of each type of personnel needed in the clinics. These amounts are yearly evaluated and updated if necessary. The financial parameters are controlled very precisely here.

In conclusion the main findings of the DSA analysis can be summarized as:

1. Long waiting lists lead to logistical issues in the clinics.
2. The new HIS provides operational data that remains unused.
3. The current focus of control is on financial parameters instead of patient requirements

The latter observation can be best illustrated using Figure 3. When we analyse how the established system requirements are controlled, we see a clear lack of control mainly in the areas of the patient. No KPI's, standards of result measurements are available for these KPI's. The areas coloured red will be the main focus of the creation of a new control structure, with more emphasis on the patient requirements and using the raw data available in HiX.

	Requirement	KPI	Standard	Measurement	Evaluation
Hospital	**Yearly production goal**	Number of new patients	Contractual agreement	Appointment roster HiX	Yearly negotiations
	OR-requirements	-	OR-schedule	-	-
	Utilization of staff	Staff/session	Clinic specific	Completed schedule	Yearly discussion
Patient	**Cancellations**	?	?	Cancellations in HiX	?
	Access time	TNAA	?	TNAA	?
	Sufficient time with doctor	?	?	?	?
	Internal waiting time	?	?	?	?
Doctor	**Utilization of doctors**	?	?	?	?
	Yearly production goal	Number of new patients	Contractual agreement	Appointment roster HiX	Yearly negotiations
	Overtime	?	?	?	?
	Flexibility for leave doctors	Leave announcement period	3 months and 6 months	-	-

Figure 3, Current function control for the identified requirements

III. Results

An improved control structure is created based on the requirements that were lacking in the old structure. Improvement is done by looking at three different areas; the creation of function control, operational improvements to steer more accurately on the standards, and strategic improvement by the evaluation of several planning strategies. Finally, a simulation tool is built that can help doctors and managers assess their ground schedule.

A. Function control

First the highest level of function control is improved. The starting point is Figure 3. For all requirements where no control was available, it has been created. This means that a KPI was identified, as well as measurements. The KPI's for access time and internal waiting time have been determined using historical measurements. The Third Available Appointment Time (TNAA) and 90-percentile waiting time respectively are determined as the KPI's best reflecting the requirements. The % of rescheduling is the KPI for cancellations and for doctor utilization and -overtime the % of empty slots and double bookings in the agenda are determined as the KPI's respectively.

After determination of the KPI's a program was written in RStudio to convert the raw data into measurable results of these KPI's. Based on the historical results, for every KPI a standard is recommended as well as an evaluation period. Now all parameters needed for good function control are established, as shown in Figure 4.

Requirement	KPI	Standard*	Measurement	Evaluation
Overtime (working days)	Extra sessions/3 months	5	Compare initial and achieved roster	Three months
Cancellations	% appts rescheduled by hospital	5	Appointment mutation analysis	Three months
Access time	TNAA	Per clinic	TNAA by unit head	One month
Overtime(hours) & Utilization of doctors	% OS	8	Agenda analysis	Three months
	% DB	4		
	% OOR	4		
Internal waiting time	90th percentile minutes	30	Appointment analysis	Three months
Sufficient time with doctor	Patient grade	7	Feedback Radar	One year

Figure 4, Developed function control table

The interface that goes along with this table is shown in Figure 5. The user can enter the period, the clinic and the doctors that must be taken into account. The reporting tool will then show the dashboard with values compared to their standards and important graphs. This dashboard can be used for periodical evaluation of the performances by the clinic managers, with the goal of intervening when the results deviate strongly from the standards. The reporting dashboard can also be used by hospital managers for comparison of performance between different outpatient clinics.

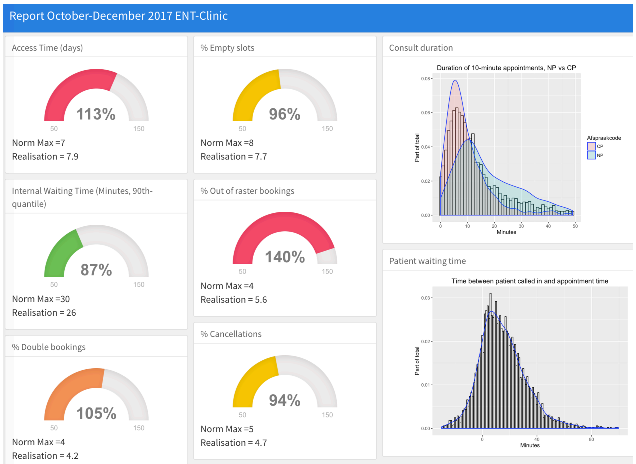

Figure 5, Developed reporting tool with dashboard

B. Operational improvement

In the as-is situation a number of improvements have been identified. The interventions proposed here can help every clinic to steer more accurately on the standards. First, the measurements for consult duration can be improved. Currently, the measurements cannot be deemed accurate enough to use for further purposes. The first reason for this inaccuracy is that frequently, co-assistants see patients first however do not have the authority to call in the patients in HiX. Second, doctors regularly forget to put the patients on "leave", after the patient has left. Doctors are often busy with the preparation for their next patient. Due to these two reasons the measurement results of consult duration are clouded, and cannot be deemed reliable. To improve this, it is recommended to give co-assistants the authority to call in the patients and to let HiX automatically "leave" the patients when the next patient is called in. When these improvements are implemented, it is believed that the measurements can be used for determination of consult length based on historical data.

Second, it is recommended to measure the urgent patients, patients that need to be seen within one or two days, in the system. Although it is possible in HiX, momentarily there is no incentive for the planners to register these patients. It is recommended to do this for a significant period of time, so that clinic managers have data and slots can be reserved for empty patients based on data, not on a feeling. It is recommended to appoint one doctor per day that is responsible for the urgent patients, and to reserve empty slots at the end of the shift so the rest of the consultation hours are not messed up.

Third, it is recommended to perform a screening three days ahead of the schedule. This screening can be performed by the planners. This to make sure that empty slots that are not seen by the HiX algorithm are filled, in order to improve the doctor utilization. Fourth, it is recommended that specific appointment types be only used in the case of:

- Specific appointment duration
- Specific nurses or assistants are needed
- Specific rooms or equipment are needed

More appointment types and specialized doctors increase the number of waiting queues. It can therefore happen that some appointments stay empty whilst other patient types face very long access times. The advice is to only use specific appointments if strictly necessary.

C. Strategic improvement

For the outpatient clinic, three different planning strategies have been identified that are regularly used. The first is the traditional method, which is used currently in the Haga by most clinics. The traditional method uses access time as a buffer and books check-up patients and semi-urgent patients double, leading to extra busy moments in the consultation hours. Some clinics try to avoid these double bookings with the carve-out strategy. This method keeps space for check-ups and (semi-) urgent patients by reserving empty slots in the schedule. A drawback is that the access time increases if this strategy is applied. More important, practice shows that informal systems develop to "steal" empty slots meant for semi-urgent patients, often under pressure of high access time.

The third strategy is the advanced access strategy [3][5]. This strategy attempts to avoid double bookings and pressure during the shifts by actively steering on a low access time. This way, there is always a slot available for check-up and semi-urgent patients and new patients can be seen within a week. An important condition for advanced access to work is that demand and supply are equal.

A Multi Criteria Decision Analysis (MCDA) [6] is made to assess which strategy is preferred for the clinics taking all stakeholders' interest in account. For the criteria, all established requirements are taken that are thought to be influenced by the choice of strategy. First the criteria are given their weight. The three stakeholders have done this: Thirty patients, three doctors and five hospital employees in various leading positions. The three stakeholders are considered equally important, meaning that the final criteria weights are the average of the three stakeholders' weights.

With the weighted criteria, the next step is to assess the different strategies. Based on the expected performance of the strategy, a grade between 0 and 5 is given. These grades are first normalized per criterion, then multiplied by the criterion weight and then all added per strategy leading to a final score. The weights, grades and final scores are shown in Figure 6. According to the MCDA, the advanced access strategy is the preferred strategy when taking into account all stakeholders requirements. A sensitivity analysis has been performed by adding and subtracting 0,1 to/from each of the weight factors. In all these scenarios the result was robust: advanced access was the highest scoring strategy.

Criterion	Weight factor	Traditional	Carve-out	Advanced Access
Production goal	0,17	0,8	0,8	0,4
Cancellations	0,17	0,4	0,4	0,6
Internal waiting time	0,17	0,4	0,8	0,8
Utilization of doctors	0,16	0,6	0,4	0,8
Access time	0,15	0,4	0,2	0,8
Overtime (WD)	0,09	0,8	0,8	0,4
Overtime (WH)	0,09	0,4	0,8	0,8
Normalized weighted score	-	0,30	0,31	0,39

Figure 6, MCDA result table with final scores of the planning strategies

D. Simulation tool

As explained earlier, doctors use the access time as a buffer to prevent empty slots in their agenda as a result of daily patient arrival fluctuation. They also expressed their fear for this when using the advanced access strategy. This is why a simulation tool is made in TOMAS Delphi [7][8] to give the doctors more quantitative insight in what the theoretical minimum access time is they can achieve. It can also be used to see what changes in the ground schedule can lead to shorter minimal access times, and what tactics can be used in case of expected seasonal fluctuations and holiday periods.

The simulation, shown schematically in Figure 7, consists of three main aspects: First the ground schedule of an outpatient clinic, consisting of the number of doctors and when they work, and a set of different appointment types. Second; the creation and arrival of patients. These patients arrive with a daily variation, and can be new, check-up or (semi-) urgent patients. The third aspect is the planning of these patients in the schedule, and updating the schedule. The planning algorithm searches the first available timeslot that suits the patient's characteristics. The patient can then either accept or refuse the offered appointment, and in case of a refused appointment the next suitable timeslot is offered.

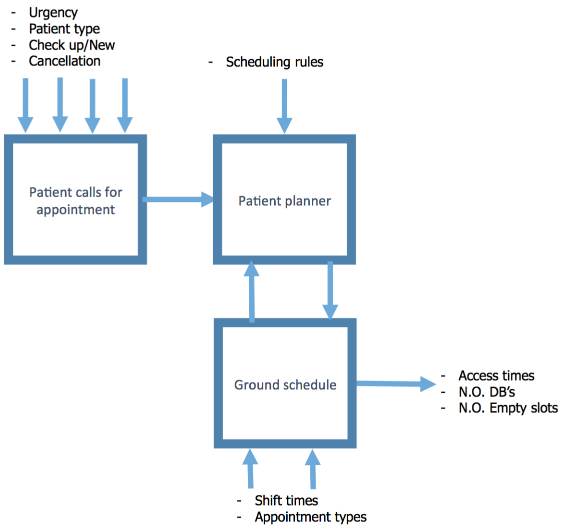

Figure 7, Schematic overview of the planning simulation model

The most important input parameters consist of the doctor's schedule, number of appointment types, CP factor and percentage of urgent patients. These figures differ from clinic to clinic. After the simulation is run, the schedule is checked. The most important output parameters are the average access time, the number of open slots and the number of double bookings in the schedule.

Finally, the simulation has been tested at the lung clinic. To test the shortest access time acceptable, an allowed access time was introduced: Every new patient must be offered at least on appointment within this allowed access time. After simulation completion the number of double bookings and empty slots per day per doctor are measured. Four thresholds are introduced, as well as how often they are allowed to be exceeded:

- 3 double bookings per day, not more than 1 in 10 days
- 6 double bookings per day, not more than once per month
- 2 empty slots per day, not more than 1 in 10 days
- 4 empty slots per day, not more than once per month

The current doctor's schedule has many fluctuations: Some days only two doctors do a shift, other days six doctors do multiple shifts. The current appointment schedule has six different appointment types that are frequently used. With this current scenario it is tested what the theoretical minimum access time is so that it fulfils the threshold requirements. The results can be seen in Figure 8, with on the x-axis the allowed access time for new patients. Ten working days is the minimum: All threshold requirements are met.

The minimum access time is tested again in a second scenario: Daily demand is equal, meaning that the same amount of doctor shifts is planned every day. Moreover, six specific appointment types is reduced to two; only check-up and new patients, increasing schedule's flexibility. The result can be seen in Figure 9, the minimum access time in this scenario is reduced to four working days.

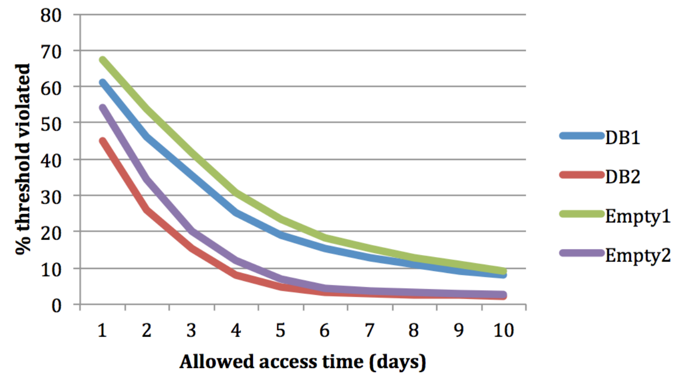

Figure 8, Results: Exceedance of thresholds under various allowed access times, current scenario

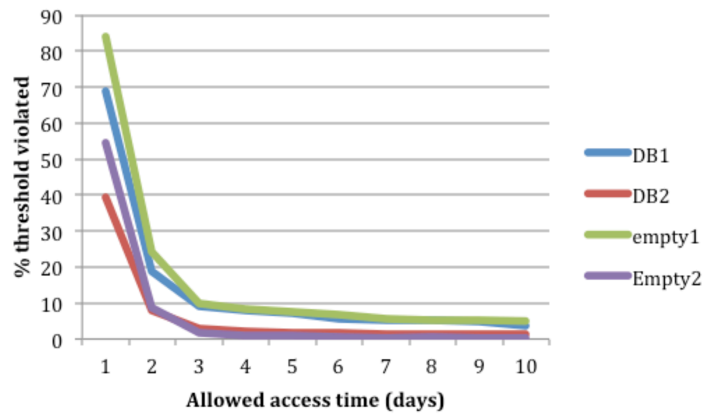

Figure 9, Results: Exceedance of thresholds under various allowed access times, experimental scenario

IV. Discussion

This study provides a clear control structure for the outpatient departments in the areas where it was lacking, and provides a number of generic improvements to achieve a better performance in terms of these control parameters. It is believed however that significant logistic improvement opportunities can be found in clinic-specific follow-up studies. The clinic performance outcomes of the reporting tool can be used as a starting point for further research, focusing on issues in a clinic that have a very explicit character.

This study places the patient as a stakeholder on the same height as the doctor and hospital, by adding their requirements in the control structure. Literature is provided to support this choice. It is deemed important and necessary to continuously discuss this balance between financial requirements and the patients' interest in healthcare processes, now and in the future.
During the creation of function control, a number of sharply set standards have been defined based on assumptions about improvements, and to keep staff motivated to search for improvements. However, too sharp standards can demotivate the staff, as they are unable to reach these. It is the task of the clinic managers to handle this process. An option is to use past year's average as a standard to begin with, and gradually demand better results.

The simulation tool is built on a strategic level, to keep an overview of access times and the booking of schedules. A next logical step is to extent this simulation model to the operational level. Then the consequences of double bookings and empty slots can be modelled accurately, as well as choices for the service times, staffing and lateness of doctors and patients. From the structure of the model in TOMAS Delphi, it is possible to directly extent the current model to operational level. It is advised to make such an extension clinic specific, as it is estimated that a general model cannot reflect all logistically different challenges that the clinics face.

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APPENDIX B: LIST OF HAGA SPECIALISMS (DUTCH)

Anesthesiologie
Cardiologie
Dermatologie
Gynaecologie
Heelkunde
Hematologie
Interne Geneeskunde
Kindergeneeskunde
Keel-, Neus- en Oorheelkunde
Longziekten
Maag-, Darm- en Leverziekten
Mondziekten, Kaak- en Aangezichtschirurgie
Neonatologie
Neurochirurgie
Neurologie
Oogheelkunde
Orthopedie
Plastische chirurgie
Reumatologie
Urologie

APPENDIX C: PROGRAMMATIC DEFINITION OF OS, OOR, DB

A tool in RStudio calculates the OS, OOR, and DB rates based on raw data from the appointment schedules in the past. The input for the tool are the clinics' specialists agenda-codes and the clinic-specific start-, end- and lunchtimes. The tool then gathers the agendas per specialist.

An open slot (OS) is detected if the duration of the appointment is shorter than the time between the appointment and the successive appointment, following:

IF starttime(i) – starttime(i+1) > 1.5*duration(i) THEN OS = OS + 0.5

IF starttime(i) – starttime(i+1) > 2*duration(i) THEN OS = OS + 1

Corrections are made so that lunchtime is not seen as an OS.

A Double Booking is detected if two appointments start at the same time, or if the successive appointment starts within the duration of the first appointment, following:

IF starttime(i) == starttime(i+1) THEN DB=DB + 1

IF starttime(i) – starttime(i+1) < 1*duration(i) THEN DB = DB + 0.5

An Out Of Roster booking (OOR) is detected if the start time of the appointment falls outside the consultation hours, following:

IF starttime(i) < sessionstart1 THEN OOR = OOR + 1

IF starttime(i) > sessionend2 THEN OOR = OOR + 1

IF starttime(i) > sessionend1 & starttime(i) < sessionstart2 THEN OOR = OOR + 1

After scanning the agendas of all doctors in a given period, the total number of OS, DB and OOR are divided by the total number of appointments in that period. The results are the percentages of open slots, double bookings and out of roster bookings.

APPENDIX D: QUANTITATIVE KPI DETERMINATION

Internal waiting time measurements

The data of the internal waiting time of the Lung department since the beginning of measurements in June 2016 has been researched. The aim was to find the best key performance indicator to reflect the internal waiting time of patients in the waiting room. For the data it was important that there had not been any policy changes or other known alterations during the sample period that can affect the internal waiting times. The lung clinic fitted this requirement.

The KPI should be a clear value. The average waiting time is an option but without the standard deviation it does not well indicate the waiting time of the extreme cases, which are often problematic for the clinics. Another option is the waiting time within which all patients are helped, a KPI that is used by the NHS in England. The problem with this parameter is that it probably varies too much per month. The best KPI therefore will be a quantile as close to 1, which is consistent during a prolonged period of time. The goal is to find the appropriate quantile that can be used as a KPI.

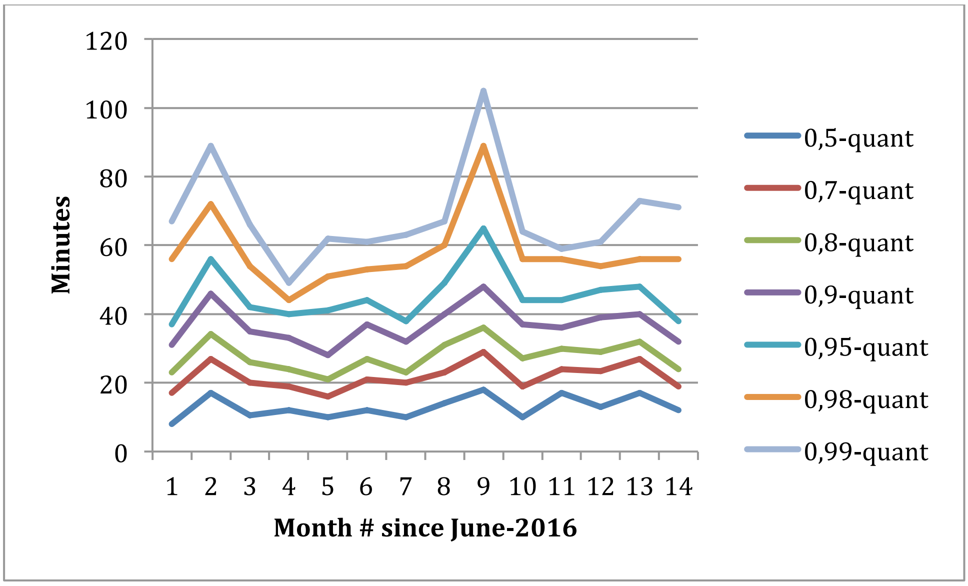

FIGURE 29, VALUES OF DIFFERENT IWT-QUANTILES JUNE-2016 UNTIL AUG-2017 (LUNG)

Quantiles	0,5-quan	0,7-quan	0,8-quan	0,9-quan	0,95-quan	0,98-quan	0,99-quan
Average(min)	13	22	28	37	45	58	68
Variance	10	16	21	32	59	115	190

TABLE 19, AVERAGE AND VARIANCES OF QUANTILES JUNE-2016 UNTIL AUG-2017 (LUNG)

The plot shows the different quantiles from 0,5 to 0,99 during a period where the average waiting time can be expected to be stable. The 0,5-quantile shows a very high stability as expected rising exponentially to the 0,99-quantile, which shows high sensitivity for incidental changes. For example a few extra urgent patients can rise the

99-quantile significantly. As explained the chosen KPI is a balance of high quantile and low variance. Based on the plot and table, the most suitable KPI is chosen to be the 0,9-quantile. It is still sensitive to extreme cases but is also reasonably stable – varying between 32 and 44 minutes – during a prolonged period where no differences were expected.

Next Available Appointment measurements

Measurements have been carried out for the KPI-determination of access time. This is done by daily monitoring of the first- until sixth- next available appointment for a period of four weeks. The Gynaecology and Dermatology department have been chosen for these measurements, mainly because for these clinics it is possible to use online appointment planning. This way the monitoring could be done without interfering in daily activities of the planners.

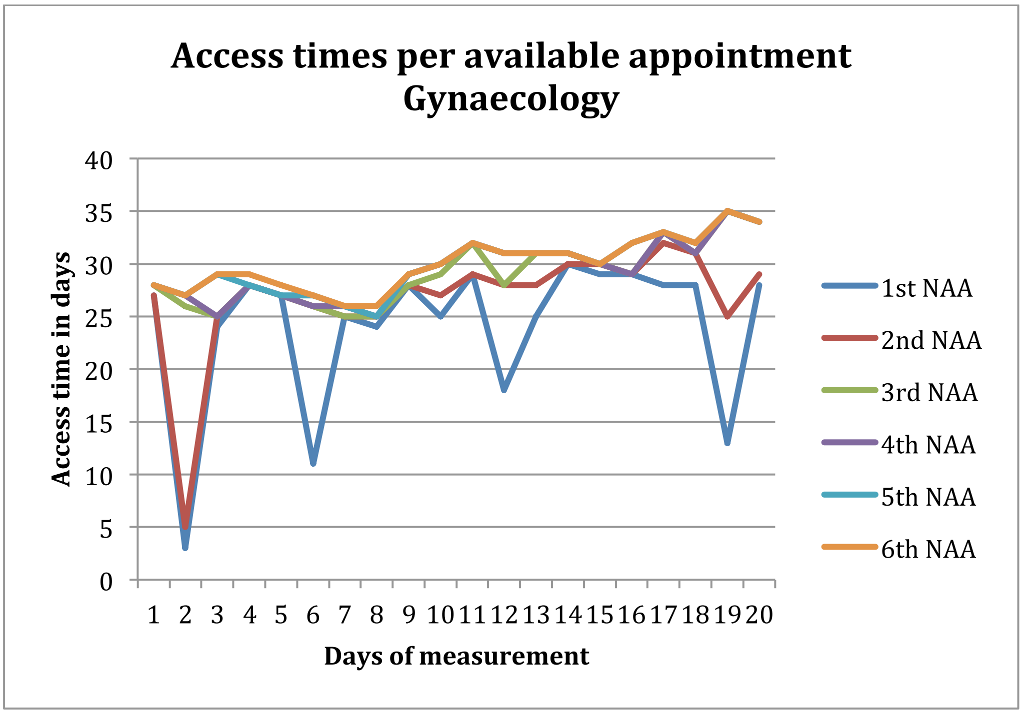

FIGURE 30, ACCESS TIME PER AVAILABLE APPOINTMENT (GYN)

NAA	Average	Variance
1st	23,95	48,9475
2nd	26,7	28,71
3rd	29,05	8,6475
4th	29,4	8,04
5th	29,85	7,1275
6th	30	6,3

TABLE 20, AVERAGE AND VARIANCE OF NAA'S (GYN)

Gynaecology

The table shows a logical pattern: The average access time of the first available appointment is lower than the second, the second lower than the third and further. As can be seen from both table and plot, the variance of the first and second available appointment are significantly higher than the others, because on some days, one or two cancelled appointments create an opportunity for a very soon appointment. This variance however implicates unreliability for KPI measurement. As can be expected, the sixth available appointment time is the most stable. These values also vary however, most probably due to varying doctor schedules and patient arrival variance.

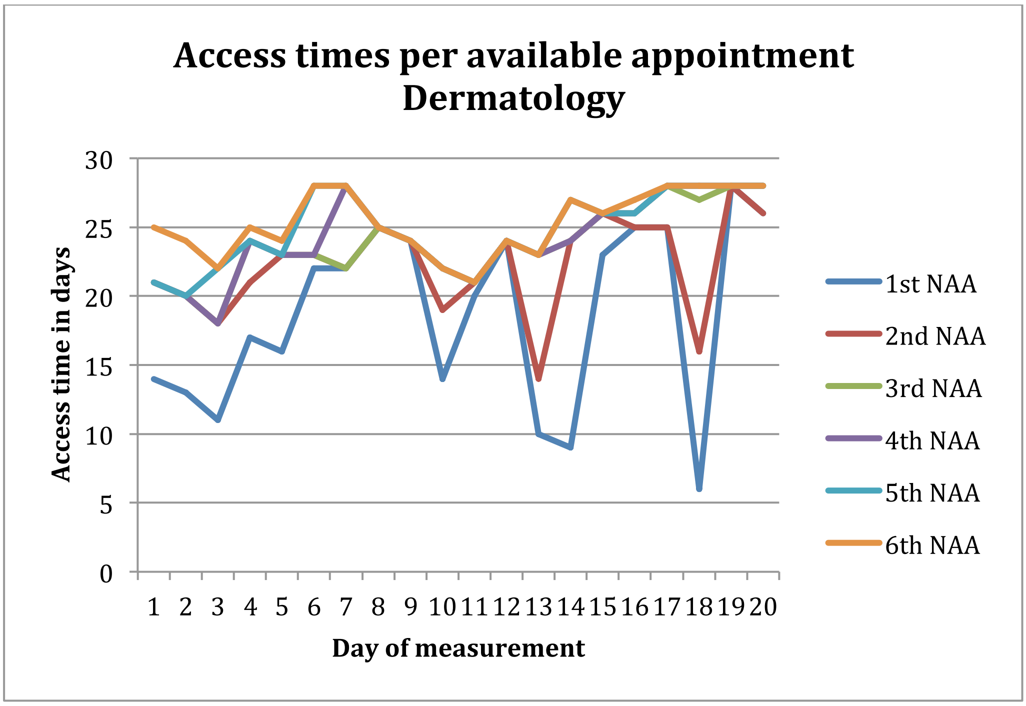

FIGURE 31, ACCESS TIME PER AVAILABLE APPOINTMENT (DERM)

NAA	Average	Variance
1st	18,7	41,71
2nd	22,25	11,9875
3rd	23,85	7,3275
4th	24,2	8,26
5th	24,8	7,26
6th	25,35	5,1275

TABLE 21, AVERAGE AND VARIANCE OF NAA'S (DERM) *Dermatology*

Although average access times are lower, the patterns observed are similar to those of the gynaecology department. The difference in variance however between the second and third available appointment is not as significant as with gynaecology. In the plot of the second available appointment time there are some troughs most likely due to cancelled appointments.

Conclusion

When combining the results of the gynaecology and dermatology clinics, it can be concluded that the third next available appointment is the best choice for the key performance indicator. This reflects the shortest possible access time that is stable, and therefore reliable.

These conclusions are drawn from a four-week sample of two clinics in the Haga hospital. At the moment there is no reason to believe that other clinics have very deviating characteristics. It is therefore recommended to take the third next available appointment as a KPI for all clinics.

Appendix E: Sensitivity runs

Sensitivity runs for model verification

This verification has the aim to verify the simulation model by varying different input parameters, and verifying the results to make Figure 23 (Chapter 6) better interpretable, the number of exceedances of thresholds is taken in the following figures. The thresholds are, after consulting with the doctors of lung department, determined as:

DB1 = 3 double bookings/shift

DB2 = 6 double bookings/shift

Empty1 = 2 empty slots/shift

Empty2 = 4 empty slots/shift

All runs have been done for 5000 days and with different seeds. An extra measure for the verification is the average number of double bookings/day versus empty slots/day. In the situation of equal demand and supply, these values should always be equal (apart from small start/termination effects). In all runs for all seeds this is the case, as was expected.

With average Npatient/day = average Nslots/day, the following runs have been executed on sensitivity for

- Number of doctors
- Patient arrival standard deviation
- Number of appointment types
- Allowed access time

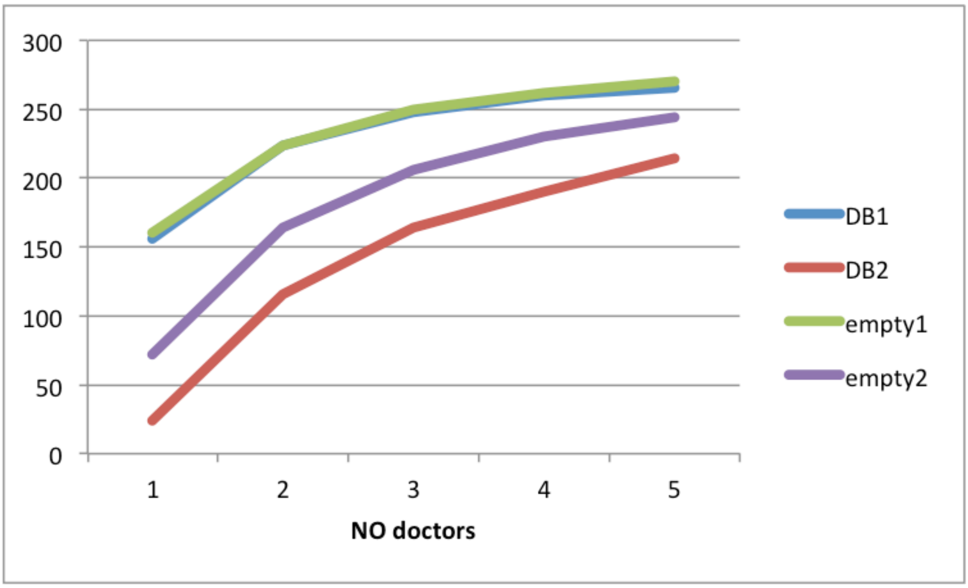

FIGURE 32, SENSITIVITY NUMBER OF DOCTORS

In Figure 32 the number of doctors is varied. The number of double bookings and empty slots per day rise as expected. However the number rises less then linearly. For a system in which each doctor had their own specific patient set and access time, a linear relation would be expected, as a second doctor would give twice as much double bookings and empty slots exceedance. However this system is more flexible as every patient can see every doctor. A less then linear relation can therefore be expected.

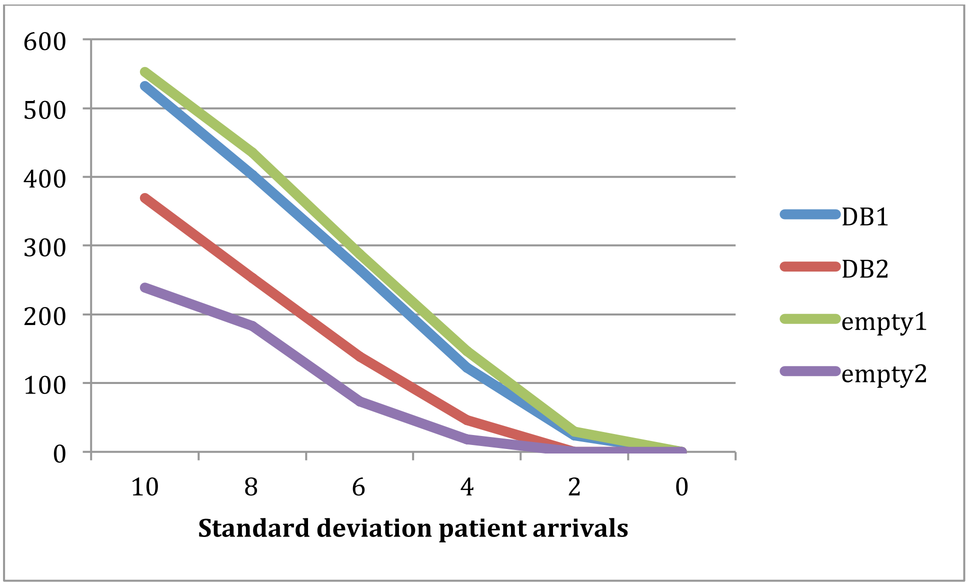

FIGURE 33, SENSITIVITY STANDARD DEVIATION PATIENT ARRIVALS PER DAY

The number of exceedances versus standard deviation appears to be linear. This needs to be investigated further to explain this completely. For verification purposes however it is easy to explain that all exceedances should be equal to 0 for standard deviation = 0, which is true for this graph.

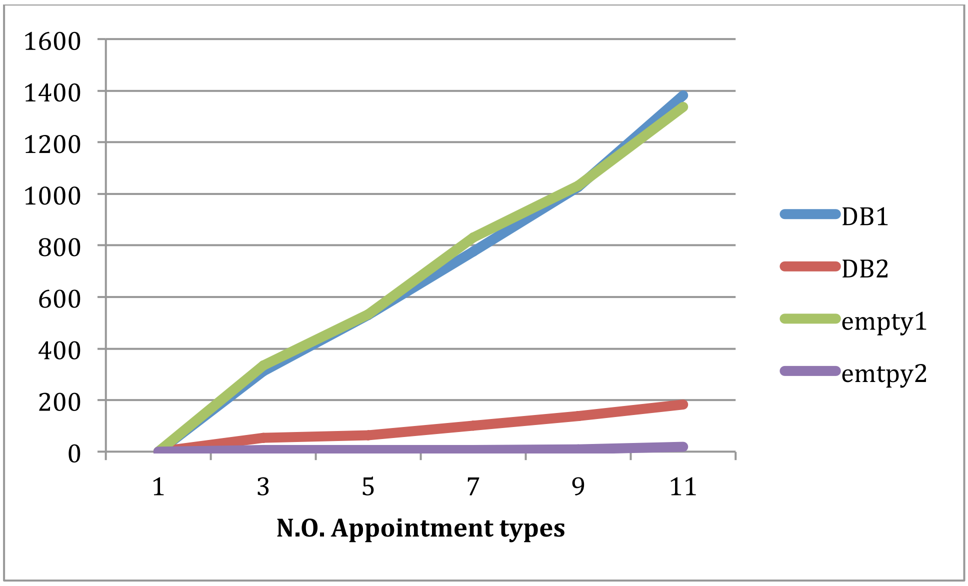

FIGURE 34, SENSITIVITY NUMBER OF APPOINTMENT TYPES

In Figure 34 the number of appointment types is varied, with standard deviation = 0. This explains why with 1 appointment type the number of exceedances = 0 for all thresholds. With a rising number of specific appointment types, extra waiting queues are created in the system. Every extra appointment type virtually creates an extra queue with their specific patients. These are created randomly and therefore create variance in the system, which leads to an increasing number of exceedances.

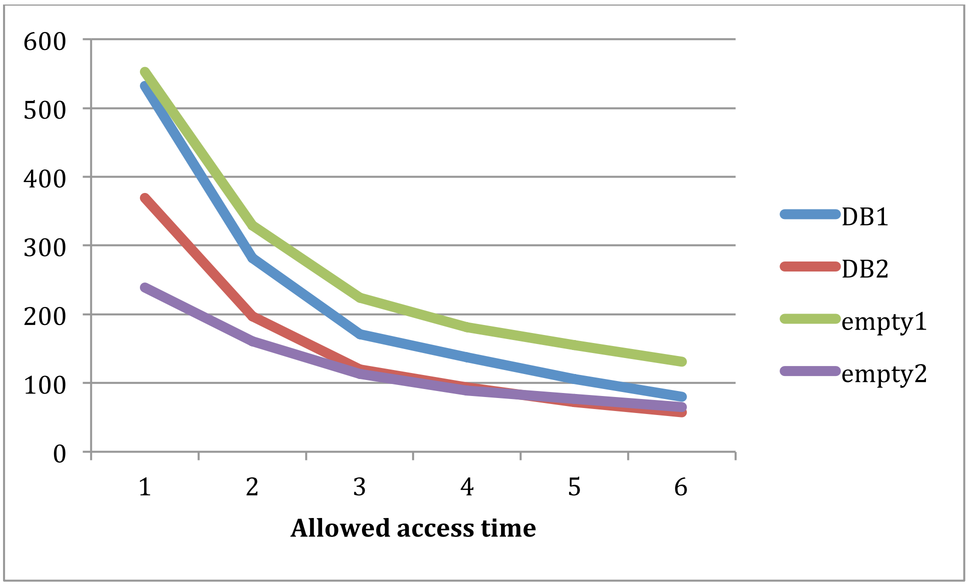

FIGURE 35, SENSITIVITY ALLOWED ACCESS TIME

In Figure 35 the allowed access time is varied with arrival SD = 10. The allowed access time can be viewed as the space in which the patient arrival number is allowed to vary. From 1 to 2 days, this space increases with 100%, from 2 to 3 days with 50 %, from 3 to 4 days with 33% etcetera. This can explain the exponential nature of the graph.

In conclusion, it is safe to state that the model is verified through varying different parameters and test whether the results are sound based on logic reasoning.

Sensitivity runs for estimated parameters

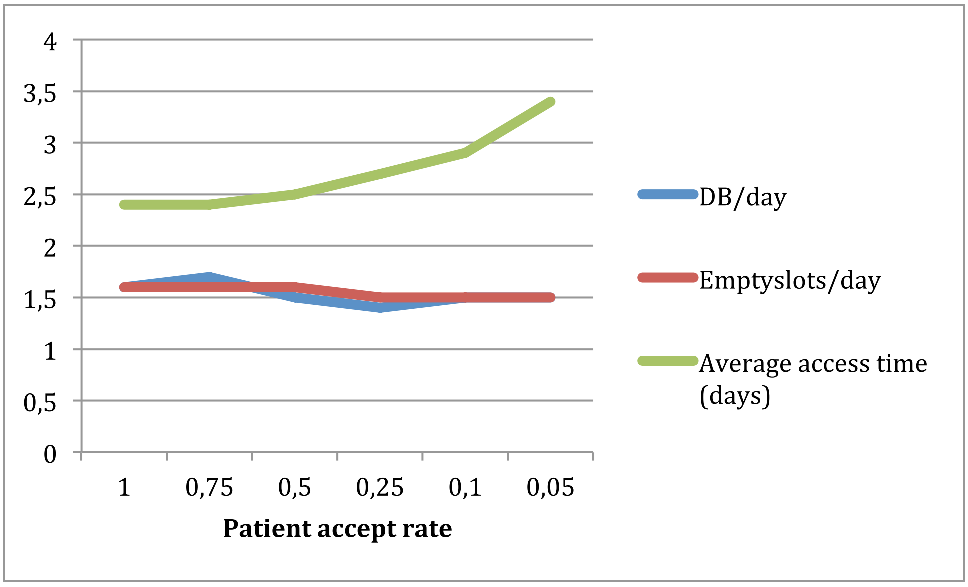

FIGURE 36, SENSITIVITY FOR APPOINTMENT ACCEPTANCE BY PATIENTS, ESTIMATED REAL VALUE = 0,6

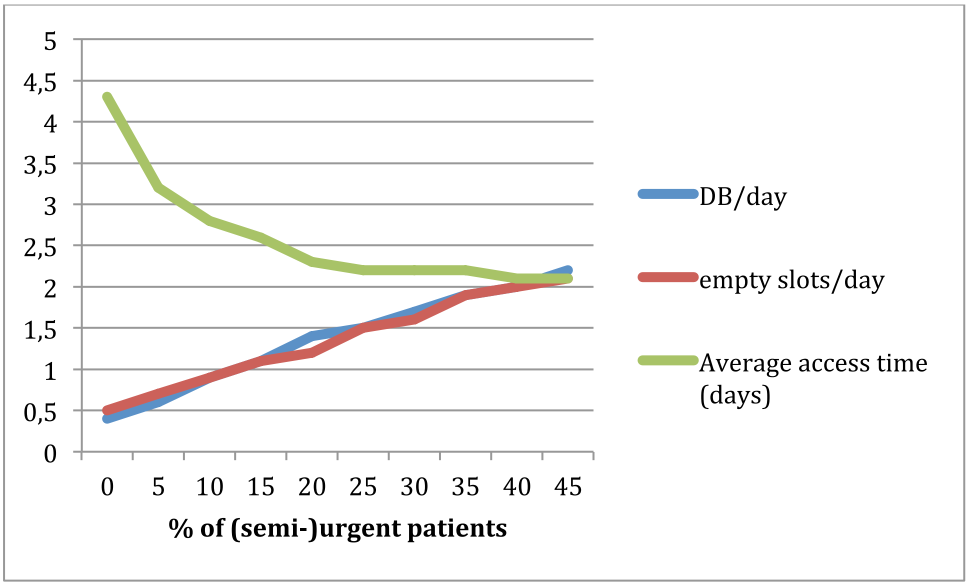

FIGURE 37, SENSITIVITY FOR PERCENTAGE OF (SEMI-)URGENT PATIENTS, ESTIMATED REAL VALUE = 0,15

Simulation: verification for normality

We want to see what the daily arrival rate of appointment requests is, and whether the assumption of normality is valid. In the system we cannot see when patients call for an appointment, but we can see when an appointment is made: time and date. Unfortunately, the current practice in the lung clinic needs to wait for triage before making an appointment, after triage all these appointments are made at once. This data does not give accurate information on the arrival of appointment requests.

It seems a reasonable assumption that daily arrival of appointment requests follows a general pattern that does not differ per clinic. In this case, we can test for another clinic --without triage- whether appointment request arrival follows a normal distribution. We therefore test this at the gynaecology clinic during the period October 2016-March 2017. In total these are 141 measurement points.

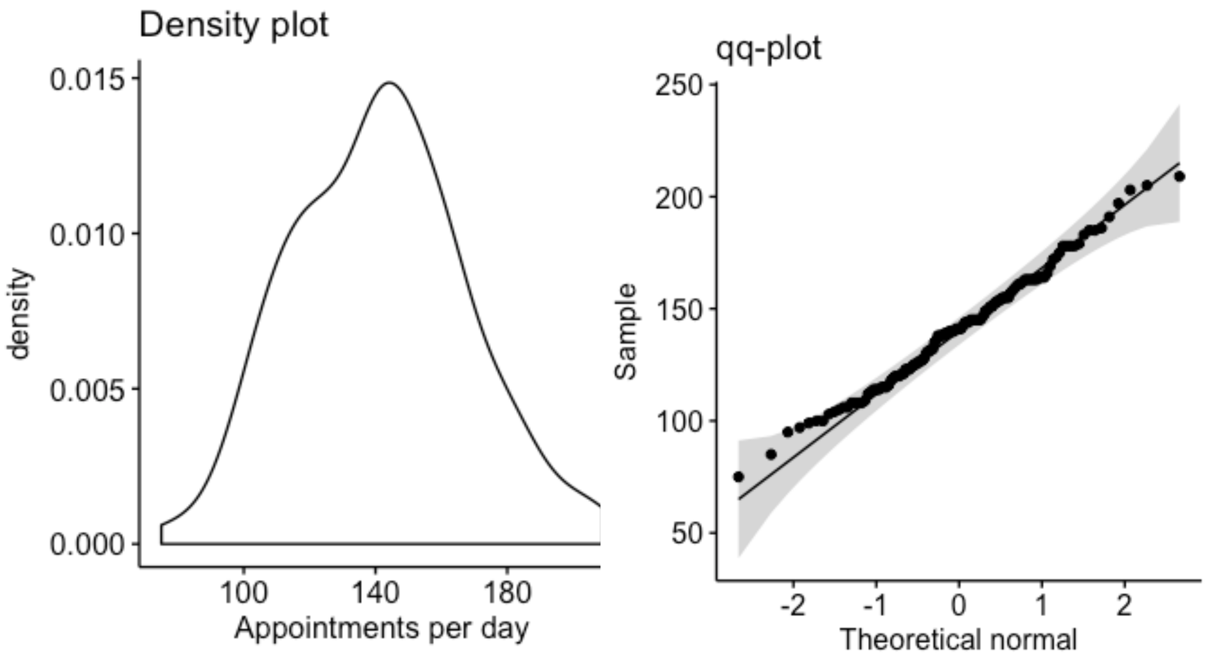

FIGURE 38, L: DENSITY PLOT OF THE APPOINTMENT REQUESTS PER DAY AT GYNAECOLOGY, R: QQ-PLOT OF REQUEST DISTRIBUTION VERSUS THEORETICAL NORMAL DISTRIBUTION

First, we inspect the distribution visually, afterwards a Shapiro-Wilk normality test is performed. From the visual inspection the density plot shows a graph in Figure 38 that could resemble a normal function, given the bell-shape of the graph. On the right side a Quantile-quantile plot is drawn, connecting the quantiles of the sample set to the quantiles of a perfect normal distribution. If the sample set were perfectly normal distributed we would expect the dots to be on a straight line, which is drawn for visual support. We see that the dots lie fairly in a straight line, indicating that the sample set might be best reflected by a normal distribution. Visual inspection cannot give a definite answer however; therefore a Shapiro-Wilk normality test is performed. The output of this test gives a p-value of 0.67. With this p-value larger than 0.05, we cannot reject the hypothesis that the sample comes from a population which has a normal distribution. Combining this result with the outcome of the visual inspection, we assume that the daily arrival of appointment requests is normal for the input of our model.

APPENDIX F: MULTI CRITERIA DECISION ANALYSIS

Weight changed	Changed to	Traditional	Carve-out	Advanced Access
Production goal	0,27	0,34	0,35	0,40
Production goal	0,07	0,26	0,27	0,37
Cancellations	0,27	0,33	0,34	0,43
Cancellations	0,07	0,27	0,28	0,34
IWT	0,27	0,32	0,35	0,43
IWT	0,07	0,28	0,27	0,35
Utilization	0,26	0,34	0,34	0,43
Utilization	0,06	0,27	0,29	0,34
Access time	0,25	0,33	0,33	0,44
Access time	0,05	0,27	0,30	0,33
Overtime(WD)	0,19	0,34	0,35	0,40
Overtime(WD)	0,0	0,26	0,28	0,37
Overtime(WH)	0,19	0,32	0,33	0,45
Overtime(WH)	0,0	0,28	0,28	0,35

TABLE 22, VARYING CRITERIA WEIGHTS; SENSITIVITY ANALYSIS OF MCDA

Stakeholder criteria	Traditional	Carve-out	Advanced Access
Doctor	0,33	0,34	0,33
Hospital	0,31	0,32	0,38
Patient	0,26	0,27	0,45

TABLE 23, MCDA ANALYSIS OF SINGLE STAKEHOLDER CRITERIA WEIGHTS

Criterion	Weight factor	Traditional	Carve-out	Advanced Access	Walk-in
Production goal	0,17	0,8	0,8	0,4	0,4
Cancellations	0,17	0,4	0,4	0,6	0,8
Internal waiting time	0,17	0,4	0,8	0,8	0
Utilization of doctors	0,16	0,4	0,2	1	0
Access time	0,15	0,4	0,2	0,6	1
Overtime (WD)	0,09	0,8	0,8	0,4	0,2
Overtime (WH)	0,09	0,4	0,8	0,8	0
Normalized weighted score	-	0,24	0,26	0,34	0,16

TABLE 24, MCDA VERIFICATION; ADDITION OF FOURTH STRATEGY

APPENDIX G: SUCTION EFFECT IN-VIVO RESEARCH

In the research of van der Voorde the production of the clinics was monitored in the first year of application of advanced access. In fourteen clinics, the average access time improved from 47 to 21 days. The increase in production, in terms of number of new patients, was on average 10,1% in the first year. This production increase is considered a combination of the backlog elimination as well as the suction effect*.

With the actual backlog elimination given, the suction effect can be calculated. The average backlog elimination in the clinics was *47 – 21 = 26* days. Over the yearly total, this means an average extra production of *26/365 * 100% = 7,1 %.* The rest of the production increase is then *10,1 – 7,1 = 3,0%.* The average suction effect of the fourteen clinics therefore was 3,0% in the first year of the project, given an decrease of 26 days of access time, which is nearly four weeks.

To show how a 3,0 % increase can be compensated for by increased efficiency through advanced access, we take a practical example in the lung clinic. In this clinic, on average there are seven doctors at work at seven outpatient shifts per week, or 49 shifts in total per week. On average there are twelve patients per shift of three hours, which gives a total of *49*12 = 590 patients per week*. This means a total of *590/2,6 = 225 new patients per week*, as the check-up/new patients ratio is 1,6. These new patients referrals need to be triaged in the current situation. According to triaging doctors, it takes on average 1,5 minutes to fill out such a triage form. This means that triaging doctors spend *1,5*225 = 340 minutes per week* for triaging new patients, or 5,5 hours. This figure comes close to what doctors say they spend on triaging.

On average *3*7 = 21 hours* are spent on consulting outpatient clinics per doctor per week, or a total of *7*21 = 147* hours per week. If triage based on urgency could be eliminated because of an access time of one week, this means that *5,5/147 * 100 % = 3,7%* could be spent more productively. If we go back to the first conclusion that an average suction effect of 3,0 % with an access time gain of four weeks, we can now conclude that for the lung clinic this suction effect can be more than compensated for by the reduction in triage time by the doctors.

* A third effect could be a general annual increase or decease of patients. The only information found on this subject is a gradual increase of hospitalized patients nationally in the years of research. Since this does not have to be true for the investigated clinics, these figures are not taken into account

APPENDIX H: DELPHI CODE

```
unit Unit2;

interface

uses
  Winapi.Windows, Winapi.Messages, System.SysUtils, System.Variants, System.Classes, Vcl.Graphics,
  Vcl.Controls, Vcl.Forms, Vcl.Dialogs, tomas, Vcl.StdCtrls, VclTee.TeeGDIPlus,
  VCLTee.TeEngine, VCLTee.Series, Vcl.ExtCtrls, VCLTee.TeeProcs, VCLTee.Chart;

type
  TForm2 = class(TForm)
    Button1: TButton;
    Button2: TButton;
    Memo1: TMemo;
    Memo2: TMemo;
    Memo3: TMemo;
    Memo4: TMemo;
    Label1: TLabel;
    Label2: TLabel;
    Label3: TLabel;
    Label4: TLabel;
    Label5: TLabel;
    Label6: TLabel;
    Label7: TLabel;
    Label8: TLabel;
    Label9: TLabel;
    Label10: TLabel;
    Label11: TLabel;
    Edit1: TEdit;
    Edit2: TEdit;
    Edit3: TEdit;
    Edit4: TEdit;
    Edit5: TEdit;
    Edit6: TEdit;
    Edit7: TEdit;
    Edit8: TEdit;
    Memo5: TMemo;
    Memo6: TMemo;
    Label12: TLabel;
    Label13: TLabel;
    Chart1: TChart;
    Series1: TLineSeries;
    Series2: TLineSeries;
    procedure Button1Click(Sender: TObject);


  private
    { Private declarations }
  public
    { Public declarations }
  end;

  {predefenition of classes}

  TGeneratePatient = class;
  TPlanPatient = class;
  TDoctor = class;
  TPatient = class;
  TWrite = class;
```

```
  TAnnulering = class;
  TPlanAnnulering = class;

  {detailed defenition of classes}

  TGeneratePatient = class(TomasElement)
    NewPatient: TPatient;
    Patient : TPatient;
    PatientTypeDistribution: TUniformdistribution;
    NrOfPatientsPerDay: TNormalDistribution;
    PatientQ: TomasQueue;
    NewAnnulering: TAnnulering;
    AnnuleringQ: TomasQueue;
    published
    Procedure Process; override;
  end;

  TPlanPatient = class(Tomaselement)
    public
    MyPatient : TPatient;
    PatientType : integer;
    PatientQ: TomasQueue;
    Patient: TPatient;
    published
    Procedure Process; override;
  end;

  TPlanAnnulering = class(TomasElement)
    public
    MyAnnulering: TAnnulering;
    AnnuleringQ: TomasQueue;
    published
    Procedure Process; override;
  end;

  TAnnulering = class(TomasElement)
    public
  end;

  TPatient = class(TomasElement)
        public
        PatientType: Integer;
        end;

        TWrite = class(TomasElement)
          public
          NuPatient: TPatient;
          published
          procedure Process; override;
       end;

       TDoctor = class(TomasElement);





      {All global variables are declared here}
      var
        Form2: TForm2;
        a,x,y, Runtime: Integer;
        b: Integer;
        c: Integer;
        i, Ptype, Atype, NOAfspraakTypes: Integer; //1.2.3.-1. etcetra
        d: real; //1.2, 3.4, -2.334  etcetera
        s, sk, sl: string;
```

```
        ch: Char;
        multiarray: Array of Array of Array of Array of byte;
        AccessTimes : Array of integer;
        DoubleBookings: Array of integer;
        EmptySlots: Array of integer;
        j,h,k,m,p, day, Annulering, lookday, NOpatients, Accesstimeday, Patientteller, TotalDB, Totalempty, Filldays, Arts, Urgentday, AllowedAccess: integer;
        Lengthi, Lengthj, Lengthk, Lengthm, PatientsPerDay, PatientsPerWeek, WithinDays, threshold1empty, threshold2empty, threshold1db, threshold2db: integer;
        Pctgevuld, AVAC: Single;
        Isplanned, IsCP, Patientreject, IsCancelled: Boolean;
        AcceptRate, CPFactor, Artss, Urgentrate: Double;
        PtypeS, ATypeS, PatientAccept, CPrate, Totalaccess, AverageAccess, AverageDB, AverageEmpty: Single;
        Footnokkel : TNormalDistribution  ; // Store text
        MyFile : Textfile;
        Generator: TgeneratePatient;
        PatientPlanner: TPlanPatient;
        AnnuleringPlanner: TPlanAnnulering;
        Writer: TWrite;



      implementation
      {$R *.dfm}

       Procedure TGeneratePatient.Process;
       begin
        while TNow < Runtime do
        begin
          for i := 0 to patientsperday-1 do
          begin
          NewPatient := TPatient.Create('Patient');
          NewPatient.PatientType := Round(PatientTypeDistribution.Sample);

          PatientPlanner.PatientQ.AddToTail(NewPatient);
          end;
          hold(1);
          showmessage(inttostr(patientsperday));
          Annulering := round(random*0.06*PatientsPerDay);//0*(round(random*AllowedAccess));
          for i := 0 to Annulering do
          begin
            NewAnnulering := TAnnulering.Create('Annulering');
            AnnuleringPlanner.AnnuleringQ.AddToTail(NewAnnulering);
          end;
              day := round(Tnow);
              y:= Doublebookings[Day-1];
        form2.Series1.AddXY(TNow, y);
        accesstimeday := 0;
          for i := (day-1)*patientsperday to day*patientsperday do
          accesstimeday := accesstimeday + accesstimes[i];
          AVAC := accesstimeday/patientsperday;
          form2.Series2.AddXY(Day,AVAC);
        end;
       end;



      Procedure TPlanPatient.Process;
      begin
        while TNow < Runtime do
        begin
          while PatientQ.Length = 0 do StandBy;
```

```
            Day := round(TNow);
            MyPatient:= PatientQ.FirstElement;
            Isplanned := false;
            Lookday := Day+1;
            patientteller := patientteller + 1;
            Patientreject := False;
            Withindays := AllowedAccess-1;
            PTypes := 0.5+(NOAfspraaktypes*random);    //Patiententypes is nu 1tm5 random mogelijk
            Ptype := round(PtypeS) ;
            CPRate := random;    // Welke patienten zijn CP's
            IsCP := False;    //Als CP is True dan kijk pas 4 dgn verderop in het schema
            if CPRate < CPFactor then begin
            IsCP := True;
            Artss := (lengthm*random) - 0.5  ;
            Arts := round(Artss);
            Withindays := 5;
            Lookday := Day + 14; end
            else begin
            IsCP := False;
            Urgentrate := random;
            if Urgentrate<0.15 then begin
            Urgentday := round(0.5 + random*5);
            Withindays := Urgentday;
            end;
            end;
            for j := 0 to lengthj-1 do
            begin
             for i := 0 to lengthi-1 do
             begin
             Patientaccept := random;
               for m := 0 to lengthm-1 do
                begin
                   if ((IsCP = True) and not (Arts = m))  then Continue;
                   if not (multiarray[i,j,m,1] = 0) then
                  // else if not (multiarray[i,j,3,m] = 1) then
                   else if not (multiarray[i,j,2,m] = PType) then
                   else
                   begin
                   if patientaccept < acceptrate then
                     begin
                       Isplanned := True;
                       multiarray[i,j,m,1] := 1;
                       PatientQ.Remove(MyPatient);
                       Break;
                     end
                     else
                       Patientreject := TRUE;
                   end;
                   if (IsCP = False) and (j = (LookDay + Withindays)) and (i = lengthi-1)  and (m = (Lengthm - 1)) and (Patientreject = False) and (Isplanned = False) then
                   begin
                     DoubleBookings[j] := DoubleBookings[j]+1;
                     AccessTimes[Patientteller] := j-day;
                     Isplanned := True;
                   end;
                   if (IsCP = True) and (j = (LookDay + withindays)) and (i = lengthi-1) and (Patientreject = False) and (Isplanned = False) then
                   begin
                     DoubleBookings[j] := DoubleBookings[j]+1;
                     AccessTimes[Patientteller] := j-day;
                     Isplanned := True;
                   end;
```

```
                end;
                if Isplanned = True then begin Break;
                end
                else Continue;
             end;
             if Isplanned = True then begin Break;
             end
             else Continue;
            end;
         end;
       end;

       Procedure TPlanAnnulering.Process;
       begin
         while TNow < Runtime do
         begin
           while AnnuleringQ.Length = 0 do Standby;
           MyAnnulering := AnnuleringQ.FirstElement;
           IsCancelled := False;
            for j := day to lengthj-1 do begin
             for m := 0 to lengthm-1 do begin
              for i := 0 to lengthi-1 do begin
               if(multiarray [i,j,1,m] = 1) then begin
                 multiarray[i,j,1,m] := 0;
                 Iscancelled := True;
                 AnnuleringQ.Remove(MyAnnulering);
                 Break; end Else
               end; if Iscancelled = True then begin Break; end
                    else Continue;

             end; if Iscancelled = True then begin Break; end
                    else Continue;
            end;
           end;
       end;

       Procedure TWrite.Process;
       begin
          while TNow < Runtime do begin
          hold(1);

            if lengthj< 31 then
            form2.Memo1.Clear;
            begin
             for i := 0 to (Lengthi-1) do
             begin
               s:= ''  ;
               for j := 0 to (Lengthj-1) do
               begin
                 s := s + ' ' + IntToStr(multiarray[i,j,1,1]);
               end;
               form2.Memo1.Lines.Add(s);
             end;
            end;

            begin
             for i := 1 to Patientteller do
             begin
               s := IntToStr(AccessTimes[i]);
               Totalaccess := Totalaccess + AccessTimes[i];
               Form2.Memo2.Lines.Add(s);
             end;
            end;

             begin
               for j := 0 to Day-1 do
```

```
              begin
              s := IntToStr(DoubleBookings[j]);
              if DoubleBookings[j] > 5 then
                threshold1DB := threshold1DB + 1 ;
              if DoubleBookings [j] > 15 then
                threshold2DB := threshold2DB + 1;
              TotalDB := TotalDB + DoubleBookings[j];
              Form2.Memo3.Lines.Add(s);
              end;
        end;


        for i := 0 to (lengthi-1) do
          for j := 0 to Day-1 do
            for m := 0 to (lengthm-1) do
              if (multiarray[i,j,1,m] = 0) and (multiarray[i,j,3,m] = 1) then
              begin
              Emptyslots[j] := Emptyslots[j]+1
              end;

        begin
        Totalempty := 0;
          for j := 0 to Day-1 do
              begin
                s := IntToStr(Emptyslots[j]);
                if emptyslots[j] > 5 then
                threshold1empty := threshold1empty + 1 ;
                if emptyslots [j] > 10 then
                  threshold2empty := threshold2empty + 1;
                  TotalEmpty := TotalEmpty + Emptyslots[j];
                  Form2.Memo4.Lines.Add(s);
              end;
        end;

        // Write results: Access time, Doublebookings, Empty slots
        AverageAccess := Totalaccess/PatientTeller ;
        {Form2.label4.Caption := 'Average accesstime =' + formatfloat('0.0', AverageAccess); }


        AverageDB := TotalDB/Day ;
        Form2.label12.Caption := 'Doublebookings/day =' + formatfloat('0.0',AverageDB);

        AverageEmpty := TotalEmpty/Day;
        Form2.Label13.Caption :=  'Empty slots/day =' + formatfloat('0.0', AverageEmpty);

        Form2.Memo6.Lines.Add('empty threshold 1 exceeded ='+ formatfloat('0.0' ,(100*threshold1empty/lengthj))+'%') ;
        Form2.Memo6.Lines.Add('empty threshold 2 exceeded =' +formatfloat('0.0', (100*threshold2empty/lengthj))+'%') ;

        Form2.Memo5.Lines.Add('DB threshold 1 exceeded ='+ formatfloat('0.0', (100*threshold1DB/lengthj))+'%') ;
        Form2.Memo5.Lines.Add('DB threshold 2 exceeded =' +formatfloat('0.0', (100*threshold2DB/lengthj))+'%') ;

        begin
        Assignfile(myfile, 'Test.csv');
        ReWrite(myFile);
        begin
          for j := 0 to Day-1 do
              begin
              sk := sk + IntToStr(Emptyslots[j])+ ';';
```

```
                    end;
                end;
                begin  for j := 0 to Day-1 do
                    begin
                    sl := sl + IntToStr(DoubleBookings[j])+ ';';
                    end;
                end;

                WriteLn(myfile, sk);
                WriteLn(myfile, sl);
                Closefile(myfile);
                end;

            end;
        end;








        Procedure InitializeHagaSim;
        begin
        Runtime := 30;
        Lengthi := 36;
        Lengthj := Runtime;
        Lengthk := 7 ;
        Lengthm := 2 ;
        PatientsPerDay := (lengthm*lengthi);//round(lengthi*(3/7) * lengthm);

        Setlength(multiarray, Lengthi, Lengthj, Lengthk, Lengthm);
        Setlength(AccessTimes, (lengthj*PatientsPerDay)+10000);
        Setlength(DoubleBookings, lengthj);
        Setlength(Emptyslots, lengthj);
        Patientteller := 0;
        Totalaccess:= 0;
        TotalDB := 0;
        Withindays := 8;
        NOAfspraakTypes := 1;
        CPFactor := 0;
        Filldays := 0;
        Acceptrate := 1;
        Threshold1empty := 0;
        Threshold2empty := 0;
        Threshold1DB := 0;
        Threshold2DB := 0;
        Footnokkel := TNormalDistribution.Create(821371, patientsperday, 18*sqrt((lengthm)));
        for I := 0 to (Lengthj-1) do        // Moet op 0 to DAY voor grote aantallen voor betere output
        begin
          Doublebookings[I]:= 0;
        end;

        for I := 0 to (Lengthj-1) do
        begin
          Emptyslots[I]:= 0;
        end;

         for i := 0 to (Lengthi-1) do
           for j := 0 to (Lengthj-1) do
              for k := 0 to (Lengthk-1) do
                for m := 0 to (Lengthm-1) do
             begin
```

```
           multiarray[i,j,k,m] := 0;
         end;



    for i := 0 to (Lengthi-1) do
      for j := 0 to (FillDays-1) do
          for m := 0 to (Lengthm-1) do
         begin
           multiarray[i,j,1,m] := 1;
         end;




    for i := 0 to (Lengthi-1) do
      for j := 0 to (Lengthj-1) do
        for m := 0 to (Lengthm-1) do
      begin
       AtypeS := 0.5+NOAfspraaktypes*random;
       Atype := Round(ATypeS);
       multiarray[i,j,2,m] := Atype;
      end;

    begin
     for i := 0 to round((Lengthi/2)-1) do
       for j := 0 to (Lengthj-5) do
            if round(j/5) = j/5 then
            begin
              multiarray[i,j,3,0] := 1;
              multiarray[i,j,3,5] := 1;
              multiarray[i,j,3,6] := 1;
              multiarray[i,j+1,3,3] := 1;
              multiarray[i,j+1,3,5] := 1;
              multiarray[i,j+2,3,1] := 1;
              multiarray[i,j+2,3,2] := 1;
              multiarray[i,j+2,3,3] := 1;
              multiarray[i,j+2,3,4] := 1;
              multiarray[i,j+3,3,0] := 1;
              multiarray[i,j+3,3,5] := 1;
              multiarray[i,j+4,3,2] := 1;
              multiarray[i,j+4,3,1] := 1;
              multiarray[i,j+4,3,4] := 1;
              multiarray[i,j+4,3,6] := 1;
            end;
    end;


    begin
     for i := round((Lengthi/2))to Lengthi-1 do
       for j := 0 to (Lengthj-5) do
            if round(j/5) = j/5 then
            begin
              multiarray[i,j,3,1] := 1;
              multiarray[i,j,3,2] := 1;
              multiarray[i,j,3,3] := 1;
              multiarray[i,j+1,3,5] := 1;
              multiarray[i,j+2,3,0] := 1;
              multiarray[i,j+2,3,1] := 1;
              multiarray[i,j+2,3,6] := 1;
              multiarray[i,j+2,3,3] := 1;
              multiarray[i,j+2,3,4] := 1;
              multiarray[i,j+3,3,0] := 1;
              multiarray[i,j+3,3,5] := 1;
              multiarray[i,j+4,3,2] := 1;
              multiarray[i,j+4,3,1] := 1;
```

```
                multiarray[i,j+4,3,4] := 1;
                multiarray[i,j+4,3,6] := 1;
              end;
      end;


        Generator:= TGeneratePatient.Create ('Generator');
        Generator.NrOfPatientsPerDay := TNormalDistribution.Create(520623, patientsperday, 5);
        Generator.PatientTypeDistribution := TUniformDistribution.Create(520522, 1, 5);
        Generator.Start(TNow);
        PatientPlanner := TPlanPatient.Create('PatientPlanner');
        Patientplanner.PatientQ := Tomasqueue.Create('PatientQueue');
        PatientPlanner.Start(TNow);
        Writer := TWrite.Create('Writer');
        Writer.Start(TNow);
        AnnuleringPlanner := TPlanAnnulering.Create('AnnuleringPlanner');
        AnnuleringPlanner.AnnuleringQ := Tomasqueue.Create('AnnuleringQueue');
        AnnuleringPlanner.Start(TNow);

        end;





      procedure TForm2.Button1Click(Sender: TObject);
      begin
            TomasForm.Trace:=True;
            TomasForm.StepMode:=False;
            startsimulation;
            if form2.Edit8.GetTextLen > 0 then
            Runtime := strtoint(form2.Edit8.Text);
                  if form2.Edit1.GetTextLen > 0 then
            Lengthk := strtoint(form2.Edit1.Text);
                  if form2.Edit2.GetTextLen > 0 then
            NOafspraaktypes := strtoint(form2.Edit2.Text);
                  if form2.Edit3.GetTextLen > 0 then
            CPfactor := strtoint(form2.Edit3.Text);
                  if form2.Edit4.GetTextLen > 0 then
            Acceptrate := strtoint(form2.Edit4.Text);
                  if form2.Edit5.GetTextLen > 0 then
            Withindays := strtoint(form2.Edit5.Text);
                  if form2.Edit6.GetTextLen > 0 then
            Urgentrate := strtoint(form2.Edit6.Text);
      end;

      initialization
        InitializeHagaSim;
      end.
```