Happy ENT: Assessing and Improving Efficiency of the UMCU ENT Outpatient Clinic

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Management Summary

The Ear, Nose and Throat-department (ENT) of University Medical Center Utrecht (UMCU) experiences long waiting times for patients, as well as high idle time and overtime for doctors at the ENT outpatient center. The management of the department believes that the number of patients seen at the outpatient clinic will increase in the future. However, increasing patient numbers without changing the way of working will also increase the experienced waiting time and overtime. The main area that has been identified by the management as opportunity for decreasing these waiting times, idle time and overtime is the patient and staff scheduling at the outpatient clinic. In order to find ways to achieve the desired improvements, this study aims to quantify the current performance, and identify and prospectively assess interventions to the patient and staff scheduling systems.

In the current situation, appointments are scheduled based on the *individual block, variable-interval* rule. This means that no more than one patient is scheduled for a given appointment time for a given doctor, and that appointment intervals vary based on the appointment classification. These appointment classifications are also used for sequencing patients at the time of booking the appointment. Appointment times for patients are not adjusted for patients that will be seen by a medical student. The outpatient clinic utilizes a daily walk-in session, for which a single doctor is responsible.

The current consultation and appointment scheduling systems result in an average doctor's idle time of 38 minutes per session, with empty appointment slots and desirable interconsultation time (time not spent usefully, but not on a patient directly) as main reasons. The average overtime for doctors is approximately 18 minutes, with peaks of up to an hour. The average patient's waiting time is 10 minutes, with 73% of patients being seen within 15 minutes. The walk-in doctor spends only 41% of the walk-in session duration treating walk-in patients.

With the aim of improving the performance of the current scheduling system, we have developed a computer simulation program of ENT's consultation processes with new, return, and walk-in patients. We use this simulation program to evaluate the following experimental factors:

- Appointment rule (4 variants);
- Patient sequence (4 variants);
- Sharing new patients among doctors;
- Sharing walk-in patients among doctors;
- In the case of shared walk-in patients, scheduling empty appointment slots for walk-in patients;
- Improving the doctors' punctuality;
- Adjusting appointment times for medical student appointments.

We examine all combinations of these experimental factors, leading to a total of 384 different configurations. Since sharing walk-in patients among doctors leads to a change in input (there is one fewer doctor to see patients), we differentiate between configurations that do and those that do not share walk-in patients. In order to determine which configurations are the best, we evaluate their performances based on the performance indicators waiting time, idle time and overtime.

This analysis leads to two configurations that are fully efficient and offer balanced improvements for the configurations with a walk-in doctor, and one fully efficient and balanced configuration for those that share walk-in patients. The following table shows these configurations and their output, along with the results of the base scenario for comparison. Further explanation of terminology follows after the table:

Input	Experiment number	Appointment Rule	Patient Sequence	Share New Patients	Doctor's Punctuality	Med. Student Appointments	Share Walk-ins	Empty Slots for Walk-ins
	62	Dome	NPP Late*	False	Impr.	True	False	False
	64	IAI**	NPP Late*	False	Impr.	True	False	False
	320	IAI**	NPP Late*	False	Impr.	True	True	True
	1	*Base*	*Base*	*False*	*Current*	*False*	*False*	*False*

Output	Experiment number	% Wait < 15 min.	Waiting time	Idle time	Overtime	Walk-in waiting time	Relative Doctor's Performance	Relative Waiting time
	62	77%	09:07	38:49	15:32	11:19	79%	94%
	64	84%	06:55	45:47	18:33	11:58	94%	71%
	320	77%	09:27	31:41	25:53	09:02	95%	97%
	1	*75%*	*09:44*	*42:16*	*22:55*	*11:51*	*100%*	*100%*

% Wait < 15 min is the percentage of scheduled patients with waiting time under 15 minutes

Waiting time = max(0,appointment start time - max(appointment time, patient's arrival time))

Idle time = (realized session finish time - doctor's arrival time) - sum of time spent on patients

Overtime = max(0,realized session finish time - expected session finish time)

*Relative doctor's performance = (2*overtime + idle time) / (2*overtime(base scenario) + idle time (base scenario))*

Relative waiting time = waiting time / waiting time (base scenario)

Input and output of most efficient and balanced configurations and explanations of performance indicators. *NPP Late is late new patient pool. **IAI are improved appointment intervals. Given the nature of the relative doctor's performance and relative waiting time, both improve with a lower score.

The appointment rule Dome works by compressing the appointments at the start and finish of the consultation session, and giving some appointments in the middle of the session a little more time. The improved appointment intervals (IAI) is based on the fact that return patients are currently scheduled for 10 minutes, but take on average almost 14 minutes. With the IAI-rule, the appointment intervals of return patients alternate between 10 and 15 minutes.

The patient sequence of the late new patient pool schedules all return patients at the start of the session and all new patients at the end of the consultation session. None of the selected, most efficient configurations share new patients. In the current situation doctors tend to start their consultation sessions late. All selected configurations have an improved doctor's punctuality, which was tested as the doctor being on average 5 minutes early. For the medical student appointments, some new patients receive an appointment that is 10 minutes earlier than the actual doctor's appointment, reserved for the medical students to be able to see these new patients.

For Experiment 320, where walk-in patients are shared among the already available general doctors and the walk-in session is no longer used, a total of five empty slots are scheduled over these doctors' consultation sessions, to give them the possibility to treat walk-in patients. This, however, does mean that there are fewer appointment slots available for scheduled patients per consultation session; in order to achieve the same production level as the current situation with the same amount of consultation sessions, 99% of appointment slots have to be booked.

A sensitivity analysis shows that especially configuration 64 is robust against changes in utilization of the consultation sessions. Experiments 62 and 64 remain efficient when the relative importance of idle time and overtime changes in the calculation of RDP. All experiments 62, 64 and 320 have a higher sensitivity of overtime for the attendance of medical students, because the new patients, which are also seen by medical students, are scheduled for the end of the consultation session.

Given these model results, we recommend to implement the configuration of experiment 64, which drastically improves patient waiting time and overtime at the cost of a small increase in idle time. A sensitivity analysis shows that this scheduling system is better able to deal with a 10% increase in scheduled utilization than the other configurations and the current scenario.

PREFACE

The document that you are currently reading is my master's thesis. It is the final result of the research that I have been conducting the last six months for the ENT outpatient clinic of UMCU. For me personally, this document also marks the end of my time at the University of Twente. After six and a half years, where I started with a bachelor's in civil engineering, continued with a master's in production logistics and finally ended up in the hospital, I can look back on a time well spent, where I have made friends that I hope to keep for a long time.

As, probably, all graduating and graduated students can confirm, you get a lot of help from a lot of people throughout your research. Some of this is worth mentioning. Therefore:

Erwin, thanks for your support and help with this research. Although I may have spent some time waiting for you at an appointment, I always had the feeling that you took as much time for me as I needed. I would like to thank you as well for the amicable feedback sessions, it is much easier to handle criticism when it is accompanied by some laughter. Ingrid, thanks for the much appreciated feedback.

Hans and Ivonne, thank you for the times you spent with me, the long meetings, and all the confidence you had in me. I would also like to thank all the doctors and the MAAZen for their help with my research, their advice, and for all the laughter and interesting conversations.

I also like to use this opportunity to thank my girlfriend, Diana, for her continued love and support these past 6 years. I know this can't have been a small achievement. I would also like to thank my parents, who have always been there for me when I needed them, and are even there for me when I don't. And, lastly, I would like to thank everybody that feels left out because I did not mention them in these acknowledgements. Don't think for a moment that I am not grateful for your help, whatever it was.

I recently learned that the recommendations from this research will be implemented at the outpatient clinic with a pilot study. This was great news to hear, and I sincerely believe that this will help improve the clinic.

Finally, I would like to finish this preface with some good advice for any readers enjoying the pleasure of writing their own thesis. To use the words of Douglas Adams, as he so eloquently put it in his timeless trilogy of the Hitchhiker's Guide to the Galaxy: Don't panic.

Koen van Stek

Amsterdam, March 2015

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1. INTRODUCTION

The Ear, Nose and Throat-department (ENT) of University Medical Center Utrecht (UMCU) experiences long waiting times for patients, as well as high idle time and overtime for doctors at the ENT outpatient center. The main area that has been identified by the management as opportunity for decreasing these waiting times, idle time and overtime is the patient and staff scheduling at the outpatient clinic. In order to find ways to achieve the desired improvements, this study aims to quantify the current performance, and identify and prospectively assess interventions to the patient and staff scheduling systems.

This chapter discusses the context of the ENT outpatient clinic and UMCU in Paragraph 1.1 and continues with the scope of the research, a problem description and the goal of the research in Paragraphs 1.2, 1.3 and 1.4. The chapter concludes by presenting the research questions used in this research in Paragraph 1.5.

1.1. CONTEXT

The UMCU is one of the largest of the Netherlands' eight university hospitals, with over 11,000 employees and more than 125,000 individual patients at its outpatient centers in 2012 (UMCU, 2013).

One of UMCU's departments is ENT. This department consists of a nursing ward, a function center, and an outpatient clinic. The nursing ward is for patients that have to undergo surgery. The operating rooms where surgeries are performed are not part of ENT. At the function centre patients can undergo several tests. This is often combined with a visit to the outpatient clinic, so the function centre is located near the outpatient clinic. The outpatient clinic of ENT is the focus of this research. It is used for medical consultations with both new patients that have not yet started their treatment and patients that need to be seen during or after a treatment. Besides eight rooms for medical consultation, the outpatient clinic houses two treating rooms where small surgeries are performed. The ENT outpatient clinic this research focuses on is only for adults. Children under the age of 18 are treated in the children's hospital that is located in an adjacent building.

Figure 1 shows a generalized schematic of the possible flow of an ENT-patient through the hospital; it starts with the general practitioner that refers the patient to the outpatient clinic, where an ENT-doctor sees the patient, gives treatment and may order one or more tests. If surgery is necessary, the patient undergoes this path as well. The highlighted area indicates the place of the ENT-outpatient clinic and function center.

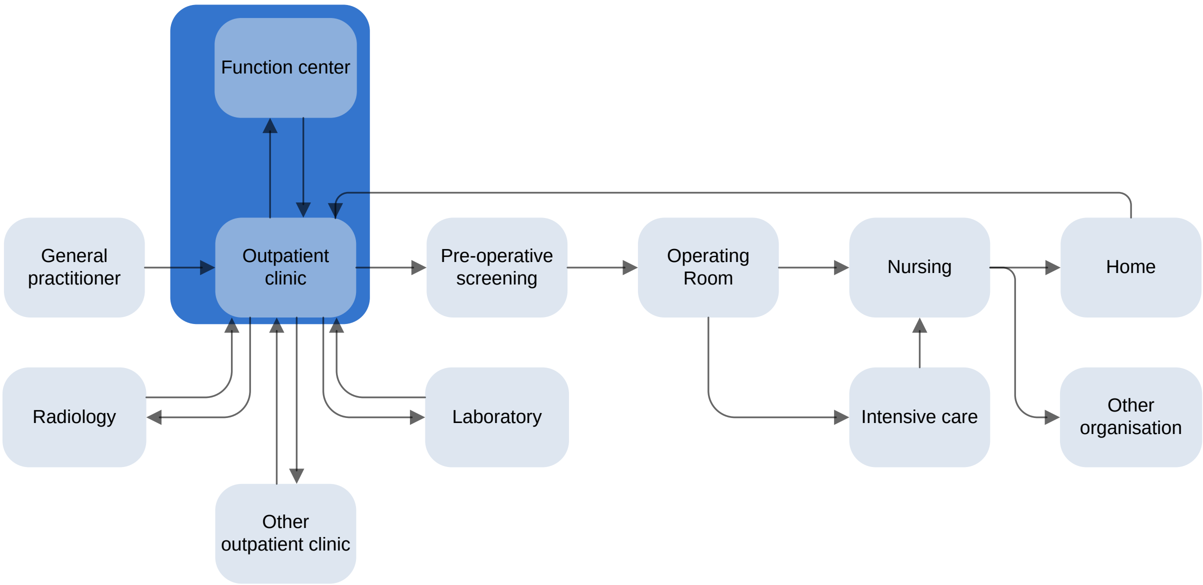


Figure 1: Scope of the research indicated in a general overview of a patient's care pathway (adapted from Rouppe van der Voort, 2014).

1.2. SCOPE OF THE RESEARCH

The ENT-outpatient clinic currently has three specializations: Otology (Ear); Rhinology (Nose), and; Head and neck oncology (Throat). These are all covered by medical specialists. Besides medical specialists, the outpatient clinic employs resident doctors, medical students and medical assistants. Resident doctors have their own consultation sessions but need some supervision from specialists. Medical students are not allowed to have their own consultation sessions, but do practice by seeing some new patients. Medical assistants make appointments with patients, do paperwork and assist doctors when necessary.

At the function center audiological and logopaedic tests are performed. Audiological tests often precede an appointment at the ENT-outpatient clinic. Logopaedic tests mostly occur either in cooperation with an ENT-doctor, or separate from the outpatient clinic. Of these two types, audiological tests occur most frequently.

Figure 2 shows the outpatient clinic and function center as shown in Figure 1 in a more detailed way. The dark blue figure indicates the scope of the research. Note that the link between general practitioner and the outpatient center is also inside the scope of the research; it largely determines the inflow of patients.

Since head and neck oncology transfers to another department around the end of this research, its activities remain outside the scope of the research. The audiological testing at the function center has a stronger connection to the outpatient clinic, so this is the focus in the function center. Given the variety of activities of medical assistants and their interchangeability, medical assistants are beyond the scope of the research.

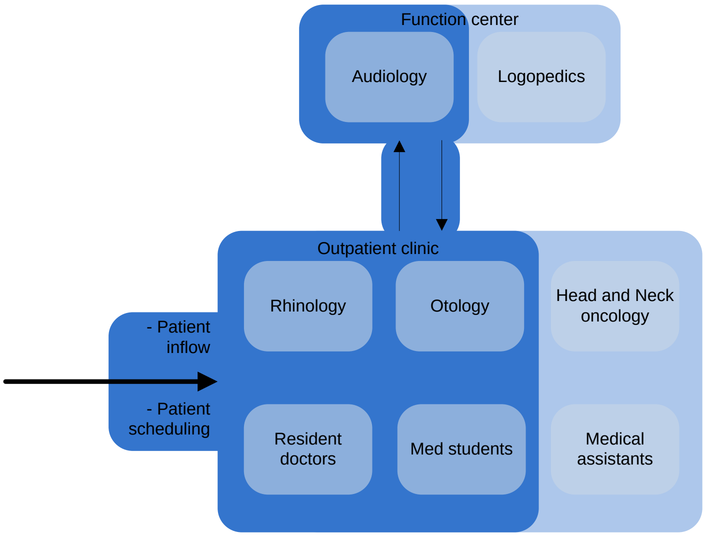


Figure 2: Scope of the research indicated within the ENT outpatient clinic and function center.

1.3. Problem description

There are difficulties with the use of the available capacity at the outpatient clinic: Doctors experience idle time during their clinic sessions, while patients incur excessive waiting time and employees have overtime.

The management of the department has expressed the desire to increase the number of patients seen at the outpatient clinic, in order to increase income of the department. However, increasing patient numbers without changing the way of working will also increase the experienced waiting time and overtime. This leads to the following problem description:

The outpatient clinic of ENT of UMCU experiences a suboptimal use of the available capacity for medical consultations, causing waiting times for patients and idle time and overtime for doctors; this situation is expected to worsen.

1.4. Research goal

We formulate the research goal as follows:

The goal of this research is to analyze the current scheduling process, the consultation schedules and the scheduling constraints, and identify and prospectively assess ways to improve these, at the outpatient center of the ENT department of UMCU.

This research, as well as its goal, concerns the scheduling of medical consultations, limited to those at the ENT outpatient clinic of UMCU. This focus is positioned in the healthcare planning and control framework (Hans, Van Houdenhoven & Hulshof, 2012) shown in Figure 3. The research takes place in the managerial area of resource capacity planning. Because the examined scheduling systems are on the medium- and short term, the research takes place on the tactical and operational offline hierarchical level. Some of the interventions include small alterations to the online operational level, so this is also included in the focus.

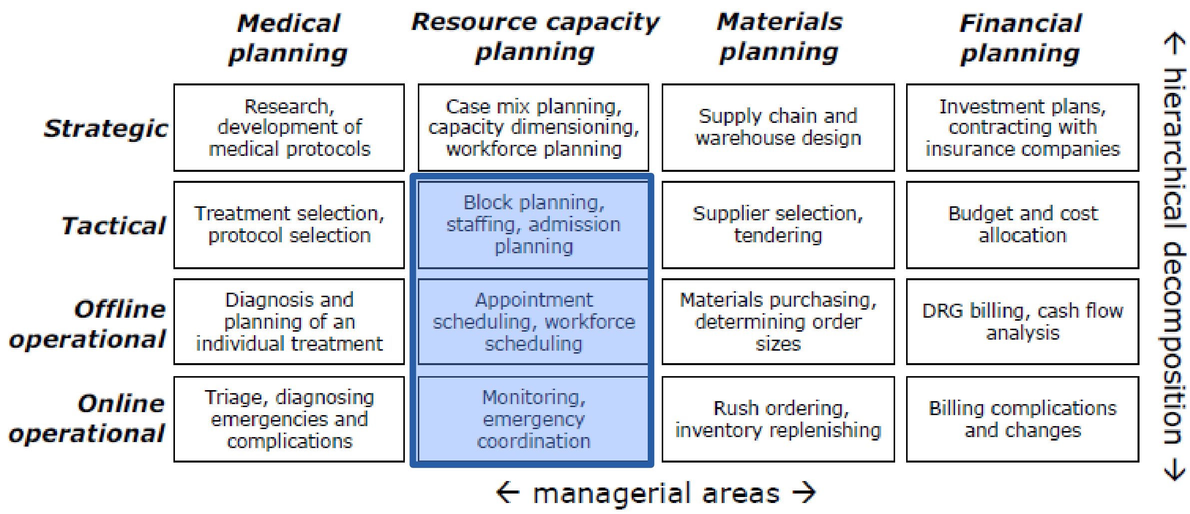


Figure 3: Focus of the research positioned in the healthcare planning and control framework (Hans, Van Houdenhoven & Hulshof, 2012).

1.5. Research questions

This section presents the research questions. The chapter in which each research question is answered is mentioned in brackets after each question. The method of answering these questions is explained directly after each question.

1. What is the current situation at the outpatient clinic in terms of consultation and scheduling processes and what is the performance of these processes? [Chapter 2]
    - 1.1. What are the consultation processes?
    - 1.2. How does the current scheduling method work?
    - 1.3. What constraints exist that influence the consultation schedule?
    - 1.4. What is the performance of the current scheduling method?
        - 1.4.1. How should the performance of consultation scheduling methods be measured?
        - 1.4.2. How does the current scheduling method score on these measures?
    - 1.5. What bottlenecks appear to hinder the outpatient clinic's performance?

Question 1.1 is answered through interviews with employees and by observing employees during consultation hours. Both Question 1.2 and 1.3 are answered by conducting interviews with the outpatient clinic manager, who is responsible for the scheduling, as well as with one of the assistants that are responsible for making the appointments. The performance measures used for Question 1.4 are inspired by the literature. The final decision on performance measures is made in collaboration with the department's board. The actual performance of the department is determined using a series of time registration systems, as well as with readily available data about access times. The bottlenecks in the system are determined by analyzing the data gathered for Question 1.4.

2. What interventions can be made to the consultation scheduling system that are expected to improve the system? [Chapter 3]
    - 2.1. What consultation scheduling methods for outpatient clinics are recommended by the literature?

2.2. What interventions to the consultation scheduling method can be conceived through careful analysis of the current scheduling method?

Question 2.1 is answered through the means of a literature study. As Question 2.2 already states, it is answered through careful analysis of the current scheduling method. For Question 2.2 attention is paid to interventions that do not just improve a single doctors clinic session, but also interrelationships among doctors. There are vast bodies of work on outpatient appointment scheduling, but all the literature treats the doctor as a single server and disregards interdependencies. The focus on interrelationships between doctors is aimed at reducing this discrepancy between practice and literature.

3. How can the processes, scheduling, and interventions be modeled? [Chapter 4]
   3.1. How should the consultation processes be modeled?
   3.2. What are the input parameters required for the model?
   3.3. Is the model valid and can its correctness be verified?

To model the consultation process, first a conceptual model is established, which is verified by employees to improve the accuracy of the model. The input parameters required for running the simulation models are extracted where possible from available hospital data. If the input data is not readily available, it is determined from measurements. The simulation model is verified by comparing it with the conceptual model. Model validity is examined by simulating a real life consultation schedule and comparing real life performance with simulation results.

4. What is the expected impact of the interventions on the performance of the outpatient clinic under various scenarios? [Chapter 5]
   4.1. What should the experimental design be?
   4.2. What are the effects of the various interventions?
   4.3. What is the sensitivity of the model output to changes in assumptions and (estimated) model parameters?

The impact of the interventions is assessed by performing several statistical analyses on the output of the model developed for research Question 3. The experimental design used to obtain the output is determined with methods proposed by Law (2007). The sensitivity of the model output is examined by studying the output of the model after altering certain assumptions and paramaters.

5. What recommendations can be made about the implementation of the recommended interventions? [Chapter 6]

Recommendations about the implementation of interventions are made in consultation with multiple employees at ENT, such as the outpatient clinic manager, counter personnel, or doctors.

2. Context analysis

This chapter discusses the context of the outpatient center of the ENT department in the UMCU, the staff and patient scheduling methods, and the outpatient clinic's score on five performance measures. We start with a description of the processes that patients and employees go through in Paragraph 2.1, followed by a closer look on the scheduling method and scheduling constraints in Paragraph 2.2 and 2.3. After we determine the performance of the outpatient clinic in Paragraph 2.4, we describe the effects of several potential bottlenecks in Paragraph 2.5, and we finish the chapter with a conclusion on the current situation and its performance in Paragraph 2.6.

2.1. Process description

This paragraph covers the processes that take place in the outpatient clinic for treating a patient. Figure 4 and Figure 5 show the generalized process that patients go through when visiting the outpatient clinic. The figures group the activities into 4 categories: Appointment scheduling, counter processes, paramedic processes, and doctor's processes. This section starts by covering these categories, then continues with a description of special clinic sessions that are held at the outpatient clinic.

2.1.1. Appointment scheduling

In order for patients to enter the system at the hospital, a doctor's referral is required. This can be either from a general practitioner or from a hospital physician. Three possibilities exist for patients to enter the system: They make an appointment, they go to a walk-in session, or they arrive as an emergency patient.

Upon receiving the doctor's referral at the reception, a medical assistant judges the referral for urgency, which doctor should be visited, and the required consultation duration. In case the referral is for a specific doctor, is from another ENT-doctor, or it concerns a difficult case, the medical assistant will send the referral to the outpatient clinic manager, who will then assess the referral. The outpatient clinic manager returns the assessment of the referral to the medical assistant, who then schedules the appointment in cooperation with the patient.

The urgency of the appointment has three options: Not urgent, urgent, and emergency. Non urgent patients get an appointment at a time preferred by the patient, urgent patients are scheduled within a few days, and emergency patients are scheduled the same day. In the case of return patients, the doctor will give a general target date for the appointment.

Two options exist for patients to be treated without a scheduled appointment: The first is the daily walk-in session in the early afternoon, where new, non-oncology patients can come with only a doctor's referral; the second option is coming to the emergency session, where patients can arrive with a referral from their general practitioner, or when they are sent from the emergency department.

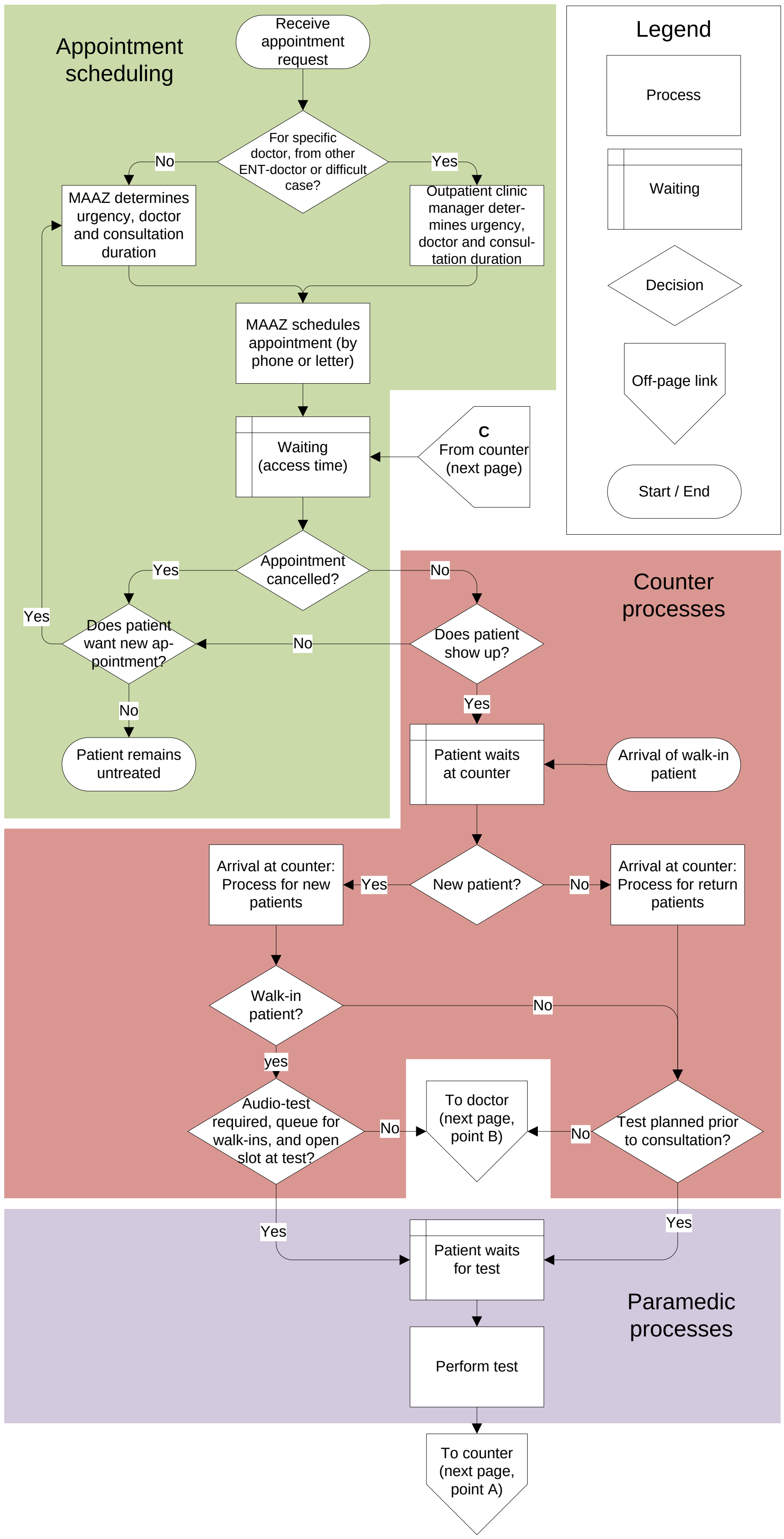


Figure 4: Patient's process part 1 of 2. Adapted from Westeneng (2007).

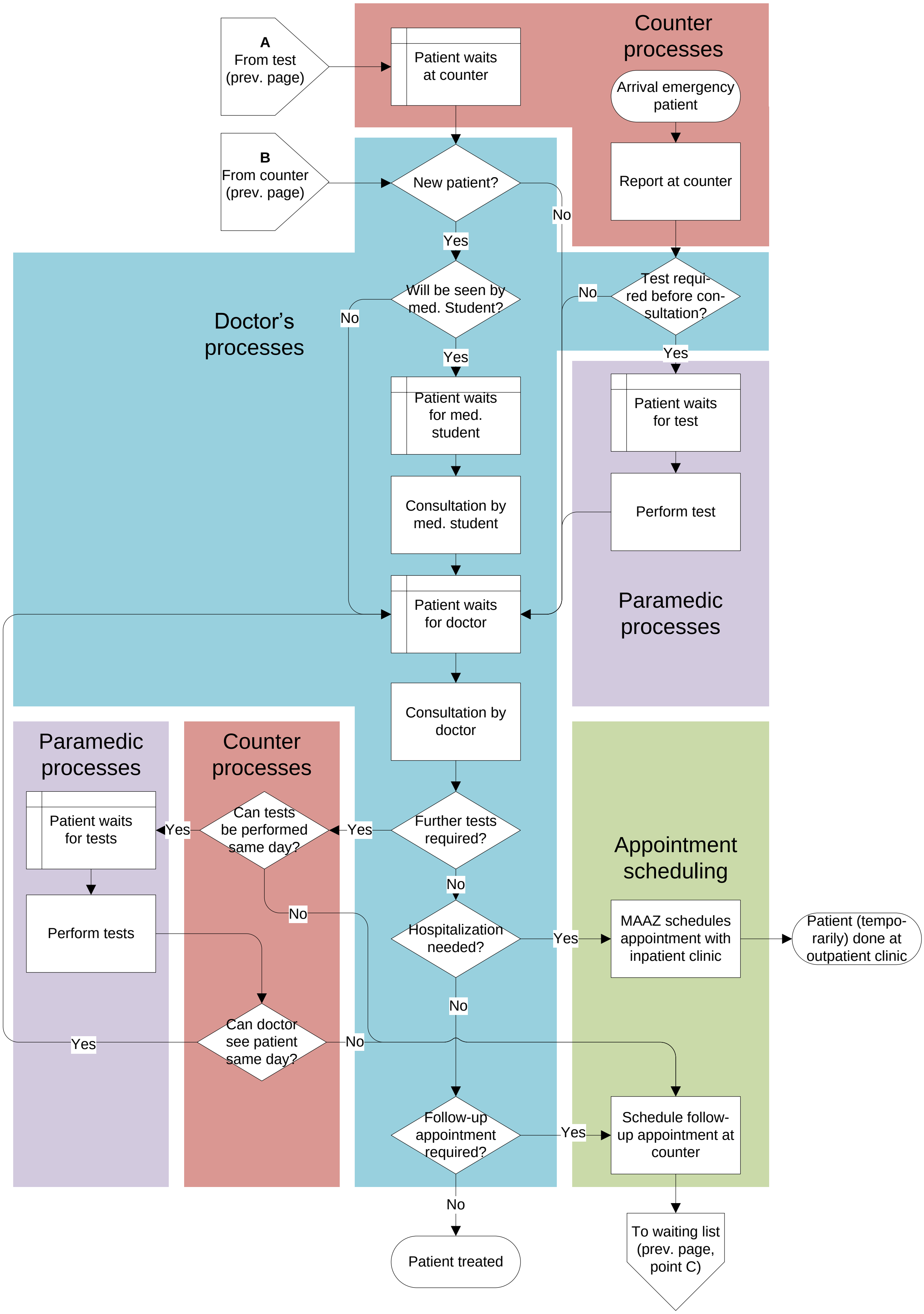


Figure 5: Patient's process part 2 of 2. Adapted from Westeneng (2007)

2.1.2. Counter- and paramedic processes

Upon arrival at the outpatient clinic, the patient has to report at the counter. The process for new patients upon arrival at the counter entails checking and entering the patient's data, such as their dentist, pharmacy, and health insurance. The process for return patients entails checking and potentially updating the patient's data.

Paramedic processes are the actions performed on patients by paramedic personnel. This includes helping doctors with outpatient surgery and performing non-invasive tests on patients. Some tests are performed by the MAAZes that assist the doctors at the outpatient clinic. These are generally performed shortly before the consult with the doctor, in an unoccupied room at the outpatient clinic.

Other paramedic processes occur at the function center, where audiological and logopaedic testing is done, as well as testing of the vestibular system. The function center has its own counter and waiting room, with a similar counter process as the outpatient clinic. If a patient has to see an ENT-doctor and undergo paramedic testing, the aim is to schedule the test prior to the consult on the same day, with little time in between. If this is not possible, tests can be scheduled after the consultation (if the need for a test was not recognized in advance), or on a separate date.

2.1.3. Doctor's processes

The outpatient clinic employs three kinds of doctors: Medical specialists, resident doctors (Dutch: arts-assistenten or AIOS), and medical students (Dutch: co-assistenten).

Medical specialists are fully licensed specialists that work in both the inpatient and the outpatient clinics. They have individual weekly schedules that include time for the OR, outpatient clinic, supervision for resident doctors and medical students, and secondary activities such as management, educational activities or scientific research. These medical specialists have their own medical field of focus, such as otology and rhinology. They mostly treat patients within their own field of focus, but are able to treat other ENT-patients as well. Currently, there are four otology specialists, four rhinology specialists, and three general ENT-specialists working at the outpatient center.

Resident doctors have their basic medical degree, but are still studying to become ENT medical specialists. Resident doctors have their own consultation hours during which they can ask a medical specialist for supervision and advice. Resident doctors work at the UMCU, but also have internships at other hospitals. The number of ENT-residents changes regularly, but is around fifteen. Currently, there are eight resident doctors having sessions at the outpatient center.

Medical students are medical students that have to do an internship in a hospital setting. They are not allowed to treat patients on their own, but do get to see some new patients before the actual doctor does, to let the medical student get accustomed with getting a patient's relevant medical history and performing a physical examination on the patient. After the medical student is done, the patient will have a normal consultation with a resident doctor or medical specialist.

Patients take up a certain amount of the doctor's time; this is the 'gross consultation time'. It consists of three parts: Preparation time, where the doctor prepares for the patient by reading relevant parts of the patients file in the Electronic Care Information System (EZIS) (Some doctors prefer to prepare prior to the consultation session); Net consultation time, the time that the patient is physically in the consultation room, and Administration time, in which the doctor updates the EZIS-file on the patient. Administration is usually done briefly during the consultation session, and finished thoroughly after the last patient has been seen.

Every shift, one staff doctor has supervision duty. During supervision, the staff doctor is available to be consulted by resident doctors. The doctor on supervision duty sees fewer patients during these shifts.

Doctors also have telephonic consultations. These consultations are used for situations where the patient is not required to physically be at the hospital, for instance for giving test results. Telephonic consultations are usually scheduled at the end of a shift.

2.1.4. Special clinic sessions

Aside from regular, single-server clinic sessions that can be scheduled well in advance, the outpatient clinic employs several special clinic sessions: an otology session, an oncology session, walk-in sessions, and emergency sessions. These sessions are designed to improve patient friendliness and the quality of care. They are described below.

Otology session

The outpatient clinic has a weekly otology-day, where multiple residents and medical specialists have coordinated clinic sessions. These include set appointment times for new and return patients, as well as set times for supervision. This special clinic session is coordinated with the audiology department, so patients can more easily undergo their hearing tests and see the doctor on the same day. This session is usually fully booked with patients.

Throat session

For patients with problems with swallowing and the voice, the outpatient clinic employs a concept similar to the otology-session. The throat session also uses set appointment times for new and return patients, and set times for consultation between resident doctor, logopaedic counselor and medical specialist. This session is also coordinated with the function center, in order to assure that patients can undergo their test on the same day. This session is generally fully booked with patients.

Walk-in session

In order to attract more patients, the outpatient clinic started in 2013 with walk-in sessions. During these sessions, patients can come by without an appointment. These sessions are held daily from 12.30 to 15.00 and are scheduled for the full attention of one resident doctor. Walk-in sessions are meant only for new, non-oncology patients. During a session, the doctor has time to see seven patients. From January to September 2014, the average number of walk-in patients per session was 2.35. However, the demand for the walk-in sessions varies strongly.

Emergency session

Every day, emergency sessions are held. Patients with urgent problems are seen during these sessions. These sessions are partially plannable; patients often get scheduled appointments for the next day. A first year resident doctor is responsible for the emergency session, and they do not see other patients during these sessions. The doctor responsible for the emergency session can also be called for ENT patients in the Emergency Room.

2.2. CURRENT SCHEDULING METHOD

Following the Healthcare planning and control framework (Hans et al., 2012) shown in Figure 3, the current scheduling method used in the outpatient clinic is described in terms of Tactical level, Offline operational level, and Online operational level.

2.2.1. TACTICAL LEVEL

The tactical level concerns medium term decisions. The most relevant aspect of this is the block scheduling. The ENT department uses a block schedule for staff and for resident doctors to be able to address staffing issues. In this schedule, the location that they will be working (e.g. outpatient clinic, OR, children's hospital) in the morning and afternoon from Monday to Friday is set. Because of rotation in internships, the residents' tactical schedule is updated every two months. The tactical schedule for medical specialists is not updated periodically.

2.2.2. OFFLINE OPERATIONAL LEVEL

The offline operational level concerns the day-to-day patient- and doctor scheduling that is done in advance. The appointment system used in the outpatient clinic is the most important aspect of this. We describe the appointment system using a framework provided by Cayirli and Veral (2003). This framework discerns the decision areas of the appointment rule, patient classification and adjustments made to reduce disruptive effects of walk-ins, no-shows and emergency patients.

The appointment rule used in the outpatient clinic is the *individual block, variable-interval* rule. This means that appointments are scheduled for one patient at a time, as opposed to multiple block systems, where multiple patients are scheduled for a single appointment time. It also means that the interval between two appointments is variable, meaning that for different consultation types, different service times are scheduled.

Patient classification can be used for two purposes: sequencing patients at the time of booking and to adjust appointment intervals in order to accommodate for differences between patient classes in service times and variation thereof (Cayirli & Veral, 2003). The outpatient clinic uses patient classification for adjusting appointment intervals. Over 30 different codes for consultation types are used, which have 8 different appointment intervals. Sequencing patients based on classification is also done, but in practice this is used more as a guideline than a rule when making appointments for general clinic sessions. The main goal of the sequence used is to reduce queues at the counter by scheduling new patients throughout the day. The otology and throat session use a strict schedule for patient sequence and appointment times, in order to accommodate consultation between doctors.

Cayirli and Veral (2003) consider adjustments made for disruptive effects from no-shows, walk-ins, urgent patients, emergencies and second consultations. Second consultations occur when the patient first needs to undergo a test before the consultation can be finished. Possible adjustments mentioned by Cayirli and Veral (2003) are overbooking to cope with no-shows, or leaving appointment intervals open to cope with walk-ins, urgent patients, emergencies or second consultations. The outpatient clinic does not explicitly use overbooking. The daily walk-in clinic session is coped with by putting one resident doctor on walk-in duty for the duration of the session. Emergency patients are seen by a first year resident doctor that has specific emergency duty. Besides the aforementioned effects, the ENT outpatient clinic also has disruptive effects from medical students that also see patients. These disruptive effects are just accepted, no further measures are in place to cope with them.

2.2.3. *Online operational level*

The online operational level of scheduling is about dealing with on-the-day changes to the appointment schedule. This concerns the method of dealing with walk-ins, emergencies and the queuing discipline used. The methods for dealing with walk-ins and emergencies are explained in Section 2.1.4. Since medical student clinics are not scheduled, the activities performed by medical students are also on the online operational level.

The queuing discipline dictates the order in which patients are seen by a doctor. At the outpatient clinic, doctors generally see patients with appointments in the order that they were scheduled, but doctors will prevent sitting idle by seeing later patients if earlier patients are not yet present. In other words, the doctor sees the available patient that has the earliest appointment time.

Medical students regularly have clinic sessions with a few new patients, after which the student discusses the case with the doctor, and the doctor sees the patient as he normally would. These medical student clinic sessions are not scheduled, which means that patients that are seen by the student are not advised to come early. The medical student clinic sessions generally start around the time that the normal consultation would start, and ends later. The effect this creates is comparable to the patient being considerably late.

2.3. Scheduling constraints

When drawing up the consultation schedules, several external influences have to be taken into account. Paragraph 2.3.1 covers these constraints. Paragraph 2.3.2 is about the constraints that are experienced when scheduling appointments with a patient.

2.3.1. *Constraints on consultation schedules*

The following constraints have been determined in collaboration with the outpatient clinic's scheduler.

Besides the outpatient clinic, doctors concern themselves with inpatient care, surgeries, and either research, management or educational activities. The outpatient clinic schedule is generally considered third in line, after surgeries and inpatient care, but before research, management or educational activities. The scheduler considers the existing schedules for surgeries and inpatient care to be some of the most difficult constraints.

Regular days off (because of part-time working hours) are considered fixed constraints for the consultation schedules. Irregular days off, for instance for holidays or conventions, are seen as less important than the schedule; doctors can apply for days off some months in advance, and have to find their own replacement doctors.

Working hours for doctors are from 08.00 to 18.00. The start of clinic sessions is limited to 8.20 at the earliest because of the hand-off in the morning. The doctors' working hours are not limiting to the finish time of clinic sessions. The working hours of assisting paramedics are scheduled such that they fit to the start and finish time of clinic sessions. The paramedics' schedules are finalized a few months in advance by one of the paramedics. These schedules are flexible; they only need to adhere to a certain number of working hours for every paramedic.

Resident doctors have strict educational requirements that need to be fulfilled. These include limitations for working hours, quota for types of patients treated, given lecture hours and internships at peripheral hospitals. The scheduler considers this to be one of the two most difficult constraints.

Clinic sessions such as the otology session are coordinated between doctors. These sessions are meant to always be incorporated in the consultation schedules, so they effectively mean that a few consultation session moments per week are already scheduled.

The number of rooms at the outpatient center limits the number of simultaneous consultation sessions to a maximum of 9. However, since there is an average of 5 to 6 simultaneous sessions and the scheduler aims to spread consultation sessions evenly, this is generally not seen as a problem by the scheduler.

The schedule at the function center is a constraint for scheduling coordinated consultations for patients, but is not seen as a constraint when making the consultation schedule. However, the wish for better coordination between the function center and the outpatient clinic has been voiced by the scheduler, doctors and paramedic personnel at the outpatient clinic.

2.3.2. *CONSTRAINTS ON APPOINTMENT SCHEDULING*

Aside from the influences that have to be taken into account while scheduling in doctors, the following constraints are taken into account when scheduling appointments with a patient.

The urgency of the problem largely determines the time-frame in which the appointment is made. Emergency patients can be sent to the emergency session and urgent patients are generally seen as soon as possible, but may even be overbooked into a full session if the doctor deems this necessary. New urgent patients are sometimes directed to the walk-in session. Appointments for non-urgent patients mostly rely on the other constraints.

Doctors usually mention a target date for the next appointment for return patients. The appointment is aimed towards this date. If this is not possible, patients may be overbooked into a full session if the doctor deems this necessary. Target dates further into the future give more leeway than nearby target dates.

Usually, patients are only scheduled into empty time slots. In case of combination consults, for instance a doctor's appointment combined with audiological tests, or appointments with two doctors, this can cause longer access times.

Some appointment types are only allowed on certain days. This is especially the case for otology- and throat sessions. This constraint overlaps with the available time slots-constraint.

There is often a preference for either a resident doctor or a medical specialist when an appointment is made. It also happens that a patient is referred by an ENT-doctor. In that case, there is often a specific doctor that the patient is referred to. For return patients, the preference is to see one and the same doctor for every appointment. Whenever realistically possible, this constraint is abided by.

Patients have a life outside the hospital. This often interferes with appointment times suggested by the appointment scheduler. For instance, patients that have to travel far dislike early appointment times, and patients with part-time jobs often have specific weekdays on which they prefer an appointment.

2.4. PERFORMANCE

The current performance of the outpatient clinic is measured using performance indicators. The literature categorizes outpatient clinic performance measures into time-based, cost-based, congestion-based and fairness-based measures (Cayirli & Veral, 2003; Muthuraman & Lawley, 2008). In the literature it is common practice to use time-based and cost-based measures. Measures relating to performance for doctors are idle time and overtime, measures relating to the performance as perceived by patients are waiting time and access time. These are often measured using either a unit of time or currency, see for instance (Cayirli, Veral & Rosen, 2008; Cayirli & Gunes, 2013; Cayirli, Veral & Rosen, 2006; Cayirli, Yang & Quek, 2012; Cayirli & Veral, 2003; Harper & Gamlin, 2003; Kaandorp & Koole, 2007; Mondschein & Weintraub, 2003; Rohleder & Klassen, 2002; Klassen & Rohleder, 1996; Wijewickrama & Takakuwa, 2006).

It is recommended to not use merely a single performance measure, since focusing on improving a single measure can lead to undesirable side effects, where that single performance measure improves at the cost of other performances (Günal & Pidd, 2010). For instance, the doctor's idle time can be decreased by letting all patients arrive an hour early, but this would mean a large increase in patient waiting time.

With this in mind, we decide to use the following performance measures:

- Doctor's idle time;
- Doctor's overtime;
- Patient's waiting time;
- Percentage of patients with a waiting time less than 15 minutes;
- Access time.

Section 2.4.1. discusses the system with which the performance measures have been measured. Section 2.4.2. proposes a mathematical notation that is used to develop unambiguous performance measures. Sections 2.4.3. until 2.4.7 present the score of the outpatient department on the performance measures.

2.4.1. MEASUREMENT SYSTEM

The method used to measure the performance on idle time, overtime and waiting time is a series of time registration systems. Counter employees recorded, accurate on minute-level, when patients arrived to see the doctor. Doctors recorded when the start and finish times of preparing for a patient, net consultation time, and briefly updating the patient's administration. This was done in a specially prepared excel-file, making the measurements accurate to the second. Medical students recorded the start of preparation, net consultation time, and updating administration, they also recorded the finish time of the administration. Since medical students work on an ad hoc basis, they recorded this on sheets of paper, making the measurements accurate to the minute. At the function center, the patients' arrival times, the moment they were called for their test, and the moment they were finished were recorded accurate to the second. This was done only for patients that had an appointment at the function center and at the ENT outpatient clinic on the same day.

These measurements have been performed for a continuous period of three weeks in October and November. This period was chosen because the decrease in patients from the summertime should be finished. The data in Paragraph 2.4 and 2.5 (except 2.5.3) were gathered from regular, throat and otology sessions in which the doctor did not have supervision duty.

2.4.2. MATHEMATICAL NOTATION

In order to develop unambiguous performance measures, we define the following sets and indices:

Sets

- P Patients
- D Doctors

Indices

- $p \in P$ Patient
- $d \in D$ Doctor

With these, we define the following parameters:

- Scheduled appointment start time S_p
- Actual appointment start time S'_p
- Actual start of gross consultation time $B'_{p,d}$
- Scheduled finish of gross consultation time $E_{p,d}$
- Actual finish of gross consultation time $E'_{p,d}$
- Actual arrival time of a patient A'_p
- Date of making an appointment $D_{p,d}$
- Date of third possible appointment slot $D'_{p,d}$

2.4.3. AVERAGE DOCTOR'S IDLE TIME

The average of the total time that the doctor is not busy with a patient per consultation hour:

$$\sum_d \frac{E'_{P,d} - B'_{1,d} - \sum_p \left(E'_{p,d} - B'_{p,d}\right)}{D}$$

This performance measure gives an indication of the amount of time that can be saved by altering the scheduling system in favor of the doctor's time. Lower idle time is better.

The average doctor's idle time per session as calculated with the aforementioned formula is 38.1 minutes. Figure 6 shows a histogram of slightly differently calculated idle times. This figure uses the determined reason for any idle period longer than 2 minutes, and shows the average of these idle times per session for every reason. Only idle times longer than 2 minutes were used, because shorter idle times may be caused by slow use of the time registration system. The reason 'DICT' is desirable interconsultation time (Westeneng, 2007). This consists of activities that the doctor explicitly chooses to do instead of treating a patient. These activities range from getting coffee to explaining something to a medical student. This is also known as the interruption level (Muthuraman & Lawley, 2008). 'Patient late (FC)' describes idle time caused by a patient that is late because of an appointment at the function center.

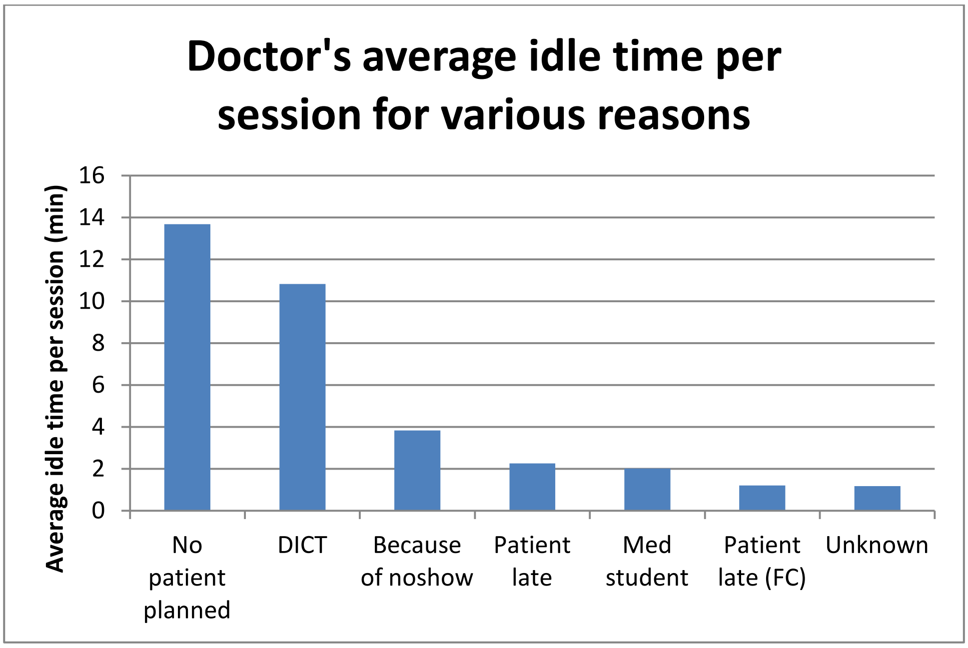


Figure 6: Average idle time per consultation session, reported for various reasons. These do not add up to the reported idle time per session because of different calculation methods.

2.4.4. *Average doctor's overtime*

This is the average difference between actual and scheduled finish time of a consultation hour. Negative overtime does not exist, so in case a doctor is finished early, this is treated as zero:

$$\sum_{d} \frac{\max(0\,, E'_{P,d} - E_{P,d})}{D}$$

Doctor's overtime provides insight in the amount of time that the doctor spends on clinic sessions while he should be performing other activities. Doctors at the hospital do not get compensated for overtime during consultation sessions, but medical assistants, that have to work overtime alongside the doctors, do. This means that overtime entails a direct cost for the department. Higher overtime means more room for improvement.

The average doctor's overtime is 17.9 minutes per clinic session. Figure 7 shows a histogram of all measured overtimes.

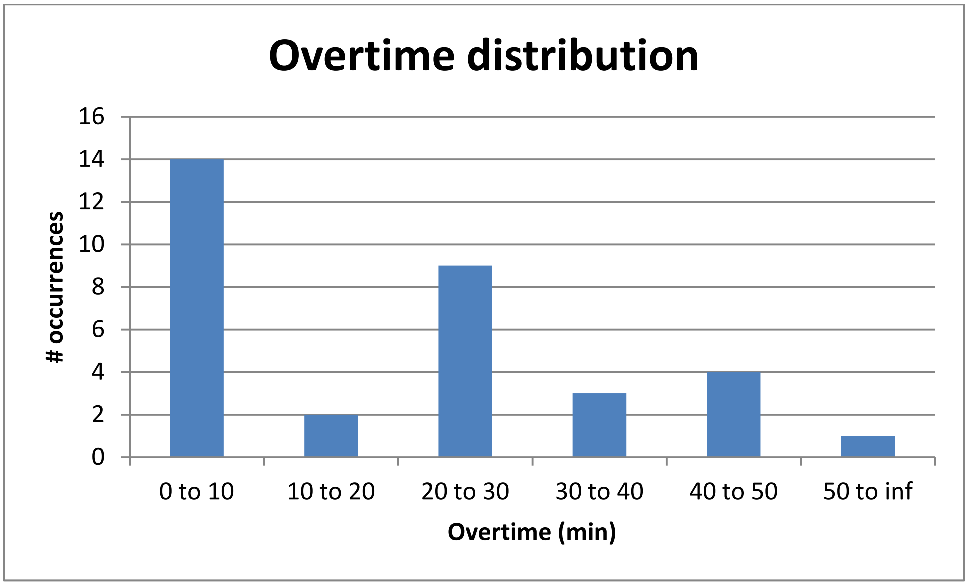


Figure 7: Histogram of doctor's overtime per session.

2.4.5. *AVERAGE PATIENT'S WAITING TIME*

The difference between scheduled appointment time (or arrival time if the patient was late) and being called in by the doctor, averaged per patient. Negative waiting times occur when patients arrive early and their consultation starts before the scheduled appointment time. These negative waiting times are seen as zero:

$$\sum_{p} \frac{\max\left(0, S'_p - \max\left(S_p, A'_p\right)\right)}{P}$$

The patient's waiting time is a widely used measure for quality of service of an outpatient clinic (Cardoen et al., 2010; Cayirli et al., 2008; Kaandorp & Koole, 2007; Klassen & Rohleder, 1996; Muthuraman & Lawley, 2008). High waiting times cause patient dissatisfaction, which could be detrimental to UMCU's competitiveness in the long run.

These waiting times have been measured for appointments with the doctor and at the function center. The average patient's waiting time for the doctor is 10.0 minutes. The average waiting time at the function center is 4.9 minutes. Figure 8 shows a histogram of all patients' times spent waiting for the doctor and at the function center. Note that, following the formula used to calculate waiting times, negative waiting times are regarded as a zero minute waiting time.

The average time spent waiting for the doctor by patients that have a combined appointment with doctor and function center is 11.2 minutes, whereas the average waiting time for patients that only see the doctor is 9.6 minutes.

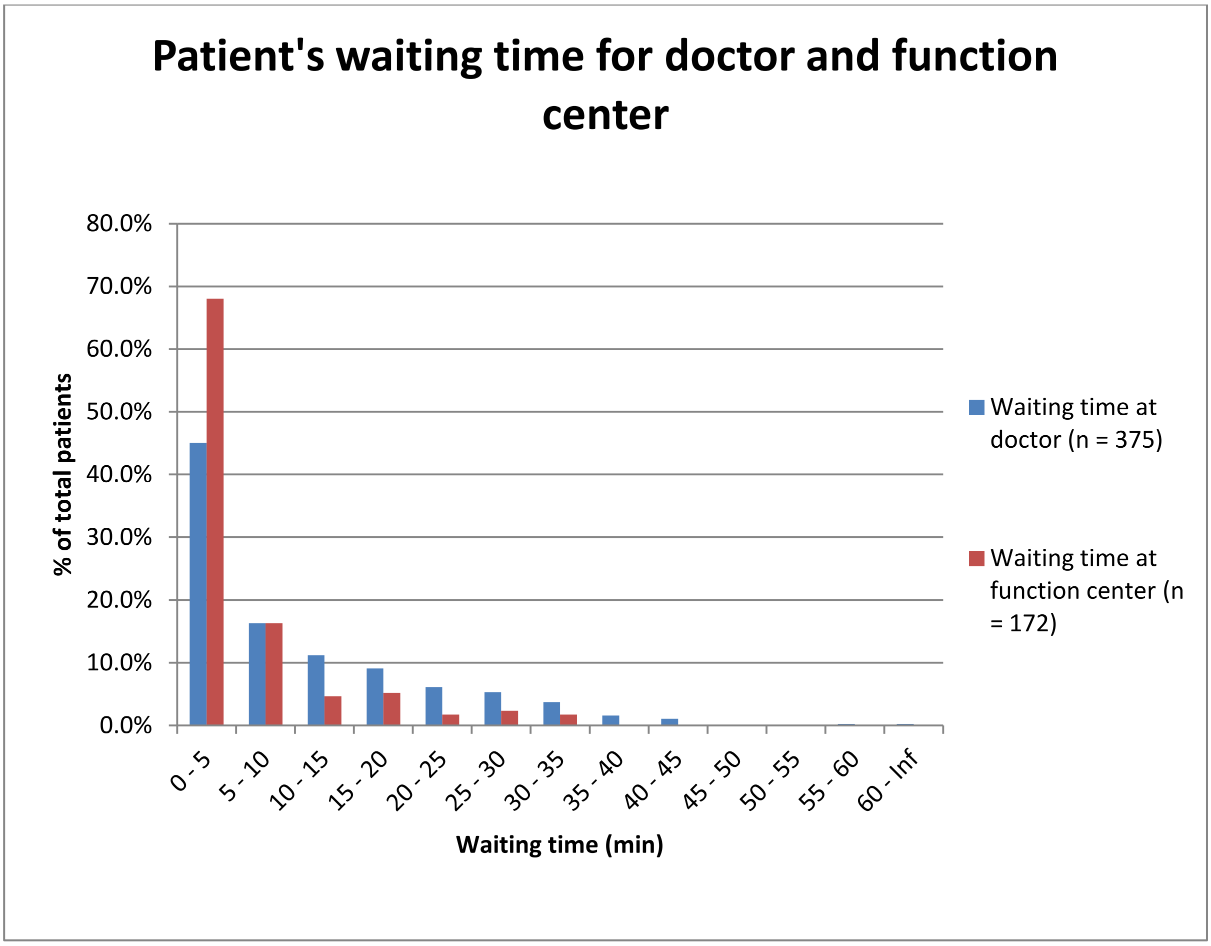


Figure 8: Comparison of patients' waiting time distributions at the doctor and at the function center.

2.4.6. *Percentage of patients with a waiting time under 15 minutes*

The percentage of patients that have an internal waiting time of less than 15 minutes. The internal waiting time is calculated with:

$$\max\left(0, S'_p - \max\left(S_p, A'_p\right)\right)$$

This performance indicator is a service level agreement that is currently used by the ENT department. It recognizes that patients rarely mind short waiting times, but that patients dislike long (in this case longer than 15 minutes) waiting times.

Of the patients waiting for the doctor, 73% has to wait for less than 15 minutes. At the function center, this percentage is 89%.

2.4.7. *Prospective average access time*

The access time is measured in accordance with the CBO (2004), as the number of days between the date of making the appointment and the third possible appointment date. This is the prospective access time. The average access time for a doctor d is calculated by:

$$\sum_p \frac{D'_{p,d} - D_{p,d}}{P}$$

This measure gives an indication of the workload for doctors and the service for patients. Lower access times mean better quality of service and in some cases a better quality of care for patients. However, since new patients may visit the walk-in consultation sessions, these patients effectively have an access time of 0 days. So, this measure is mostly useful for return patients.

The access time used to be measured monthly until September 2014. Table 1 shows the average and the average of minimum monthly values for access times from January 2014 until September 2014, ordered by specialty, for new and return patients. The average minimum indicates the quickest possibility to be helped for patients that do not prefer a specific doctor. The average total indicates the average duration before being helped for patients that do prefer a specific doctor. However, the average total values are skewed upwards, since doctors with a small number of clinic sessions tend to have longer access times, but they count equally towards this average.

Table 1: Access times per specialty. Minimum is calculated as the average of the monthly minimum access time for that specialty. Average is the average over all months for all doctors of that specialty.

	Average minimum		Average total	
	New	Return	New	Return
Rhinology	5.7	3.3	12.6	12.5
Otology	4.0	3.3	14.0	14.9
Residents	8.1	4.4	15.7	10.9

2.5. Potential bottlenecks

This section describes several factors that can be expected to be a bottleneck to the performance of the outpatient clinic, as well as the effects of other factors of influence to the clinic's performance. These potential bottlenecks and other factors are the function center, medical students that see patients, the walk-in session, doctor's punctuality, unintentional overbooking, and underutilization of the clinic sessions.

2.5.1. Function center

Average waiting times for the outpatient clinic are 9.6 minutes for patients that do not have an appointment at the function center and 11.2 minutes for those that do. Average waiting times at the function center are 4.9 minutes. This means that the function center only causes small additional waiting times for ENT-outpatients.

As Figure 6 in Paragraph 2.4.3 shows, ENT-patients with function center appointments cause some idle time because their function test runs late. However, this is only roughly 3% of all measured idle time.

2.5.2. Medical student

Table 2 shows the average waiting time, idle time and overtime for clinic sessions with and without a medical student seeing patients. This shows that sessions with medical students have somewhat better patient's waiting time and idle time, and a bit worse overtime. Overall the effect of medical students on an entire session seems negligible.

Table 2: Average waiting time, overtime and idle time for sessions with and without a medical student seeing patients.

	With med student	Without med student
Waiting time per patient (min)	8.2	9.4
Overtime per session (min)	19.2	17.5
Idle time per session (min)	36.9	38.5

2.5.3. *WALK-IN SESSION*

The above figures exclude data from the walk-in session, since the nature of the walk-in session differs from that of regular and specialty sessions. Table 3 compares the average performance of the walk-in session to the average performance of regular, throat and otology sessions. Especially the percentage of available time that has been spent on a patient during walk-in sessions seems to be a bottleneck. There seems to be much more capacity for walk-in patients then is needed. This also shows from historical data, which show that walk-in sessions attracted on average 2.35 patients, whilst there is capacity for 7.5 patients to be scheduled.

Table 3: Average waiting time, overtime, idle time and percentage worked of available clinic session time for walk-in sessions and non-walk-in sessions.

	Walk-in session	Regular and specialty session
Waiting time per patient (min)	14.0	10.0
Overtime per session (min)	14.6	17.9
Idle time per session (min)	88.3	38.1
Percentage worked of available time	41%	79%

2.5.4. *DOCTOR'S PUNCTUALITY*

It is to be expected that the punctuality of the doctor affects waiting time, idle time and overtime. The gathered data reveal that this is the case, as Table 4 shows. Doctors start their sessions, on average, 5.4 minutes late. There is only a small difference in punctuality in the morning (5.1 minutes) and in the afternoon (5.6 minutes).

Table 4: Average waiting time, overtime and idle time of sessions where doctor is on time and sessions where doctor is late.

	Doctor on time (n = 12)	Doctor late (n = 30)
Waiting time per patient (min)	4.7	11.1
Overtime per session (min)	12.1	20.5
Idle time per session (min)	40.1	37.4

2.5.5. *UNINTENTIONAL OVERBOOKING*

Paragraph 2.2.2 states that overbooking is not explicitly used in the outpatient clinic. This is true. However, the gathered data reveals that there is an implicit and unintentional form of overbooking. Return patients, which are the most common type of patients, are generally scheduled for a 10 minute appointment. However, their consultation duration is on average 13.7 minutes, which means that they are consistently overbooked.

2.5.6. *Underutilization of clinic sessions*

Clinic sessions are often underutilized. On average, 75% of available time is scheduled. This results in doctors working on average 79% of time available for clinic sessions. As Figure 6 in Paragraph 2.4.3 shows, low utilization of available time is a significant reason for idle time.

2.6. Conclusions

The question that this chapter set out to answer is:

What is the current situation at the outpatient clinic in terms of consultation and scheduling processes and what is the performance of these processes?

The doctor's consultations are scheduled using a fixed block schedule that is not updated periodically for medical specialists. Resident doctor's consultation schedules are updated every two months. The hardest constraints on making these consultation schedules, as experienced by the scheduler, are the existing schedules for surgery and inpatient care, and the educational constraints for resident doctors.

Patient appointment scheduling is done based on the *individual block, variable interval* appointment rule. The outpatient clinic uses 8 different appointment intervals with over 30 different appointment types. Aside from standard consultation sessions, the outpatient clinic has a daily walk-in session, an emergency session, otology sessions and a throat session. The walk-in and emergency session both have one resident doctor fully committed to it. The otology and throat sessions use coordinated appointment times and times for consultation between personnel.

These consultation and appointment scheduling systems result in an average doctor's idle time of 38.1 minutes per session, with empty appointment slots and desirable interconsultation time as main reasons for this. Combined consultations with the function center do not seem to cause much idle time, at an average of less than a minute per session. The average overtime for doctors is 17.9 minutes, with peaks of up to an hour.

Patient's waiting time for the doctor is on average 10.0 minutes, and is barely affected by combined consultations with the function center. This average is acceptable according to the hospital's SLA of patients being seen within 15 minutes. However, only 73% of the patients is actually seen within 15 minutes at the outpatient clinic. The function center outperforms the outpatient clinic on this measure, with 89% of patients being seen within 15 minutes.

The outpatient clinic's access times are effectively nonexistent for new patients, since they can visit the walk-in session. For return patients, the average access time is under 2 weeks. This is acceptable according to the Treeknormen (RIVM, n.d.), which state that patients should get an appointment within 3 weeks.

Bottlenecks to the outpatient clinic's performance appear to be the walk-in session where only 40% of the time is spent on walk-in patients, a low average utilization of only 75% which is a main reason for the idle times occurring. In contrast to the low utilization, there is also unintentional overbooking, created by return patients that are scheduled for only 73% of the time they actually take on average. Lastly, the doctors' punctuality worsens waiting times and overtime, since two thirds of the measured clinic sessions started late.

So, the current scheduling processes perform acceptably in terms of access times, but do leave some room for improvement in the patient waiting times at the outpatient clinic. The doctor's idle time can be decreased considerably, as can the doctor's overtime. The measured combined appointments at the outpatient clinic and the function center negatively influence performance, but only in a negligible amount.

3. POSSIBLE INTERVENTIONS

This chapter presents interventions to the current appointment system that we expect will improve the system's performance. Section 3.1 presents a brief review of the literature on outpatient appointment scheduling and interventions that have already been studied. In Section 3.2, we present some interventions that come from the analysis of the current situation, and decide which interventions are further examined in this study. Section 3.3 briefly concludes on this chapter.

3.1. INTERVENTIONS FROM THE LITERATURE

This short review of the literature uses the same framework by Cayirli and Veral (2003) as used in Section 2.2.2, which narrows the design of appointment systems down to the appointment rule, usage of patient classification, and adjustments to reduce disruptive effects of walk-ins and no-shows. This review also discusses some environmental factors that may be controlled and thus used as an intervention to the scheduling system.

3.1.1. APPOINTMENT RULE

The appointment rule concerns the number of patients scheduled for the same appointment time (block size) and the duration that the appointment is scheduled for (appointment interval) (Cayirli & Veral, 2003). Studies about appointment systems mostly focus on determining the best appointment rules (Cayirli & Veral, 2003).

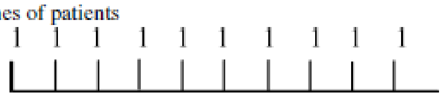
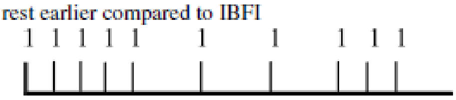
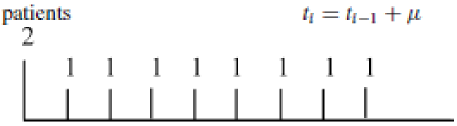
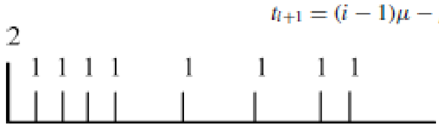
Many possible appointment rules exist. Cayirli et al. (2006) provide a comprehensive explanation and study of seven different appointment rules, which they gathered from the best performing appointment rules in multiple previous studies, including Ho & Lau (1992), Bailey (1952), and Klassen and Rohleder (1996). Figure 9 illustrates and explains the appointment rules that we will mention in this section.

The IBFI rule is used as the benchmark rule by Cayirli et al. (2006). This rule schedules patients with individual appointments and a fixed appointment interval. This is similar to the current situation in the ENT outpatient clinic.

The Dome rule works by scheduling the first few patients earlier as compared to the IBFI rule, scheduling the middle part of the session later as compared to the IBFI rule, and scheduling the last patients a bit earlier. While this appointment rule does not perform well in the study by Cayirli et al. (2006), it is roughly based on a "dome" pattern that appeared in optimal solutions from analytical studies (Wang, 1997; Robinson & Chen, 2003; Denton & Gupta, 2003). The Dome rule used by Cayirli et al. (2006) leads to small changes in appointment times, and the last patient has the same appointment time as with the IBFI rule.

The 2BEG rule is perhaps the most well-known appointment rule of the four. It is also known as the Bailey-Welch rule, and was first introduced by Bailey (1952). It is an individual block, fixed interval appointment rule, with an initial block of two patients. It is often determined to lead to good results (Ho & Lau, 1992; Kaandorp & Koole, 2007; Cayirli et al., 2006).

The last rule, 2BGDM, is a combination of the Bailey-Welch rule and the Dome rule as proposed by Cayirli et al. (2006). It combines an initial block of two patients with variable intervals that follow a dome pattern.

Symbol	*Description*	*Formulations*[1]	
IBFI	Individual-block/fixed-interval rule calls patients individually at intervals equal to the mean service times of patients 	$t_1 = 0$ $t_i = t_{i-1} + \mu$	 for $i > 1$
DOME	Individual-block/variable-interval rule, where initial $(k_1 - 1)$ patients are scheduled earlier, patients $(k_1 + 1)$ through $(k_2 - 1)$ are scheduled later, and the rest earlier compared to IBFI 	$t_i = (i-1)\mu - \beta_1(k_1 - i)\sigma$ $t_i = (i-1)\mu + \beta_2(i - k_1)\sigma$ $t_i = (i-1)\mu - \beta_3(i - k_2)\sigma$	for $i \leq k_1$, for $k_1 < i < k_2$, and for $i \geq k_2$
2BEG	Individual-block/fixed-interval rule with an initial-block of two patients 	$t_1 = t_2 = 0$ $t_i = t_{i-1} + \mu$	 for $i > 2$
2BGDM	Combination of the 2BEG and the DOME rules 	$t_i = t_{i+1} = (i-1)\mu - \beta_1(k_1 - i)\sigma$ $t_{i+1} = (i-1)\mu - \beta_1(k_1 - i)\sigma$ $t_{i+1} = (i-1)\mu + \beta_2(i - k_1)\sigma$ $t_{i+1} = (i-1)\mu - \beta_3(i - k_2)\sigma$	for $i = 1$ for $2 \leq i \leq k_1$, for $k_1 < i < k_2$, and for $i \geq k_2$

[1] t_i is the appointment time for patient i, μ is the mean service time, σ is the standard deviation of service time. β_i are multipliers that adjust how early or late appointment times are relative to the benchmark rule (IBFI), and k_i are early/delay parameters that determine which patients are scheduled to arrive early or late relative to IBFI.

Figure 9: Four most interesting appointment rules (source: Cayirli et al. (2006)).

3.1.2. Patient classification

Patient classification can be used for two purposes in outpatient scheduling, namely to use a sequencing rule to determine in what order patients are scheduled, and to adjust appointment intervals to fit different service times of different patient classes (Cayirli & Veral, 2003). As noted in Chapter 2, the outpatient clinic employs both these uses of patient classification in the current situation.

Klassen and Rohleder (1996) are the first to study patient classification in an outpatient clinic environment. Their research classified patients in two classes, namely low and high variance. They researched the following patient sequences:

- Alternating low and high variance patients 1 by 1;
- Alternating low and high variance patients in groups of 5;
- Scheduling all high variance patients at the beginning of the session;
- Scheduling all low variance patients at the beginning of the session;
- Scheduling all high variance patients at the beginning and end of the session;
- Scheduling all low variance patients at the beginning and end of the session.

The most important findings of Klassen and Rohleder (1996) are that scheduling patients with a low variance at the beginning of the session yields the best results under multiple environments. Berg et al. (2014) support these findings. Similar patient sequences have also been researched by Cayirli and Veral (2003), who sequenced new and return patients, which they generalize to long and short service times respectively. Their findings show a wider spread of efficient sequences, with new patients in the beginning, return patients in the beginning, alternated sequencing, and return patients at the beginning and end of the session as most efficient under several environments.

3.1.3. *Adjustments to reduce disruptive effects*

There are several sources of disruptive effects in outpatient appointment scheduling. According to Cayirli and Veral (2003), the most common sources are no-shows, walk-ins, urgent patients and emergency patients. Naturally, it is possible not to adjust for these disruptive effects. If the desire of dealing with these disruptive effects does exist, there are two suggested methods of coping with no-shows are overbooking extra patients to predetermined slots and reducing appointment intervals proportionally to the expected number of no-shows (Cayirli & Veral, 2003; Vissers, 1979). Vissers (1979) finds that reducing all appointment intervals gives slightly better results.

Methods for dealing with non-elective patients, such as walk-ins, second consultations, urgent patients and emergencies are the opposite of those for dealing with no-shows, namely leaving predetermined appointment slots open, and increasing appointment intervals proportionally (Cayirli & Veral, 2003).

3.1.4. *Controllable environmental factors*

In their literature review, Cayirli and Veral (2003) define a number of environmental factors that may be taken into account when modeling clinic environments. Some of these are hard or undesirable to be influenced. The service times are an example of an environmental factor that is undesirable to be influenced, since this will directly influence the quality of care. However, some of the environmental factors may be influenced by the management and then yield improvements to the system's performance.

Most researches about outpatient appointment scheduling focus on single-server systems. A reason for this might be that, in most medical services, it is assumed that the number of doctors that are allowed to treat a patient should be exactly one, in order to provide a one-to-one doctor-patient relationship (Cayirli and Veral, 2003). If it were deemed acceptable to have patients treated by the first available doctor, queuing theory proves that this should result in shorter waiting times for patients (Cayirli and Veral, 2003).

Another environmental factor mentioned by Cayirli and Veral (2003) is the doctor's punctuality, which we determined in Section 2.5.4 to be approximately +5 minutes. There is agreement among many studies (e.g. Babes & Sarma, 1991; Liu & Liu, 1998) that the patients' waiting times are highly sensitive to doctor's punctuality. Cayirli and Veral (2003) mention that punctuality should either be enforced, or that the appointment system should be designed to account for unpunctual patients and/or doctors.

3.2. Chosen interventions

This section documents the interventions that we will use. These decisions are based on the interventions found in the literature in Section 3.1 and the analysis of the current situation in Chapter 2. This section uses the same structure as Section 3.1, starting with appointment rules, followed by patient classification, adjustments to reduce disruptive effects, and finishing with controllable environmental factors.

3.2.1. *Appointment rule*

From the literature, we find the IBFI, Bailey-Welch, Dome, and combination of Dome and Bailey-Welch rule to be interesting. Since the IBFI rule is similar to the current situation, and we use the current situation for comparison purposes, we do not further pursue the IBFI rule. The combination of the Dome and Bailey-Welch rule schedules many patients shortly together at the beginning of the session. We expect that this, in combination with the discrepancy between scheduled and average appointment duration of return patients, will probably lead to unacceptable waiting times for patients at the beginning of the session. We therefore do not use the combination of Dome and Bailey-Welch as an appointment rule.

The Bailey-Welch rule has often been found to lead to good results. We therefore decide to test the effect of using the Bailey-Welch rule as an appointment rule.

For the Dome-rule, we propose a variation on the Dome-rule as it was suggested by Cayirli et al. (2006). This variation works by decreasing the scheduled duration size of two of the first few appointment slots, increasing the scheduled duration size of two appointment slots in the middle of the consultation session, and decreasing the size of two appointment slots near the end of the session. We expect this method to improve idle time and overtime, whilst not deteriorating waiting times. This because the start of the session will cause, on average, a small 'buffer' of patients, which should reduce the doctor's idle time, but the middle of the session offers the doctor a possibility to reduce this buffer, thus keeping waiting times reasonable, and the end of the session schedules patients shortly together in order to reduce the doctor's overtime.

The Bailey-Welch and the Dome-rule use the current appointment intervals as a standard. However, we determined in Chapter 2 that the appointment interval of 10 minutes for return patients does not fit the average time of 13.7 minutes spent per return patient very well. This difference effectively causes an implicit form of overbooking. To counter this effect, we decide to use improved appointment intervals for return patients. But, since intervals of 14 minutes lead to impractical appointment times, we decide to implement the improved appointment intervals by alternating appointment intervals of 10 and 15 minutes per return patient.

Using appointment intervals of 10 and 15 minutes leads to an average of 12.5 minutes, which is still less than the average time of 13.7 minutes. We deem this to be appropriate because the average time of 13.7 minutes includes preparation and quickly updating the administration of the patient. These activities can also be performed respectively prior to and after the patient has been treated. Moreover, the presence of no-shows and scheduled utilization of 75% lead to gaps in the consultation schedules. These gaps can be used to prepare for patients that are still to arrive, or to catch up on a backlog of patients.

Figure 10 shows the Bailey-Welch-rule, Dome-rule and improved appointment in a more visual manner when based on an individual block, fixed interval rule.

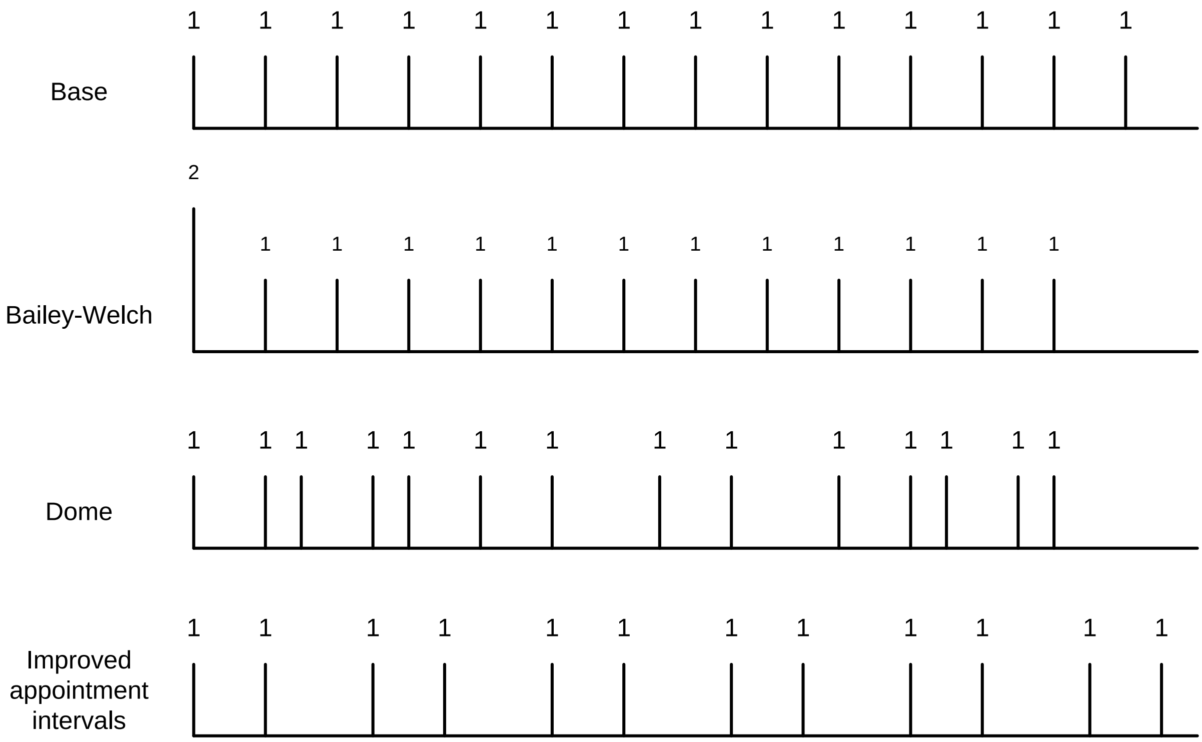


Figure 10: Visualization of the appointment rules. These schedules are based on only return patients.

3.2.2. *Patient classification*

In the current situation, new patients are divided evenly throughout the consultation session. In a sense, this corresponds to the alternating sequences as studied by Cayirli and Veral (2003) and Klassen and Rohleder (1996). Since this is the current situation, it is to be taken into account for comparison purposes.

Berg et al. (2014) and Klassen and Rohleder (1996) recommend to sequence patients with high no-show rates or high procedure duration variance later in the day. They report improvements in waiting time, idle time and overtime with the use of this sequencing. Another advantage of this sequencing intervention is the intuitiveness of its benefits, making it easier to create acceptance of the measure among its users if it is implemented.

The coefficient of variance is 0.44 for new patients, and 0.56 for return patients, so according to Berg et al. (2014) and Klassen and Rohleder (1996), new patients should be scheduled at the beginning of the consultation session.

In order to accommodate for the intervention where new patients are shared among doctors (Section 3.2.4), we also include patient sequences where new patients are pooled together in the middle of the consultation session and at the end of the session. These sequences correspond to scheduling all high variance patients at the beginning and end of the session, and scheduling all low variance patients at the end of the session, respectively, as the patient sequences have been tested by Klassen and Rohleder (1996). The ratio of new patients to return patients at the outpatient clinic is approximately 1:3, so there are not sufficient new patients to have entire clinic sessions using the new patient-pool. Therefore we decide to test the effect of scheduling four new patients in a row for at least two doctors simultaneously.

3.2.3. Adjustments to reduce disruptive effects

The literature describes no-shows, walk-ins, urgent patients and emergency patients as sources of disruptive effects. Urgent and emergency patients are not in the scope of this research. In consultation with management, we decide to treat no-shows as an uncontrollable environmental factor.

Sharing walk-in patients

In the current situation, walk-ins are coped with by a mechanism that is not mentioned in the literature: a separate doctor that is responsible for walk-in patients. However, historical data shows that on average 2.35 patients arrive per walk-in session, while the walk-in doctor has time scheduled for 7.5 patients. This means that the doctor responsible for the walk-in session has a lot of idle time. This shows in the gathered data: of the 2.5 hours that are scheduled for the session, the doctor is busy with walk-in patients on average 41% of the time.

Another possibility for taking care of walk-in patients is to stop using a dedicated walk-in doctor, and to let the doctors that are already available treat the walk-in patients. It is possible to schedule a few empty appointment slots for these doctors during their regular consultation sessions. We decide to evaluate this intervention with and without scheduling empty slots for walk-in patients.

Medical student appointments

Besides the sources of disruptions mentioned in the literature, another disruptive effect became clear from the analysis of the current situation: medical students attending consultation sessions and seeing new and/or walk-in patients. Having a medical student see patients costs time for a doctor, as Table 5 illustrates with the increased overtime and waiting time, and the decreased idle time. However, the differences that Table 5 shows are relatively small. The limited impact of medical student sessions in itself does not express a dire need for an intervention, but another side of the medical student sessions is that they also cause uncertainty for the medical students, as some have expressed during the research. With this in mind, we decide to include an intervention with scheduled medical student sessions, where all patients that will be seen by the medical student are asked to arrive early in order to facilitate a medical student consultation.

Table 5: Measured effects of medical student attendance for consultation session performance.

	With med. student (n=11)	Without med. student (n=42)
Avg. Patient waiting time [min]	11.4	10.0
Avg. Doctor overtime [min]	19.2	17.5
Avg. Idle time [min]	36.9	38.5

3.2.4. Controllable environmental factors

From the literature, we identified two possibilities for controlling environmental factors that might yield significant improvements; these are increasing the number of doctors that are allowed to treat a waiting patient, and improving the doctor’s punctuality.

Sharing new patients

In general, both patients and doctors prefer to keep a one-to-one patient-doctor relationship, so return patients are usually referred to a specific doctor. However, new patients that will be seen by a resident doctor do not yet have a patient-doctor relationship, so they do not have this restriction; they can be treated by any doctor.

However, in the current situation, the patient's treating doctor is immediately decided upon when the appointment is scheduled. This leads to an unnecessary loss of flexibility, which can be prevented by "sharing new patients" among doctors. This is effectively a multi-server queuing system, of which queuing theory proves that this results in shorter patient waiting times than with a single-server system (Cayirli and Veral, 2003).

When sharing new patients, the new patients are not yet assigned to a specific doctor when they arrive at the outpatient clinic, but they do have their own appointment slot. Which doctor will treat the patient depends on which doctor is available first. Patients are seen on a first appointment, first served basis.

Improving doctor's punctuality

Doctors are frequently late for the beginning of their consultation sessions. During data gathering, 66% of the consultation sessions started late, with a maximum of 55 minutes. There is agreement among researchers that patients' waiting time is highly sensitive to doctors' punctuality (Cayirli & Veral, 2003). Furthermore, we expect that the doctor being late also increases doctor's overtime, and decreases the doctor's idle time. Table 6 shows that, indeed, waiting time and overtime significantly increase and idle time decreases when doctors are late.

We believe that it should be possible to improve doctor's punctuality, preferably through creating awareness of its effects, so we decide to include it as an intervention.

Table 6: Measured effects of doctor punctuality on consultation session performance.

	Doctor on time (n=20)	Doctor late (n=39)
Avg. Patient waiting time [min]	4.2	12.2
Avg. Doctor overtime [min]	8.0	18.9
Avg. Idle time [min]	46.1	34.3

3.3. Conclusions

The question that this chapter set out to answer is:

What interventions can be made to the consultation scheduling system that are expected to improve the system?

The interventions that we determined might improve the system lie in the realm of appointment rules, patient classification, adjustments to the appointment system to reduce disruptive effects, and environmental factors that can be controlled. Table 7 shows a summary of the various intervention types and the interventions that they include.

Table 7: Summary of interventions.

Intervention type	Interventions
Appointment rule	Base, Bailey-Welch, Dome, Improved appointment intervals
Patient sequence	Base, NPP Early, NPP Mid, NPP Late
Sharing walk-in patients	True with empty slots, True without empty slots, False
Medical student appointments	True, False
Sharing new patients	True, False
Improve doctor's punctuality	True, False

4. SIMULATION

There may be several model types to analyze the interventions proposed in Chapter 3.

There are analytical and computer based models (Law, 2007). Analytical models are good for getting exact solutions for systems with simple relationships. Computer simulation models allow for higher levels of complexity in the model. Since our model includes several relationships with a high level of complexity and interdependencies, such as the relationships among medical student and doctor or among doctors when sharing new patients, we decide to use a computer simulation.

There are three dimensions of computer simulation models: Static vs. dynamic, deterministic vs. stochastic, and continuous vs. discrete (Law, 2007). Dynamic models represent a system as it evolves over time, in contrast to static models that simulate a system at a given point in time. In deterministic models, stochasticity of input variables is not taken into account, whereas stochastic models do account for the randomness of input variables. Discrete models represent systems of which the state changes because of instantaneous events, whereas continuous models change state continuously throughout the time.

Since the outpatient clinic changes over time, we need a dynamic model to simulate the system. The randomness of process durations is an important aspect to the performance of the clinic, so we need a stochastic model. Jun et al. (1999) argue that discrete event simulation is well suited for determining patient flows with healthcare simulations, so we decide to use a discrete event simulation. In particular, we use Tecnomatix Plant Simulation 11 (Siemens PLM Software) to make the computer simulation model.

In Paragraph 4.1, we introduce a conceptual model of the outpatient clinic. Paragraph 4.2 discusses the implementation of the model in a computer simulation model. In Paragraph 4.3, we discuss the model input. In Paragraph 4.4, we validate and verify the correctness of the representation that the model gives of the current situation.

4.1. CONCEPTUAL MODEL

This section presents the conceptual model which we use to simulate the outpatient clinic. We start with several diagrams that show the processes from various points of view. We then present a list of modeling assumptions.

4.1.1. PROCESS DIAGRAMS

Figure 11, Figure 12, Figure 13, and Figure 14 show the processes from the points of view (POV) of, respectively, the doctor, the patient, the medical student, and the walk-in doctor as we model the current situation.

The doctor's processes, as shown in Figure 11, change slightly when new or walk-in patients are shared among doctors. There are two differences. The first difference is that, when a doctor is about to prepare for a shared patient, the doctor also has to "claim" this patient for himself, to ensure that no other doctors try to see this patient. The second difference is in the way that the doctor determines whether he is done. In the case of shared walk-ins the doctor can only be finished if, in addition to the currently used rules, the walk-in time is over and the number of untreated patients in the system (waiting for, or being serviced at the counter) is smaller than the number of doctors still at the outpatient clinic. In the case of shared new patients, the doctor can only be finished if, in addition to the rules currently used, the number of non no-show new patients that is still to arrive is smaller than the number of doctors still at the outpatient clinic.

We assume a complete knowledge of which patients do or do not show up only for determining the doctor's finish time. We do this because it corresponds well to the measurements of the current situation, where time spent by a doctor waiting for a last patient that does not show up is not recognized since the time measurements are based on start and finish times of actions that are actually performed. For all other parts of the model, no prior knowledge of no-shows is assumed.

The medical student's process, as shown in Figure 13, also changes slightly when new or walk-in patients are shared among doctors. If the medical student sees a shared patient, he has to "claim" this patient for the doctor of which he is attending the clinic session. Also, since it is possible for the doctor to leave the clinic session while there might still be patients coming that can be seen by the medical student, the medical student has to leave when the doctor leaves.

In the case of medical student appointments, the medical student's process to determine which patient to see is also altered. Since it would be rude to let patients arrive early for a medical student session and then not let them be treated by the medical student, the medical student gives priority to patients with a medical student appointment.

These altered processes are visually represented in Appendix A.

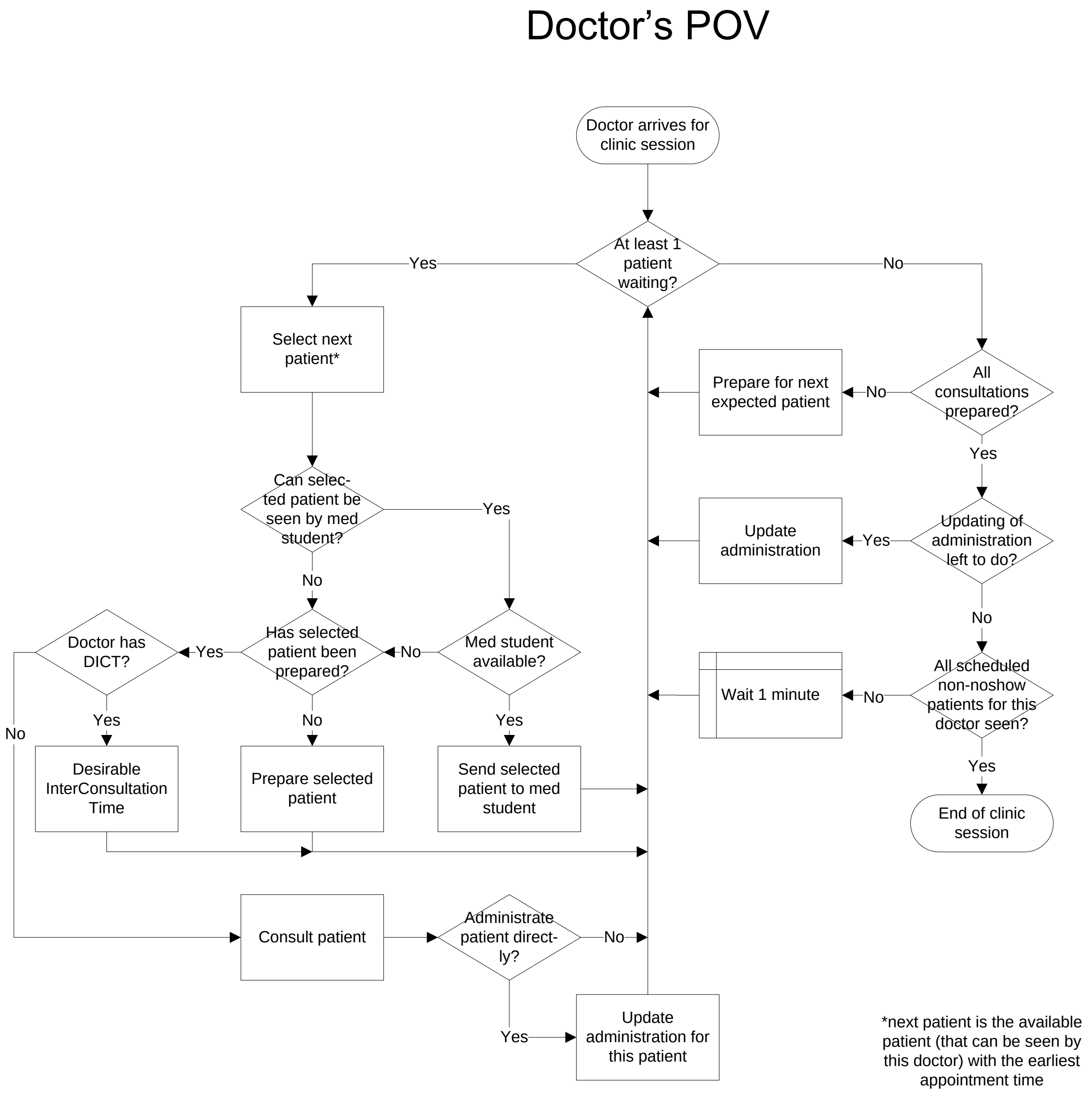


Figure 11: The doctor's process during a consultation session.

Patient’s POV

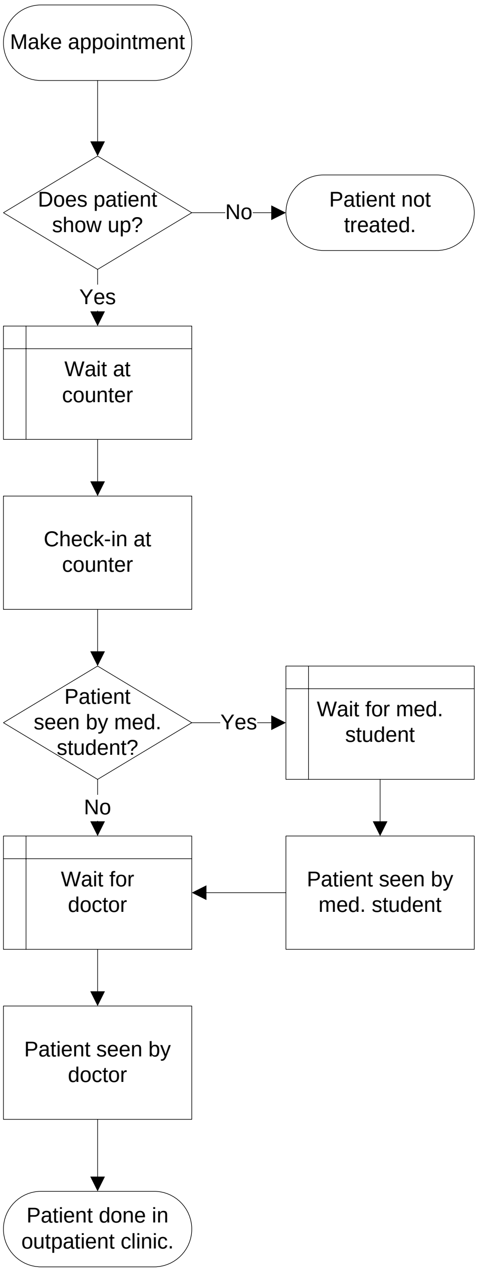


Figure 12: The patient's process in the outpatient clinic.

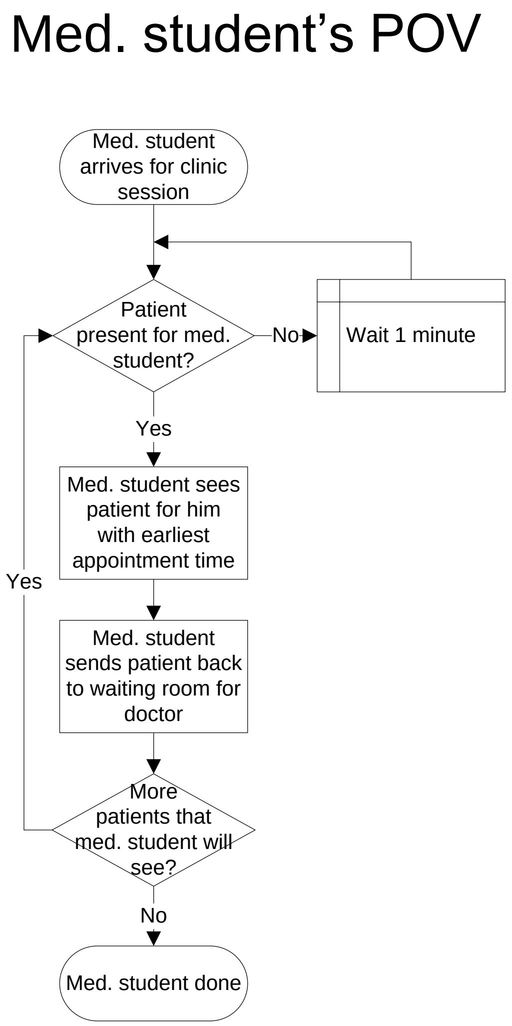


Figure 13: The medical student's process during a consultation session.

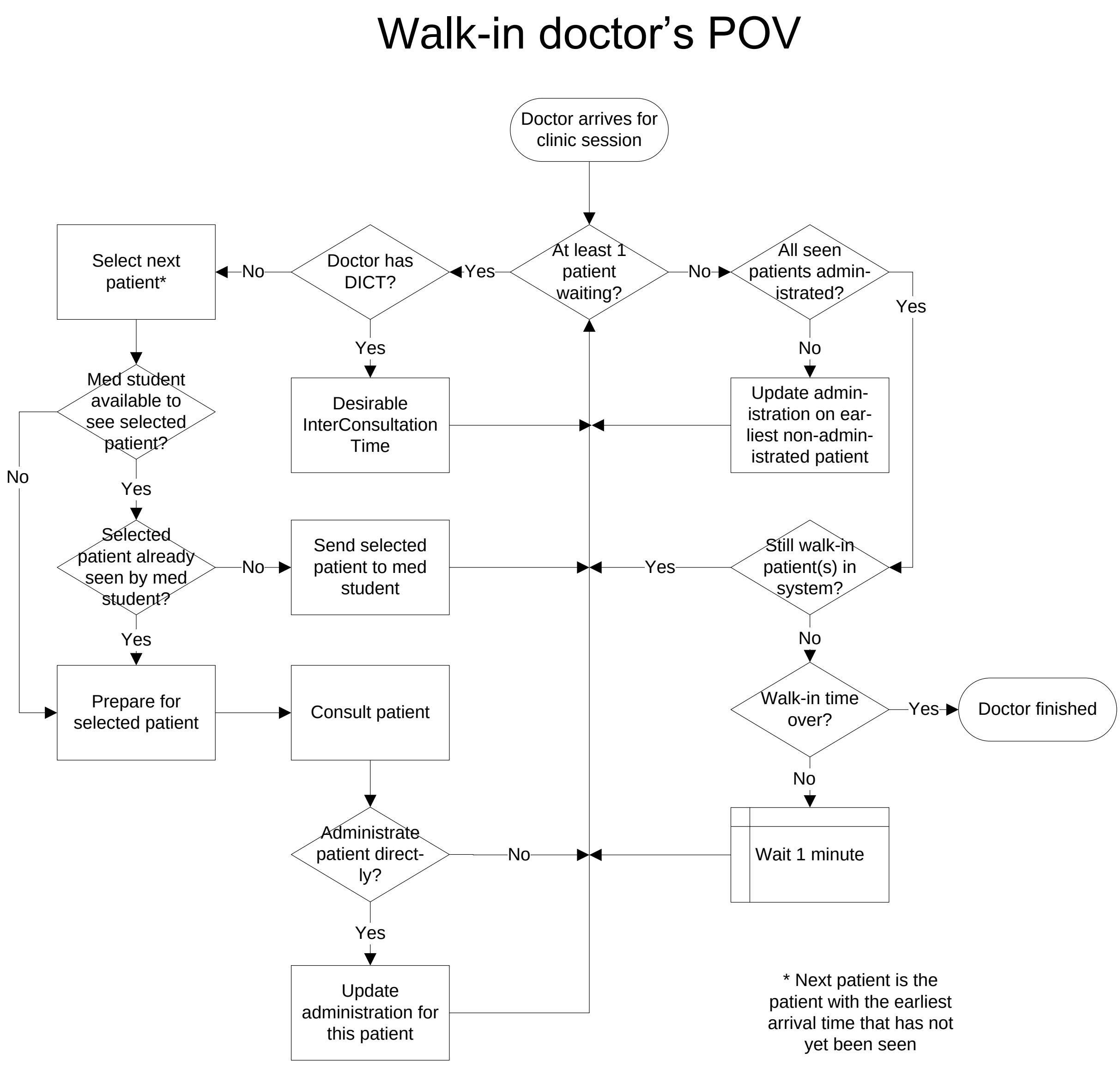


Figure 14: The walk-in doctor's process during a consultation session.

4.1.2. *List of modeling assumptions*

In the conceptual model and in the computer simulation model, we make the following assumptions:

- Processing times for the same process are always drawn from the same probability distribution. This means that employees do not speed up their work in the case of longer queues. While doctors at the outpatient clinic claim they do increase their working speed, the collected data do not show this.
- All doctors' processing times draw from the same probability distributions. This means that, in contrast to the real system, there is no structural difference between doctors. This does not reflect the actual situation, but it makes for an easier comparison between configurations and allows for better probability distributions of processing times, since there are more data to fit them to.
- Patients' punctuality is always drawn from the same probability distribution. So patients with appointments at for instance 8:20, 10:00, and 11:50 all have the same probability of arriving on time.
- The number of waiting patients does not influence the probability of doctors having desirable interconsultation time. We expect that this mostly reflects reality, since most activities that occur during desirable interconsultation time have to be performed anyway, such as consulting with a medical assistant or fixing a broken printer.
- Waiting rooms have unlimited capacity. Given that over the course of the research, no problems with waiting room capacity occurred, and if they would occur patients can wait in other places than the outpatient center, we expect that this reflects reality.
- It is not possible to overbook the schedule. In rare cases, schedulers book more appointments than the schedule allows for. However, this is not common practice and it is not the approved method. Therefore we feel that this reflects reality sufficiently.
- Walk-in patients have the same probability distribution for counter processing times as new patients. This assumption is made because of the small number of walk-in patients per day and the time it would take to gather enough data to make meaningful quantitative statements. The small amount of data on walk-in patients' counter processing times suggests that this assumption reflects reality.
- The walk-in doctor has no other duties aside from seeing walk-in patients. In real life, the walk-in doctor does have a few other responsibilities at the inpatient center. However, for the sake of simulating the outpatient center, we believe this assumption to be realistic.
- Medical students see all new and walk-in patients if they have the chance. No historical data are available about this. However, judging from conversations with a few doctors and medical students, this assumption is deemed to be reasonable for the simulation model.
- Medical students always arrive at the same time as the doctor. Medical students generally arrive early and then wait for the doctor.
- If medical students are not seeing any patients themselves, they are always available to see a new or walk-in patient. This assumption reflects reality.
- No patients that arrive are left untreated. This means that if a patient arrives 1 hour after the scheduled end of the consultation session, the doctor will still be waiting for them. This does not perfectly reflect reality. However, given the probability distribution used

for patients' punctuality, they rarely arrive very late in the model. Most of the time, if the doctor can spare the time, they would not mind waiting 10 minutes for a patient. Moreover, in real life, patients that arrive considerably late usually call to warn the doctor about their delay, so the doctors know if they have to wait.

- All decisions are made rationally and based on correct knowledge. So, for instance, doctors never forget a waiting patient. We expect that this assumption reflects reality.
- The arrival pattern of walk-in patients is distributed uniformly over the walk-in consultation hours. This assumption does not perfectly reflect reality, since walk-in patients seem to have a tendency of arriving at the start of the walk-in session. However, since walk-in patients only mildly influence general consultation sessions, and because this phenomenon is very hard to quantify because there are no historical data and there is a low number of walk-in patients per day, we assume this assumption is acceptable for the simulation model.
- Doctors prepare for all scheduled patients, so no-show patients that call beforehand are not taken into account in this. This assumption mostly reflects reality.
- Doctors do not spend time waiting for no-show patients at the end of a consultation session. This does not represent the real life situation perfectly, since not all no-show patients cancel their appointment. However, this assumption does allow for better comparison with the measurements of the current situation, which measured the end of a consultation session as the finish time of the last action, thus ignoring time spent waiting for no-show patients at the end of the consultation session.
- There is always one counter employee available to check-in patients. This reflects reality.
- If a doctor has no patients to see, he will always choose to prepare for a new patient before updating a patients administration. This generally reflects reality. If a doctor does not prepare for patients at the earliest possibility, this is most likely because he expects another possibility to prepare for the patients before they arrive. This means that this assumption would only shift around prepare time and idle times and not have an effect on the model outcome.

In cases where walk-in patients are shared among doctors, we make the following assumptions**:**

- Walk-in patients get an appointment time of arrival time + 10 minutes. This is equal to the expected waiting time to the next start of a 20-minute appointment interval.
- Medical students will claim walk-in patients for their doctor, regardless of the amount of regularly scheduled patients waiting for the doctor. This is probably not completely realistic.

When sharing new patients, we make the following assumptions:

- Any doctor will treat a waiting new patient if the patient's appointment time is earlier than that of the doctor's regular patients, regardless of differences in schedules between doctors. In reality, doctors might sometimes make agreements about the new patients to see based on the doctors' respective schedules. However, it is not unfair to treat the patient with the earliest appointment time, so this assumption is somewhat realistic.
- Medical students will claim new patients for their doctor, regardless of the amount of regularly scheduled patients waiting for the doctor. This is probably not completely realistic.

We make the following assumptions for the medical student appointments:

- Medical student appointments are 10 minutes earlier than the regular doctor's appointment. Given that patients are on average approximately 10 minutes early and the average time the medical student spends on a patient is 20 minutes, this 10 minutes should, on average, let the medical student finish on time for the patient's appointment.
- Medical students will always see a patient with a medical student appointment before seeing patients without appointment, regardless of appointment times. This reflects a form of courtesy that should be present in real life.
- In case of medical student sessions in combination with a New Patient Pool, only 2 non-consecutive new patients get a medical student appointment per medical student. This is also a form of courtesy, since medical students will likely not be able to see multiple patients with consecutive appointments.

4.2. MODEL IMPLEMENTATION

This section discusses the method used in the simulation model to create the consultation schedules in Paragraph 4.2.1, as well as the realization of the proposed interventions in Paragraph 4.2.2. For a brief manual on how to use the model, we refer the interested reader to Appendix B.

4.2.1. CONSULTATION SCHEDULE

The model simulates consultation schedules of 3 hours and 40 minutes. This corresponds to the duration of a morning session in the current situation. These schedules offer the time for appointment slots for 14 return patients and 4 new patients, which also corresponds to a current morning session. The basic schedules used by different doctors in the model are all the same.

In the model, the walk-in session starts 40 minutes after the first regular appointment time and it has a duration of 2,5 hours. This duration is also in line with the current situation.

In the current situation, the realized consultation schedules often have empty slots in between appointments. Two causes of this are that patients are, wherever possible, allowed to freely choose their own appointment slots (e.g. if only the first two appointment slots are taken, the next patient can easily schedule an appointment for the last appointment slot), and patients regularly reschedule their appointments, resulting in empty appointment slots. To mimic this effect, the model starts by creating a fully scheduled consultation schedule and subsequently checks for each appointment whether it will actually be scheduled, the probability of this is equal to the average scheduled utilization. The model also takes no-shows into account.

4.2.2. REALIZATION OF INTERVENTIONS IN SIMULATION MODEL

This section explains the ways in which the various interventions have been implemented into the simulation model, wherever this is not completely straightforward. This section uses the following notation, which is the same as used in Section 2.4.2, but augmented with a scheduled appointment duration:

Sets		Indices	
• P	Patients	• $p \in P$	Patient
• D	Doctors	• $d \in D$	Doctor

With these, we define the following parameters:

- Scheduled appointment start time S_p
- Scheduled finish of gross consultation time $E_{p,d}$
- Actual finish of gross consultation time $E'_{p,d}$
- Scheduled duration of appointment I_p

Appointment Rules

The appointment rules are implemented by altering the basic schedule on which the model bases the patient arrivals. For the Bailey-Welch and Dome rule, the basic appointment intervals are equal to the current standard of 10-minute appointments for return patients, and 20-minute appointment slots for new patients.

Implementing the Bailey-Welch rule does not create a lot of complicated situations. One change to the rest of the system is a small alteration to the calculation of overtime if both slots at the first appointment time are booked. This alteration compensates for the effect on overtime that a doubly scheduled first appointment slot has.

We did the following: If both appointments for the first appointment slot are scheduled, the overtime calculation takes the doubly scheduled time of the first appointment slot into account. Using the fact that S_1=S_2 if both appointments for the first appointment time are booked, this leads to the following calculation of a doctor's overtime when using the Bailey-Welch rule:

$$\text{if } S_1 = S_2 \text{ then: Overtime} = \max\left(0\,, E'_{P,d} - E_{P,d}\right)$$

$$\text{if } S_1 \neq S_2 \text{ then: Overtime} = \max\left(0\,, E'_{P,d} - E_{P,d} - I_2\right)$$

The Dome rule as proposed by Cayirli et al. (2006) leads to appointment times that are not multiples of 5 minutes, which is impractical in real life. Therefore we use a dome-rule that is similar in basic idea, but differs in the realization. Of the eighteen appointment slots, we reduce the scheduled duration of the first and third appointment by 5 minutes, then increase the scheduled duration of the seventh and tenth appointment by 5 minutes, and decrease the scheduled duration of the fifteenth and seventeenth appointment again by 5 minutes. Table 8 visualizes this.

As Table 8 shows, the last three appointment slots start earlier when using the Dome rule than with the base appointment rule. Since this difference is caused by a condensed consultation schedule under the Dome rule, it would give an unfair advantage to the base appointment rule if these earlier appointment start times are used for calculating overtime. In order to alleviate this unfair advantage, we make a small alteration to the overtime calculations for the Dome rule. If the last scheduled appointment in a clinic session is on one of the last three appointment slots, the overtime calculation uses the scheduled session finish time ($E_{P,d}$) of the corresponding appointment slot of the base appointment rule. For instance, when using the Dome rule, if the last scheduled appointment is the 18th appointment slot (the last appointment), we do not use $E_{P,d}$ = (11:40 + 0:10 =) 11:50, which could be expected from the data in Table 8, but we use $E_{P,d}$ =

(11:50 + 0:10 =) 12:00, which is the scheduled session finish time of the corresponding appointment slot of the base appointment rule.

For the improved appointment intervals, the aim is to better suit the scheduled appointment durations of control patients to the actual average duration. Doing this by using appointment durations of 13 or 14 minutes leads to impractical appointment times so we decide to alternate between 10 and 15 minute appointments for return patients. The drawback of this is that it leaves fewer appointment slots in the schedule. To counter this effect and still treat as many patients with the improved appointment intervals as with the other appointment rules, we delete three return patient appointment slots and increase the scheduled utilization such that the expected working time (20*#new patients + 10*#return patients) differs less than 1.5% from the base scenario. This means that simulations with and without improved appointment intervals have approximately the same workload per doctor.

Table 8: Schedules for the different appointment rules with the base patient sequencing. New patient appointments are in italic for a clearer overview. The italic appointments under the Dome-rule are the appointments with reduced and decreased durations.

Patient Type	Base	Bailey-Welch	Dome	Patient Type IAI	IAI
R	8:20:00	8:20:00	*8:20:00*	R	8:20:00
R	8:30:00	8:20:00	8:25:00	R	8:30:00
R	8:40:00	8:30:00	*8:35:00*	*N*	8:45:00
N	8:50:00	8:40:00	8:40:00	R	9:05:00
R	9:10:00	9:00:00	9:00:00	R	9:15:00
R	9:20:00	9:10:00	9:10:00	*N*	9:30:00
R	9:30:00	9:20:00	*9:20:00*	R	9:50:00
N	9:40:00	9:30:00	9:35:00	R	10:00:00
R	10:00:00	9:50:00	9:55:00	*N*	10:15:00
R	10:10:00	10:00:00	*10:05:00*	R	10:35:00
R	10:20:00	10:10:00	10:20:00	R	10:45:00
N	10:30:00	10:20:00	10:30:00	R	11:00:00
R	10:50:00	10:40:00	10:50:00	R	11:10:00
R	11:00:00	10:50:00	11:00:00	*N*	11:25:00
R	11:10:00	11:00:00	*11:10:00*	R	11:45:00
N	11:20:00	11:10:00	11:15:00		
R	11:40:00	11:30:00	*11:35:00*		
R	11:50:00	11:40:00	11:40:00		

Patient Sequencing

Similar to the appointment rules, patient sequencing is implemented by altering the basic schedule on which the model bases the patient arrivals. This research uses four different patient sequences; the base scenario, an early new patient pool, mid new patient pool, and a late new patient pool.

In the base scenario, new patients are scheduled evenly throughout the day. The new patient pools schedule all new patients in consecutive slots, either at the start of the session (NPP Early), in the middle of the session (NPP Mid), or at the end of the session (NPP Late).

Because the improved appointment intervals reduce the number of appointment slots in a consultation session, the patient sequence must also be altered. We choose to keep the number of appointments for new patients constant, and diminish the number of appointments for return patients. Table 9 visualizes these patient sequences.

Table 9: Visualization of the four patient sequences, and examples of two patient sequences under the improved appointment intervals rule. The new patient appointment are in italic for a clear overview. The underlined new patient appointments represent the patients that are eligible for a medical student appointment.

Patient sequence	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Base	R	R	R	*N*	R	R	R	*N*	R	R	R	*N*	R	R	R	*N*	R	R
NPP Early	*N*	*N*	*N*	*N*	R	R	R	R	R	R	R	R	R	R	R	R	R	R
NPP Mid	R	R	R	R	R	R	R	*N*	*N*	*N*	*N*	R	R	R	R	R	R	R
NPP Late	R	R	R	R	R	R	R	R	R	R	R	R	R	R	*N*	*N*	*N*	*N*
NPP Early (IAI)	*N*	*N*	*N*	*N*	R	R	R	R	R	R	R	R	R	R	R			
Base (IAI)	R	R	*N*	R	R	*N*	R	R	*N*	R	R	R	R	*N*	R			

Sharing new patients

For sharing new patients among doctors, new patients are no longer assigned to a doctor directly upon creation in the model. These new patients follow the normal pathway into the waiting room. When the patient is in the waiting room, either a doctor will decide to prepare for this patient or a medical student will decide to see the patient. In both cases, the patient will be "claimed" for this doctor, to ensure that this patient is not seen by another doctor. Doctors still decide which patient to see based solely on appointment time and whether the doctor can see the patient.

Sharing walk-in patients

Sharing walk-in patients is rather straightforward. As for the empty appointment slots, we choose five appointment slots uniformly spaced out over the duration of the walk-in session to leave unscheduled.

Medical student appointments

For the medical student appointments in the model, a check is made at the start of the day to see whether a medical student will be attending the consultation. If this is the case, several new patients for this consultation session get an appointment time of 10 minutes before their general doctor's appointment. We use the same probability distribution for the arrival time for medical student appointments as we use for normal appointments.

For the base patient sequence, all new patients get a medical student appointment. For the new patient pools, only non-consecutive new patients receive a medical student appointment. Since there are only four new patients per clinic session, this leads to two medical student appointments per session when using a new patient pool. The new patients that receive a medical student appointment are shown in Table 9.

Patients with a medical student appointment always get preference over new or walk-in patients without a medical student appointment.

Improving doctor's punctuality

In the current situation, doctors start their consultation sessions on average 5 minutes late, with a standard deviation of 10 minutes. For this intervention, we alter this probability distribution to a normal distribution with average -5 minutes and standard deviation 3 minutes.

4.3. Model input

In order to determine the probability distributions of input parameters used in the model, we collected data using time measurements of the consultation sessions. This was done in the same process as described in Section 2.4.1. We first determine input parameters for the model from these data in Section 4.3.1. Section 4.3.2 discusses the estimation of input parameters for which there were insufficient data available.

4.3.1. Input parameters fitted to collected data

The data we were able to collect apply to the doctor's preparation time for a patient, the consultation time for a patient, and the post-consult administration time. We also collected data on the doctor's punctuality, patient's punctuality, duration of registering at the counter, and duration of desirable interconsultation time. Table 10 presents the probability distributions we found to represent the input parameters. The goodness-of-fit of the probability distributions to the collected data is determined using Pearson's chi-square test.

Generally, a goodness of fit of less than 0.90 is considered low, so most of the fitted probability distributions have a low goodness of fit. We expect this is because measured preparation and administration durations are often 0, which makes it hard for probability distributions to approximate. Another reason for low goodness of fit-values is that the data sets used include data from multiple doctors, which means that the data actually stem from multiple probability distributions. However, given the low durations and decently approximating Q-Q-plots, we expect these distributions will yield decent results. The parameters for patient punctualities have a low goodness of fit because they were gathered on paper, where people often round times to the nearest multiple of 5. Given that all Q-Q-plots are approximately straight lines with x=y, and especially since the validation and verification of the model's in- and output (see Section 4.4) yield satisfactory results, we assume that any discrepancies between the actual and the fitted probability distributions are acceptable.

Appendix C shows an example of how we fitted the probability distributions to the collected data for the administration times of return patients.

Table 10: Probability distributions used in the model and fitted on collected data. Patient types shown are return (R), new (N) and walk-in (WI).

	Patient type	Probability distribution [min]	Goodness-of-fit
Preparation	R	Gamma, α = 0.39, β = 2.54	0.000
	N	Gamma, α = 0.65, β = 2.58	0.000
	WI	Normal, μ = 1.21, σ = 1.43	0.350
Consult	R	Gamma, α = 2.85, β = 3.67	0.221
	N	Gamma, α = 3.89, β = 4.00	0.957
	WI	Gamma, α = 4.63, β = 4.38	0.512
Administrating	R	Gamma, α = 1.02, β = 2.14	0.000
	N	Normal, μ = 2.81, σ = 2.36	0.453
	WI	Normal, μ = 2.66, σ = 2.07	0.843
Punct. Doc	-	Normal, μ = 5.40, σ = 10.49	0.966
Punct. Patient	R	Normal, μ = -9.08, σ = 22.29	0.000
	N	Normal, μ = -9.31, σ = 19.16	0.002
Counter Duration	R	Gamma, α = 4.19, β = 0.24	0.718
	N	Normal, μ = 2.36, σ = 0.58	0.931
DICT	-	Gamma, α = 1.73, β = 5.25	0.938

4.3.2. Estimated input parameters

There are some input parameters for which we were not able to collect the desired amount of data to determine a probability distribution using the abovementioned method, so we estimated their values. These are:

Inter-arrival times of walk-in patients

There are no data available on inter-arrival times of walk-in patients, so we assumed that they follow a negative exponential distribution, and estimated its labda by dividing the duration of the walk-in session (2.5 hours) by the average daily number of walk-in patients (2.27), which leads to a lambda of 66 minutes.

Consultation duration of medical students

We assume that the consultation durations of medical students follow a normal distribution. After asking a few employees, we estimated the durations to be on average 20 minutes, with a standard deviation of 8 minutes, minimum duration of 5 and maximum duration of 30 minutes.

Medical student attendance

There are no clear numbers on how often medical students attend a consultation session. By combining the opinion of a few employees and own observations, we estimated this to be around 30%.

Duration of registering at the counter for walk-in patients

While collecting the data on counter durations, only two walk-in patients arrived. This is not enough to determine a fitting distribution on. The data for these two patients fitted well with the data on new patients, so we assumed that the counter duration for walk-in patients follows that of new patients.

The no-show rate

There are historical data on the no-show rate available at the UMCU. However, these turned out to register only the part of the no-shows that did not reschedule for another appointment, so they are incomplete. Therefore we decided to use the data measured during data collection. This gives a no-show rate of 7%.

4.4. VALIDATION AND VERIFICATION

For quantitative verification and validation of the model, we use model outcome from runs with the model set such that it represents the current situation.

4.4.1. VERIFICATION

To verify the correctness of the conceptual model, we let two hospital employees carefully survey the conceptual model. They deem the conceptual model acceptable to simulate the current system.

Verification of the computer model's correctness has been performed through several techniques discussed by Law (2007). First, a basic model was written and debugged, after which additional levels of detail and complexity were added and debugged. Second, during the writing of the model, the output was regularly checked to be reasonable for a variety of settings. If the output did not seem reasonable, we debugged the model. Third, where possible, animations of the model were checked for correctness of model flow. As Law (2007) recommends, the model is written in a commercial simulation package to reduce the amount of programming required.

Lastly, we verify the correctness of model input. Table 11 shows the historical mean and variance, as well as the mean and variance of the model input. There are some minor differences between model input and historical data. The largest differences occur because a normal probability distribution best suits the data, but in order to use this distribution in the model, negative values are cut off at zero.

Table 11: Historical and simulated averages and standard deviations of input distributions for the model.

	Input distribution	Historical mean [min]	Historical standard deviation [min]	Model mean [min]	Model standard deviation [min]
Preparation duration [min]	New patients	1.7	2.1	1.7	2.0
	Return Patients	1.0	1.6	1.0	1.6
	Walk-in patients	1.2	1.4	1.4	1.2
Consultation duration [min]	New patients	15.5	7.9	15.5	7.9
	Return Patients	10.5	6.2	10.5	6.2
	Walk-in patients	20.3	9.4	20.2	9.4
Administration duration [min]	New patients	2.8	2.4	3.0	2.1
	Return Patients	2.3	2.5	2.2	2.2
	Walk-in patients	2.7	2.1	2.8	1.9
	Daily number of walk-ins [patients/day]	2.3	1.7	2.3	1.5
	Desirable Inter-Consultation Time [min]	9.1	6.9	9.0	6.9
	Scheduled utilization	75%	20%	75%	11%

4.4.2. Validation

To validate correctness of the computer model, we compare the model output for the current situation with the data that was gathered on the real system, as Table 12 shows.

Table 12: Historical and simulated mean and standard deviations of performance data.

	Historical mean	Historical standard deviation	Model mean	Model standard deviation
Patient waiting time	10.0	11.4	10.0	5.8
% waiting < 15 min	73%	-	75%	-
Doctor's idle time	38.2	30.2	42.4	17.4
Doctor's overtime	18.0	16.9	23.3	12.9
Walk-in waiting time	14.0	17.4	12.2	14.7
Walk-in idle time	88.3	28.9	99.3	32.8
Walk-in overtime	14.6	20.2	10.3	17.3

From Table 12, we conclude that the overall model predictions are acceptable. Average waiting time is predicted exceptionally well. The simulated idle time and overtime are not very accurate, but are in the same neighborhood as the measured data. The average walk-in waiting time is also predicted fairly well, and walk-in idle time and overtime also comes close to the measured data.

We identify the following reasons for differences between historical data and simulated data:

- The scheduled utilization (see Table 11) in the model is equal to the measured data on average, but its standard deviation is relatively low. Since this is an important factor for the whole model, this leads to lower standard deviations in the output.
- The measured data do not come from a very extensive research. For instance the output values of the walk-in sessions are based on less than 10 consultation sessions, so it is possible that the presented historical mean are not the actual system mean.
- Doctors claim that, when they are presented with a busy consultation session they try to treat patients more quickly than when they have a low scheduled utilization. Although this was not clearly visible in the collected data, this may explain the lower overtime in the measured data, since we did not include this in the simulation model.
- The walk-in idle time was calculated differently in the model than in the measured data, since there was more data available in the model to support better calculations.
- In reality, walk-in patients appear to have a predisposition to arriving at the start of the walk-in session. We do not include this in the model because there are not enough data avalailable to make quantitative conclusions about this, and because of the low number of walk-in patients (a little over 2 per day) these data take a longn time to gather. This partially explains the lower walk-in waiting time in the model.
- In the collected data, the walk-in doctor sometimes saw other, non walk-in patients. While these treatments were not included in the calculation of waiting times, they may have meant an increase to the walk-in overtime and walk-in waiting times.

5. Analysis of results

This chapter sets out to determine the effects of the interventions discussed in Chapter 3, based on their representation in the simulation that Chapter 4 presents. In Section 5.1, we determine the experimental design. Section 5.2 analyses the model's output. In Paragraph 5.3, we perform a sensitivity analysis of the best combinations of interventions. We present conclusions of this chapter in Paragraph 5.4.

5.1. Experimental design

For the experimental design, as Law (2007) suggests, we first determine the run length, warm up period and number of replications required to achieve the desired level of confidence of the model output. We also determine the various combinations of experimental factors that we examine with the simulation model.

At the start and end of every working day, there are no patients in the model. This means that the model is a terminating simulation. Since this is the case, the run length is automatically determined to one consultation session. Since the simulated consultation sessions are independent from each other, the simulations do not have a warm up period.

5.1.1. Number or replications per experiment

To determine the number of replications needed to achieve a given relative error, we use the following method, as proposed by Law (2007). The smallest n for which $\frac{t_{n-1,1-\alpha}\sqrt{S^2/n}}{\bar{X}} < \gamma'$ holds must be calculated. In this formula, n is the number of replications, $t_{n-1,1-\alpha}$ is the student t-value for (n-1) degrees of freedom and a confidence level of (1-α), S^2 is the variance in the n replications, and $\bar{X}$ is the average of the n replications, and γ' is the corrected relative error. The outcome is calculated in an iterative manner. We use a confidence level (1-α) of 95% and relative error (γ) of 0.05. But, when using γ as estimate for the relative error, the actual relative error will be at most γ/(1-γ). Hence, in the calculations the corrected target value γ' = γ/(1+γ) will be used, so the actual relative error will be at most γ. In this case, γ'= 0.05/1.05 = 0.0476.

We use this method to determine the required number of replications to achieve this desired relative error on the most important model outcomes: waiting time, overtime and idle time. We determine this for the model that represents the current scenario. From Table 13 we see that waiting time is the outcome that needs the most replications to achieve the target relative error, namely 534. For aesthetic reasons we round this amount of replications up to 550.

Table 13: Minimum number of replications required to achieve the desired relative error for model output.

	Number of replications	Test result	Larger or smaller than γ?
Waiting time	533	0.04763	larger
	534	0.04755	smaller
Overtime	447	0.04766	larger
	448	0.04760	smaller
Idle time	346	0.04774	larger
	347	0.04759	smaller

5.1.2. *COMBINATIONS OF EXPERIMENTAL FACTORS*

There are no mutually exclusive experimental factors that we propose. This means that we can combine all experimental factors, which leads to 384 different experiment configurations (shown in Appendix D) that we study with the simulation model.

Two interventions reduce the number of appointments that can be scheduled: Improved appointment intervals, and having empty slots for walk-in patients. To counter this effect, we change the utilization of experiments that employ these measures, such that the average scheduled time spent on patients (20*#new patients + 10*#return patients) differs at most 1.5% from the base-scenario.

5.2. OUTPUT ANALYSIS

We analyze three combinations of experiments: Experiments where only appointment rules and patient sequences differ, experiments without sharing walk-in patients, and experiments with sharing walk-in patients. We analyze appointment rules and patient sequencing separately, because these are the simplest interventions to implement. We split the experiments based on method of dealing with walk-in patients because they differ in terms of input; sharing walk-in patients has the advantage that it does not take up the time of the walk-in doctor, but because there is one less doctor and all patients still have to be treated, the patients' waiting time and doctors' overtime will naturally increase. Figure 15 visualizes the analyses in this chapter.

In order to keep the graphs clearly readable, most graphs in this section have axes that do not start at 0.

In order to keep the size of tables manageable, we use the following abbreviations in the tables:

- EN Experiment Number
- AR Appointment Rule
- PS Patient Sequence
- SNP Shared New Patients
- DPu Doctor's Punctuality
- MSA Medical Student Appointments
- PDA Probability of Directly Administrating
- RW Relative Waiting time
- Wait Average waiting time
- Idle Average idle time
- Over Average overtime
- BW Bailey-Welch
- SWiP Shared Walk-in Patients
- ESWiP Empty Slots for Walk-in Patient
- RDP Relative Doctor's Performance
- Impr. Improved (DPu)

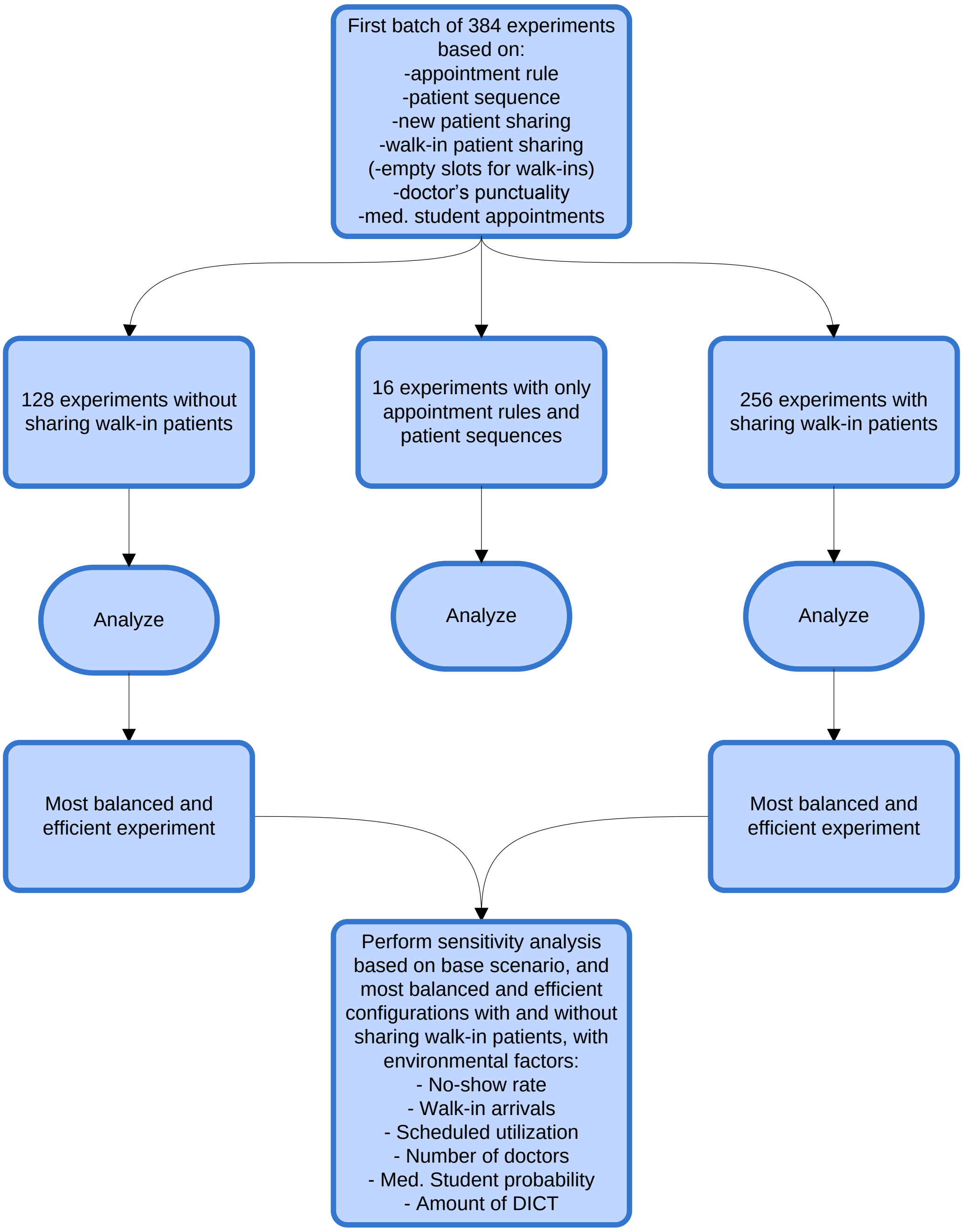


Figure 15: Visualization of the analyses performed.

5.2.1. Doctor's performance

In order to be able to clearly analyze the trade-off between the patient-related performance indicator Waiting time, and the doctor-related performance indicators Idle time and Overtime, we use a weighted average of Idle time and Overtime, called the Doctor's performance.

In all experiments, equal numbers of patients are treated. Doctors can use idle time during consultation sessions for other activities, such as consultation with colleagues, answering e-mails, or making phone calls. If doctors have overtime, chances are that they are late for consecutive appointments. Therefore, similar to Cayirli et al. (2006), we value overtime to be twice as important as idle time. This leads to the following formula for Doctor's Performance (DP):

$$DP = Idle + 2 * Over$$

In order to make this value easier to use for comparison, we define the Relative Doctor's Performance (RDP) as follows:

$$RDP = \frac{DP}{DP\ base\ scenario}$$

We use this RDP for the Patient-Doctor trade-offs. Since the specific calculation of RDP might influence results, Section 5.3.12 analyzes the sensitivity of the model outcome for changes in RDP calculation.

5.2.2. ANALYSIS OF APPOINTMENT RULES AND PATIENT SEQUENCES

Figure 16 and Figure 17 plot the relative waiting time and RDP for all experiments that differ only on appointment rule and patient sequence from the base scenario. Both figures show the same data points, but Figure 16 shows the experiments ordered by patient sequencing, and Figure 17 orders the experiments based on appointment rule.

From this, we see that the appointment rules have a more distinct effect on the performance of the system than the patient sequences. This is unexpected, since Cayirli et al. (2006) report that their most relevant finding is sequencing decisions have a bigger impact on clinic performance than appointment rules. This probably has to do with the relatively low number of new patients in our schedule.

There are only four configurations that simultaneously improve the system's waiting time and overtime. These are all settings with improved appointment times. The Bailey-Welch rule consistently improves the doctor's performance, but it does so at the cost of patient's waiting time.

The base appointment rule generally outperforms Bailey-Welch and Dome on waiting time, but combines this with worse doctor's performances.

There is only one configuration that is worse than the base scenario on both relative waiting time and relative doctor's performance, this is the configuration with a new patient pool in the middle of the session and the base appointment rule.

Besides the Bailey-Welch rule, the late new patient pool also shows the largest improvements to the doctor's performance, but is only able to improve the waiting time when combined with improved appointment intervals.

Of the 16 combinations of appointment rules and patient sequences, experiment 4 and 14 are the most efficient. Experiment 4 consists of the base patient sequence with improved appointment intervals, and configuration 14 has the late new patient pool, combined with the Dome rule.

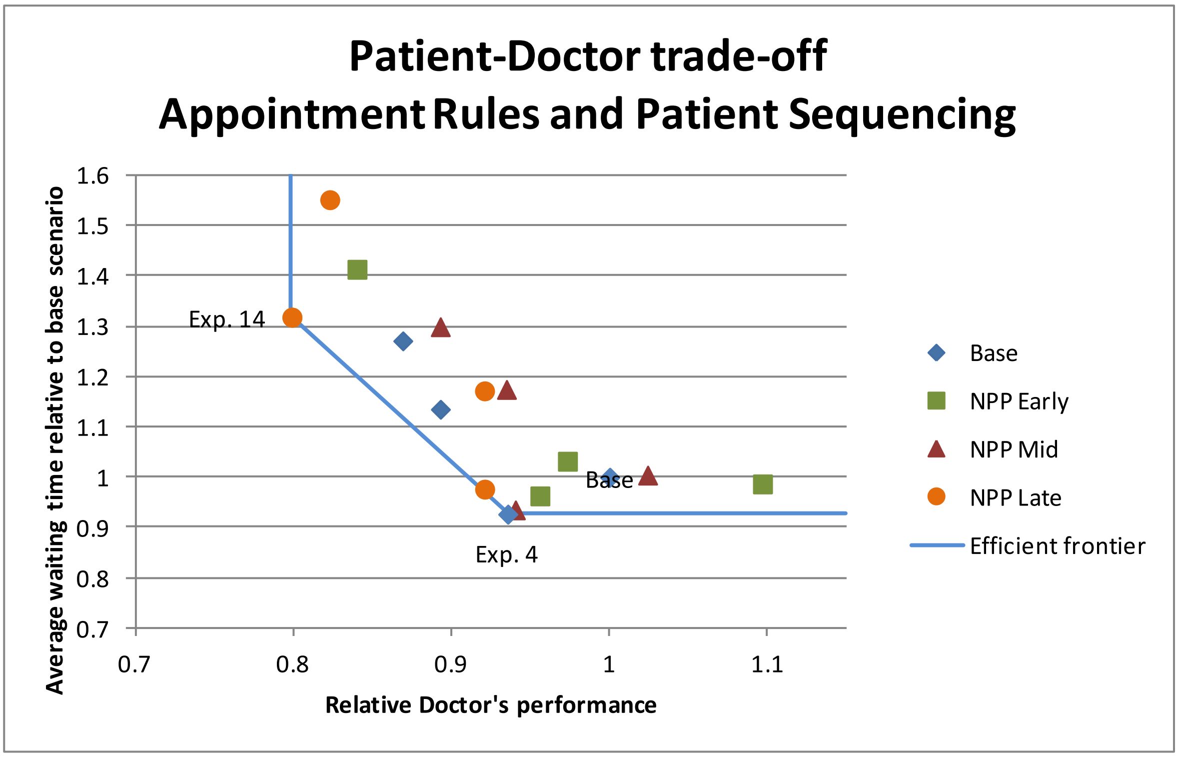


Figure 16: Patient-Doctor trade-off of experiments 1-16, ordered by patient sequence.

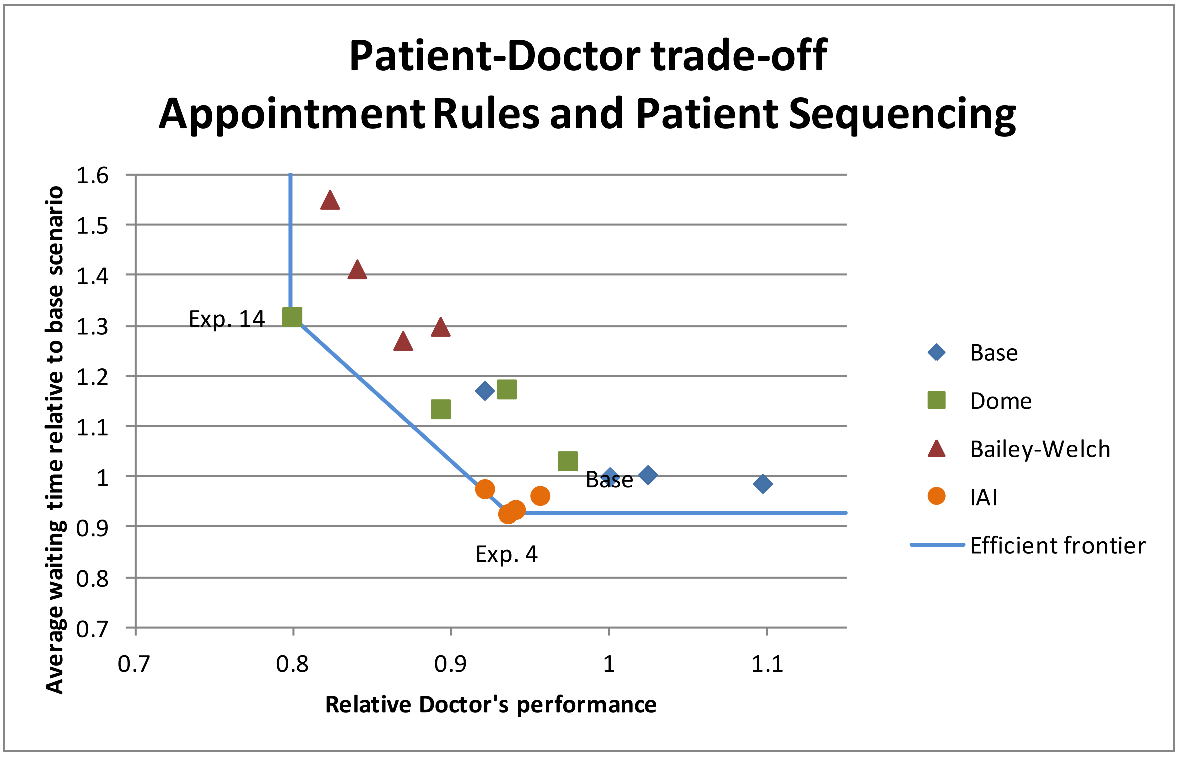


Figure 17: Patient-Doctor trade-off of experiments 1-16, ordered by appointment rule.

5.2.3. *Analysis of experiments without shared walk-ins*

This section analyzes the best performing experiments that do not include sharing walk-in patients; this corresponds with experiments 1 to 128 in Appendix D. We start with analyzing the best performing settings on the individual performance indicators waiting time, idle time and overtime. Subsequently, we evaluate which settings perform best when attention is paid to average waiting time and the RDP.

Waiting time

Waiting times in these experiments vary from roughly 6.5 minutes per patient to 15 minutes, with a corresponding 85% and 61% of patients being treated within 15 minutes.

Table 14 and Figure 18 show the five settings that perform best on waiting time, along with the base scenario for comparison. It is noteworthy that all best performing settings for waiting time employ a late or mid New Patient Pool and improved appointment intervals, and that most of the best performers combine this with sharing new patients.

The 95%-confidence intervals in Figure 18, show that the waiting times of the five best performers cannot be said to be different with 95% confidence, but they all outperform the base scenario.

Sharing new patients improves waiting times for all configurations that use a new patient pool, and for most of the configurations with a base patient sequence that have the current doctor's punctuality. The largest improvements to waiting time caused by sharing patients happen with configurations which have a high waiting time when not sharing patients, such as with configuration 23 and 7 (both Bailey-Welch with early new patient pool), with waiting times of 13:53 and 13:46 minutes, which achieve improvements to waiting time of respectively 13% and 12%. However, for configurations that already perform well on waiting time, sharing new patients does not cause such generous improvements.

For the waiting time, it appears to be of paramount importance that the doctor arrives on time. This shows in the top performers that all have improved doctor's punctuality, but also in the rest of the data: If the doctor arrives on time, the average patient's waiting time is 2 minutes and 40 seconds lower than if the doctor's punctuality follows the current situation. The effect is also clearly visible in Figure 19, where all configurations with an improved doctor's punctuality have been marked with a yellow circle.

Table 14: The five best performing configurations without sharing walk-in patients for waiting time. The base scenario is included for comparison.

EN	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over
108	IAI	NPP Mid	False	Impr.	True	False	False	06:28	49:37	19:55
112	IAI	NPP Late	False	Impr.	True	False	False	06:34	43:37	25:05
124	IAI	NPP Mid	False	Impr.	True	False	True	06:37	49:24	20:11
44	IAI	NPP Mid	False	Impr.	False	False	False	06:39	48:51	19:31
128	IAI	NPP Late	False	Impr.	True	False	True	06:41	42:58	24:06
1	Base	Base	False	Current	False	False	False	09:44	42:16	22:55

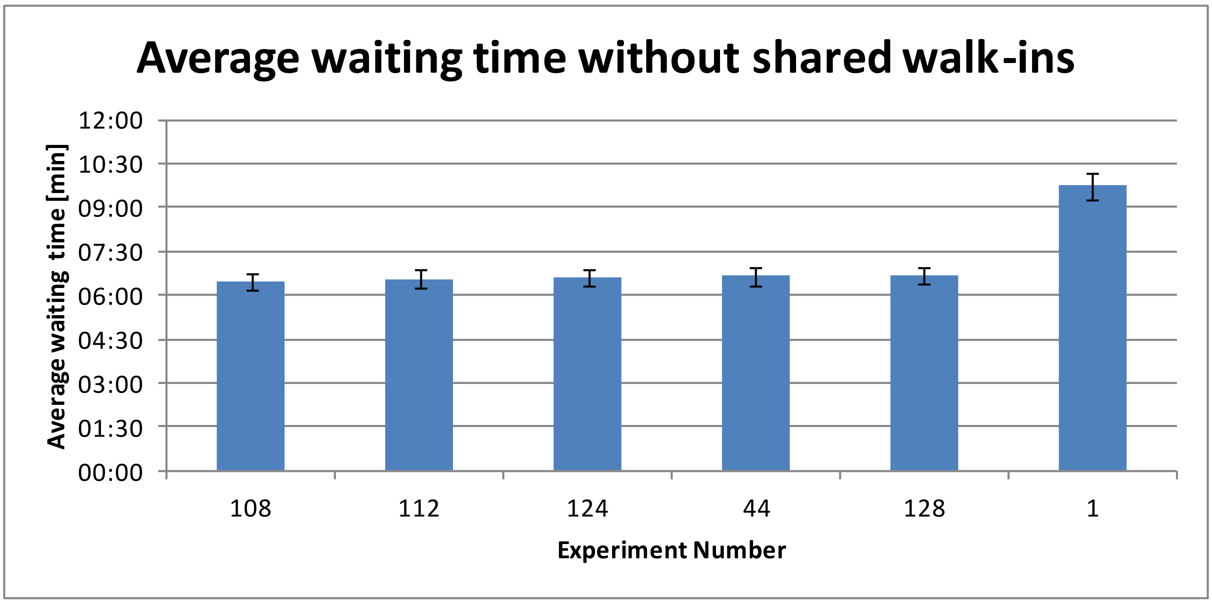


Figure 18: The five best performing configurations without sharing walk-in patients for waiting time. The base scenario is included for comparison. The black brackets show the 95% confidence interval.

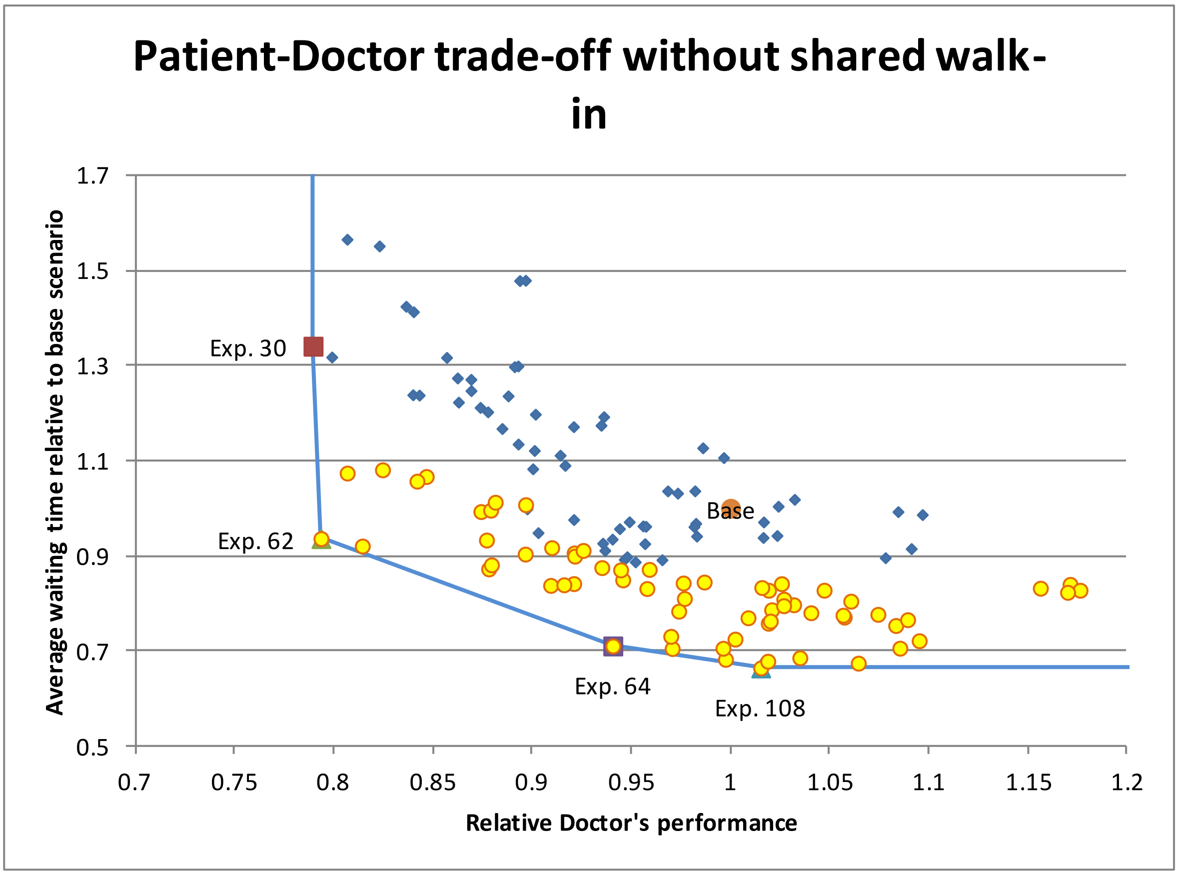


Figure 19: Patient-doctor trade-off of configurations without shared walk-in. Experiments with an improved doctor's punctuality are marked with a yellow circle.

Idle time

The doctor's idle time is the performance measure with the largest range in these experiments, ranging from approximately 26 to over 55 minutes. Table 15 and Figure 20 show the results of the best performing experiments for idle time, along with the base-scenario for comparison.

It immediately stands out that experiments that use the Bailey-Welch or the Dome rule outperform the others on this performance measure. This is as expected, since these rules basically create a small buffer of patients in the beginning of the session, which ensures that patients are waiting and the doctor does not have to wait.

All best performers also employ the late new patient pool. This patient sequence creates a similar mechanism as the Bailey-Welch and the Dome rule. All patients in the beginning of the session are return patients, which have a scheduled appointment time that is a bit lower than the actual time it takes to treat them. This gradually creates a small buffer of patients, which reduces the doctor's idle time.

All best performers use the current doctor's punctuality. This makes sense, since there will be more patients waiting for the doctor when he is late, and so the doctor has to wait less.

Sharing new patients also appears to be beneficial to the doctor's idle time. This is most likely because doctor's can fill their idle time with another doctor's patients, which will not increase the other doctor's idle time if he is already overbooked.

Sharing new patients only has a profound effect on idle time of configurations that use a late new patient pool, with decreases in idle time in the range of 3 to 4 minutes. For all other patient sequences the effect of sharing new patients on idle time ranges from a decrease of 1 minute to an increase of 1 minute.

Table 15: The five best performing configurations without sharing walk-in patients for idle time. The base scenario is included for comparison.

EN	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over
95	BW	NPP Late	False	Current	True	False	True	14:25	25:53	26:33
79	BW	NPP Late	False	Current	True	False	False	14:24	26:02	26:21
94	Dome	NPP Late	False	Current	True	False	True	12:25	28:21	23:48
78	Dome	NPP Late	False	Current	True	False	False	12:09	28:43	23:56
31	BW	NPP Late	False	Current	False	False	True	15:15	29:51	20:36
1	Base	Base	False	Current	False	False	False	09:44	42:16	22:55

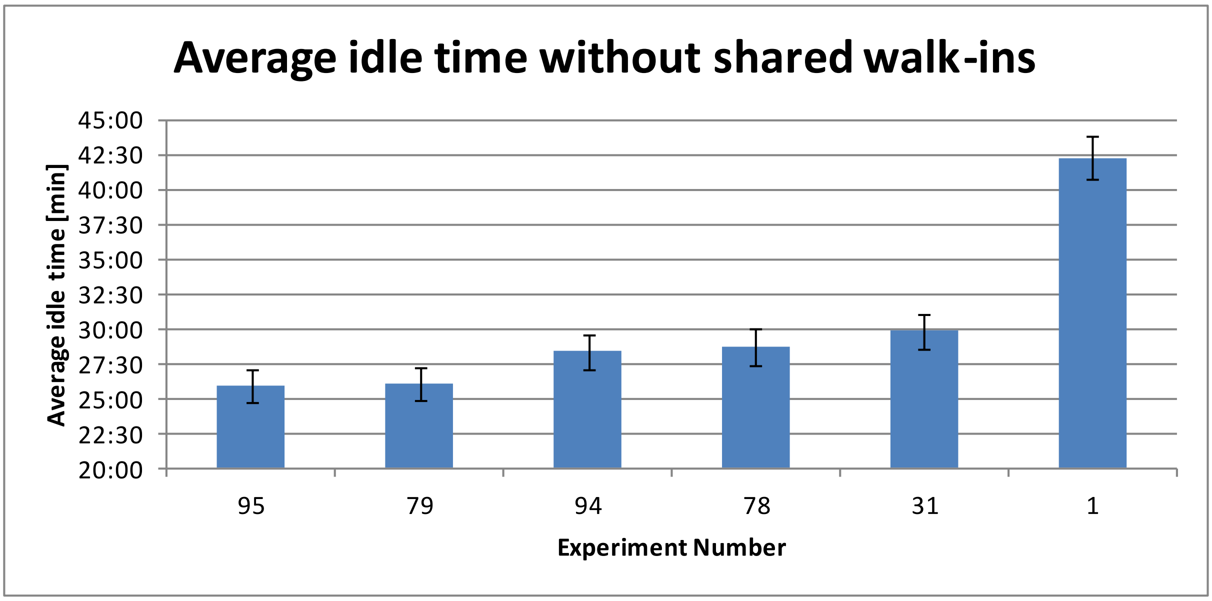


Figure 20: The five best performing configurations without sharing walk-in patients for idle time. The base scenario is included for comparison. The black brackets show the 95% confidence interval.

Overtime

Table 16 and Figure 21 show the results of the five best performing experiments on overtime, along with the base scenario for comparison. The experiments' overtimes range from 15.5 to 27.5 minutes.

From Table 16, we see that the Bailey-Welch and dome rule appear to be best for reducing overtime. This is not unexpected, since both appointment rules overbook part of the schedule, in favor of the end of the consultation session. None of the best performers use a early or mid new patient pool. This most likely stems from the fact that letting more return patients arrive early on in the consultation session slightly overbooks the beginning of the schedule, which is favorable for the session's overtime.

We also see that having the doctor arrive on time is best for a low overtime. This also shows in the rest of the data; an improved doctor's punctuality decreases the doctor's overtime on average by 10%.

While sharing new patients offered good improvements to the idle time of configurations with a late new patient pool, this is the other way around for overtime. Sharing new patients when using a late new patient pool increases overtime with on average 5.3 minutes. This may come from the way in which it is determined that the doctor is finished with a clinic session. If a doctor has to wait for some new patients that eventually turn out to be seen by other doctors, this can cause increased overtime. This also explains why the combination of improved appointment intervals and the base patient sequence shows worsened overtime when sharing new patients, because for that schedule the next-to-last appointment slot is for new patients, which increases the chances of a new patient being the last scheduled patient.

That the combination of dome and late new patient pool performs so well on overtime, may also have something to do with the way overtime is calculated. If the last scheduled patient is a no-show, the other patients can run late for the duration of the no-show's appointment, without it being considered as actual overtime. With the late new patient pool, the last scheduled patient is generally a new patient, which means that other patients have 20 minutes extra to run late, instead of the normal 10 minutes caused by return patients. For the dome-rule, these 20 minutes even turn into 30 minutes to compensate for the compressed schedule. This is part of the reason that these configurations perform so well on overtime.

From the 95%-confidence bars in Figure 21, we find that the average overtime of experiment 62 cannot be distinguished from the second and third performing configurations on a 95%-confidence level, but that the best performing experiment is better than experiments 50 and 51 on the same confidence level. All best performing experiments for overtime generously improve on the base scenario.

Table 16: The five best performing configurations without sharing walk-in patients for overtime. The base scenario is included for comparison.

EN	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over
62	Dome	NPP Late	False	Impr.	False	False	True	09:07	38:49	15:32
46	Dome	NPP Late	False	Impr.	False	False	False	08:58	39:35	16:05
63	BW	NPP Late	False	Impr.	False	False	True	10:28	36:18	17:23
50	Dome	Base	False	Impr.	False	False	True	08:12	45:44	17:42
51	BW	Base	False	Impr.	False	False	True	09:05	41:42	17:47
1	Base	Base	False	Current	False	False	False	09:44	42:16	22:55

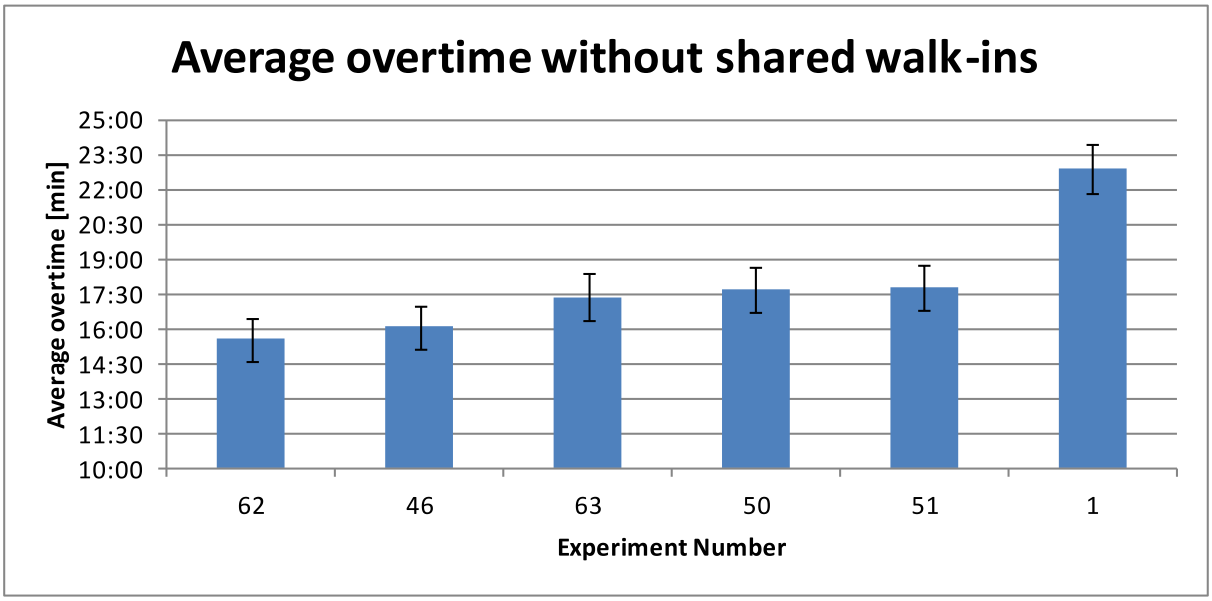


Figure 21: The five best performing configurations without sharing walk-in patients for overtime. The base scenario is included for comparison. The black brackets show the 95% confidence interval.

Patient-Doctor Trade-off

Figure 22 shows a graph that plots the average waiting time of patients (relative to the waiting time in the base scenario) versus the, previously explained, RDP. In order to compare the results on average waiting time and RDP, we plot the efficient frontier as is shown in Figure 22. From this, we see that four different configurations are 100% efficient. These are shown in Table 17, along with the base scenario for comparison.

Table 17: The four fully efficient experiments without sharing walk-in patients. The base scenario is included for comparison.

EN	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over	RDP	RW
30	Dome	NPP Late	False	Current	False	False	True	13:04	32:04	18:45	79%	134%
62	Dome	NPP Late	False	Impr.	False	False	True	09:07	38:49	15:32	79%	94%
64	IAI	NPP Late	False	Impr.	False	False	True	06:55	45:47	18:33	94%	71%
108	IAI	NPP Mid	False	Impr.	True	False	False	06:28	49:37	19:55	102%	66%
1	Base	Base	False	Current	False	False	False	09:44	42:16	22:55	100%	100%

Figure 22 shows that there are only 2 configurations that the base scenario outperforms on both waiting time and doctor's performance. These are configuration 9 and 25, very similar configurations; both use the base appointment rule, mid new patient pool, no patient sharing, and current doctor punctuality. The difference between them is that configuration 25 uses medical student appointments, where configuration 9 does not.

From Table 17, we see that both configurations that perform best on RDP use a Dome rule combined with the late new patient pool. Both configurations that perform well on waiting time use improved appointment intervals.

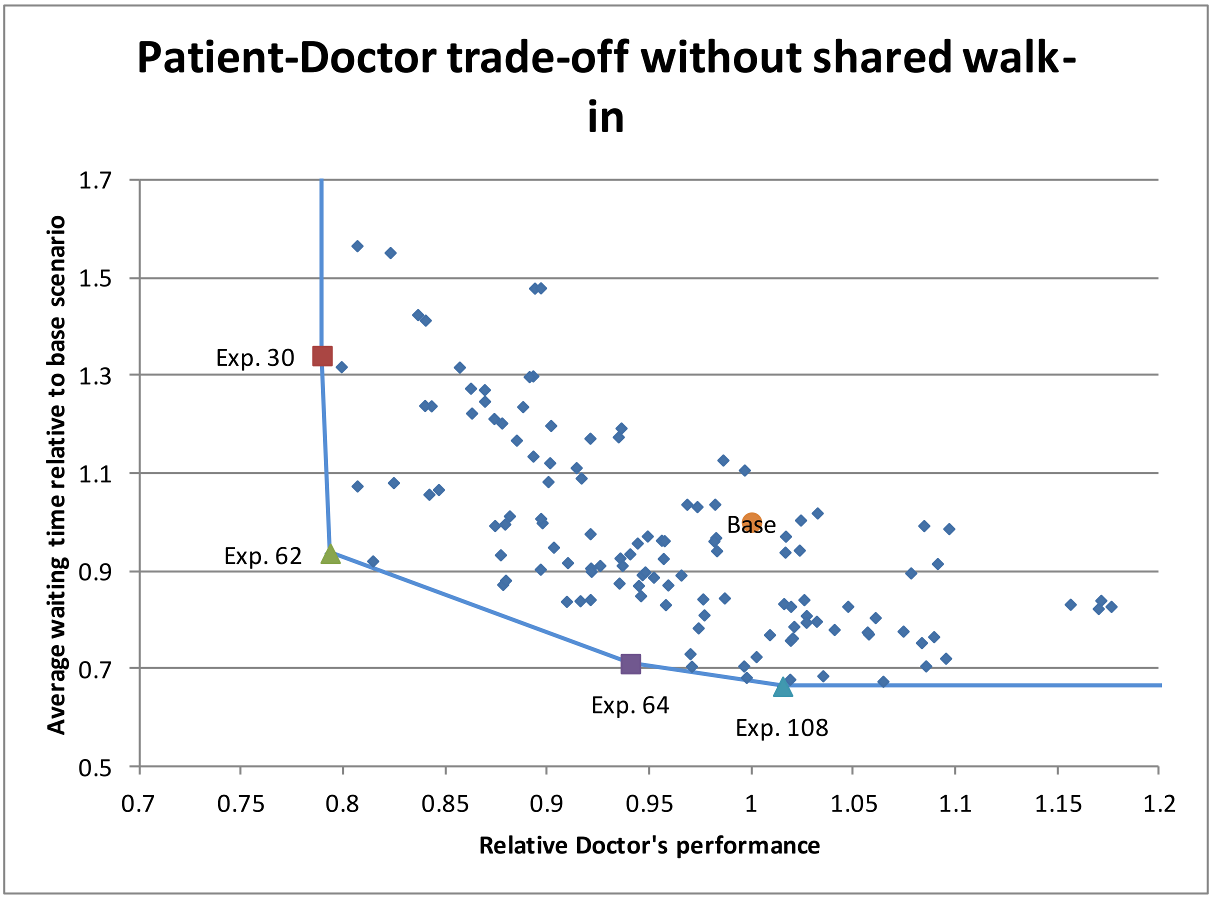


Figure 22: The efficient frontier of experiments 1 to 128.

5.2.4. *ANALYSIS OF EXPERIMENTS WITH SHARED WALK-INS*

This section analyzes the best performing experiments that do include sharing walk-in patients; this corresponds with experiments 129 to384 in Appendix D. We start with analyzing the best performing settings on the individual performance indicators waiting time, walk-in waiting time, idle time, and overtime. Subsequently, we evaluate which settings perform best when attention is paid to average waiting time and the RDP.

Waiting time

Figure 23 and Table 18 show the five best performing experiments on waiting time, along with the base scenario for comparison.

Just as with the best performing configurations without shared walk-in patients, improved appointment intervals with a late or mid new patient pool perform best in terms of waiting time. This time all best performers share new patients.

Empty slots for walk-in patients and medical student appointments appear not to make a large difference for the waiting time, since the first, second, third, and fifth best are all equal, except for the empty slots for walk-ins and medical student appointments.

It, again, seems to be rather important for the waiting time that the doctor is on time. This also shows in the whole of the data, where the best performers in terms of waiting times are dominated by configurations where the doctor arrives on time. The waiting time improves, on average, by more than 3 minutes if the doctor has an improved punctuality.

Table 18: The five best performing configurations with shared walk-in patients for waiting time. The base scenario is included for comparison.

EN	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over
252	IAI	NPP Mid	True	Impr.	True	False	True	08:38	40:09	28:01
380	IAI	NPP Mid	True	Impr.	True	True	True	08:43	39:07	26:50
240	IAI	NPP Late	True	Impr.	True	False	False	08:49	36:27	31:49
236	IAI	NPP Mid	True	Impr.	True	False	False	08:50	40:33	28:22
364	IAI	NPP Mid	True	Impr.	True	True	False	08:50	39:34	27:28
1	Base	Base	False	Current	False	False	False	09:44	42:16	22:55

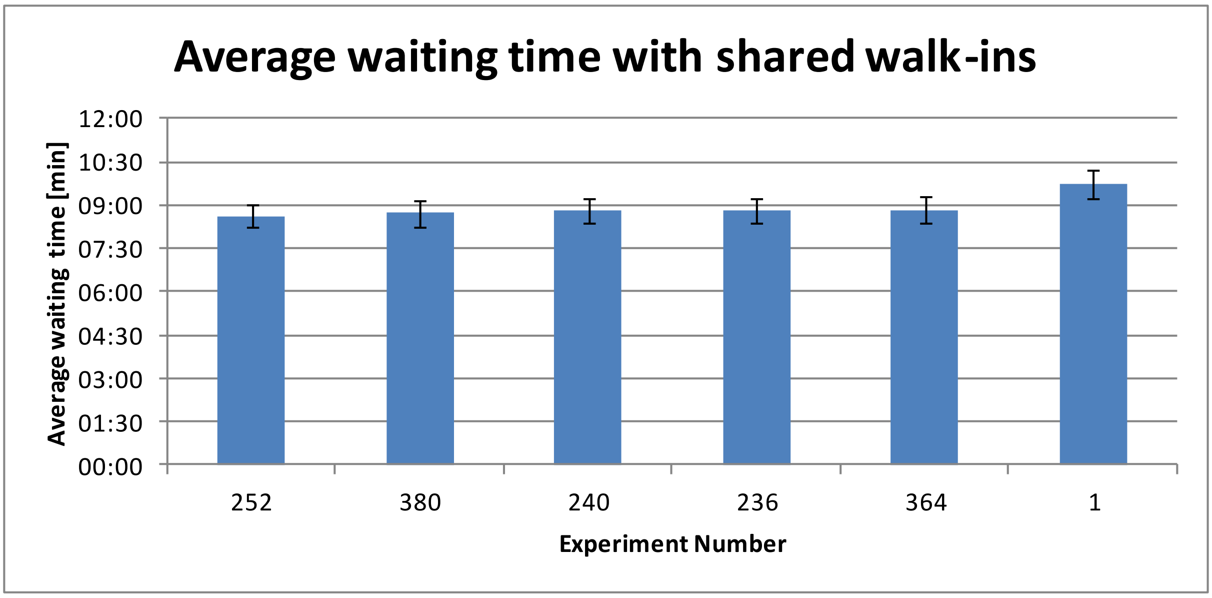


Figure 23: The five best performing configurations with shared walk-in patients for waiting time. The base scenario is included for comparison. The black brackets show the 95% confidence interval.

Walk-in patient waiting time

Figure 24 and Table 19 show the five best performing configurations for walk-in waiting time. Not very unexpectedly, we see that configurations with a low walk-in waiting time, also have relatively high idle time and low general waiting times.

Four of the five best performers include mid new patient pools and empty slots for walk-in patients. This is not surprising; this combination means that the more of the empty slots for walk-in patients are 20 minute slots from new patients, which means that the empty slots free up more time to see walk-ins.

None of the best performers share new patients, which most likely stems from the fact that shared new patients compete for the doctor's time that could otherwise be used by walk-in patients. With the walk-in waiting times, we again find that the medical student appointments only have a minimal effect, since the first and second best performing configurations are equal to the fifth and fourth best performing configurations on all but the medical student appointments.

Walk-in waiting times are lower if the doctor is on time, just as with the general waiting times. The average of walk-in waiting times over all experiments with shared walk-in patients improves by almost 20% if the doctor arrives on time.

Table 19: The five best performing configurations with shared walk-in patients for walk-in waiting time. The base scenario is included for comparison.

EN	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over	Walk-in wait
313	Base	NPP Mid	True	Impr.	False	True	True	09:18	42:28	27:47	06:18
314	Dome	NPP Mid	True	Impr.	False	True	True	10:34	40:07	27:09	06:37
180	IAI	Base	True	Impr.	False	False	True	09:37	40:25	26:16	06:39
298	Dome	NPP Mid	True	Impr.	False	True	False	10:31	40:03	27:12	06:47
297	Base	NPP Mid	True	Impr.	False	True	False	09:30	43:01	28:19	06:49
1	Base	Base	False	Current	False	False	False	09:44	42:16	22:55	11:51

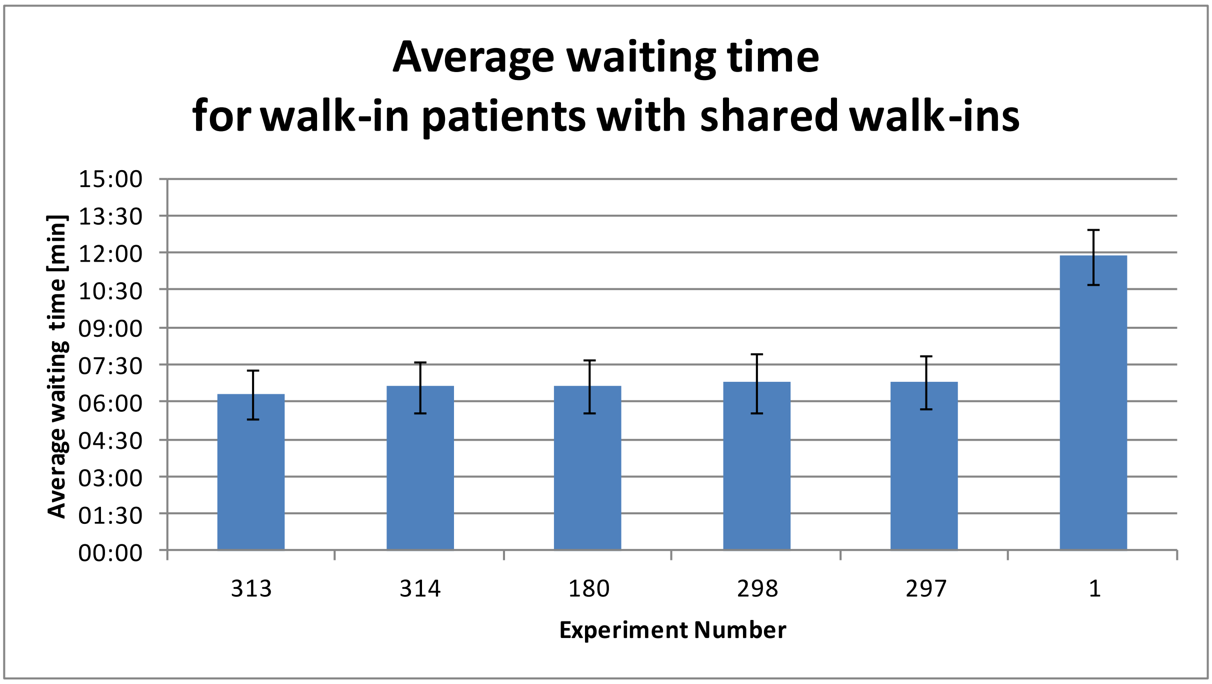


Figure 24: The five best performing configurations with shared walk-in patients for walk-in waiting time. The base scenario is included for comparison. The black brackets show the 95% confidence interval.

Idle time

Figure 25 and Table 20 show the five best performing configurations in terms of idle time. From Table 20 we see that all best performers on idle time use the Bailey-Welch rule combined with a late new patient pool. We also see that there appears to be a preference for empty slots for walk-in patients. This is not very unexpected, because configurations with empty slots have a higher scheduled utilization in the model, which means that unscheduled appointment slots have a higher chance of coinciding with walk-in times.

We also see that the current doctor's punctuality is preferred for a lower idle time, this is logical of course, since a later arrival time means more patients waiting for the doctor at the start.

Table 20: The five best performing configurations with shared walk-in patients for idle time. The base scenario is included for comparison.

EN	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over
351	BW	NPP Late	True	Current	True	True	True	18:25	21:03	32:19
335	BW	NPP Late	True	Current	True	True	False	18:07	21:04	32:06
287	BW	NPP Late	True	Current	False	True	True	19:04	22:50	27:39
223	BW	NPP Late	True	Current	True	False	True	17:24	22:59	33:57
271	BW	NPP Late	True	Current	False	True	False	18:46	23:05	27:43
1	Base	Base	False	Current	False	False	False	09:44	42:16	22:55

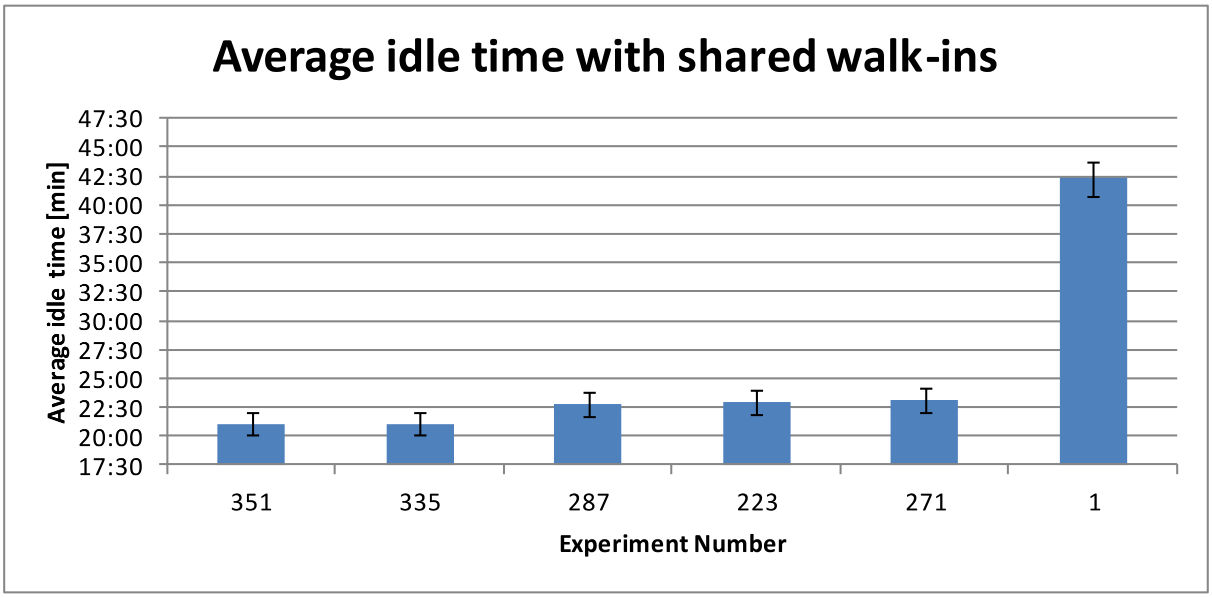


Figure 25: The five best performing configurations with shared walk-in patients for idle time. The base scenario is included for comparison. The black brackets show the 95% confidence interval.

Overtime

Figure 26 and Table 21 show the best performing experiments on overtime. Just as with the experiments without shared walk-in patients, we see that the Bailey-Welch and Dome rules dominate the best performers on overtime. Table 21 shows us, again, that the medical student appointments have little effect on the model outcomes, with the first and second, and third and fourth best performing configurations being equal in all but the medical student appointments.

All best performers do not share walk-in patients, just as with the experiments without shared walk-ins. All of them do have improved doctor's punctuality, which is not very surprising. Averaged over all these experiments, being on time reduces the doctor's overtime by almost 3 minutes.

It should also be noted that there are only two experiments that are better than the base scenario in terms of overtime; experiments 318 and 302. This is obviously because doctors just have more patients to see when walk-in patients are shared among doctors.

Table 21: The five best performing configurations with shared walk-in patients for overtime. The base scenario is included for comparison.

EN	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over
318	Dome	NPP Late	True	Impr.	False	True	True	11:48	31:13	21:53
302	Dome	NPP Late	True	Impr.	False	True	False	11:42	31:33	22:08
319	BW	NPP Late	True	Impr.	False	True	True	13:15	27:58	22:56
303	BW	NPP Late	True	Impr.	False	True	False	13:15	28:36	23:18
190	Dome	NPP Late	True	Impr.	False	False	True	11:36	32:24	24:24
1	Base	Base	False	Current	False	False	False	09:44	42:16	22:55

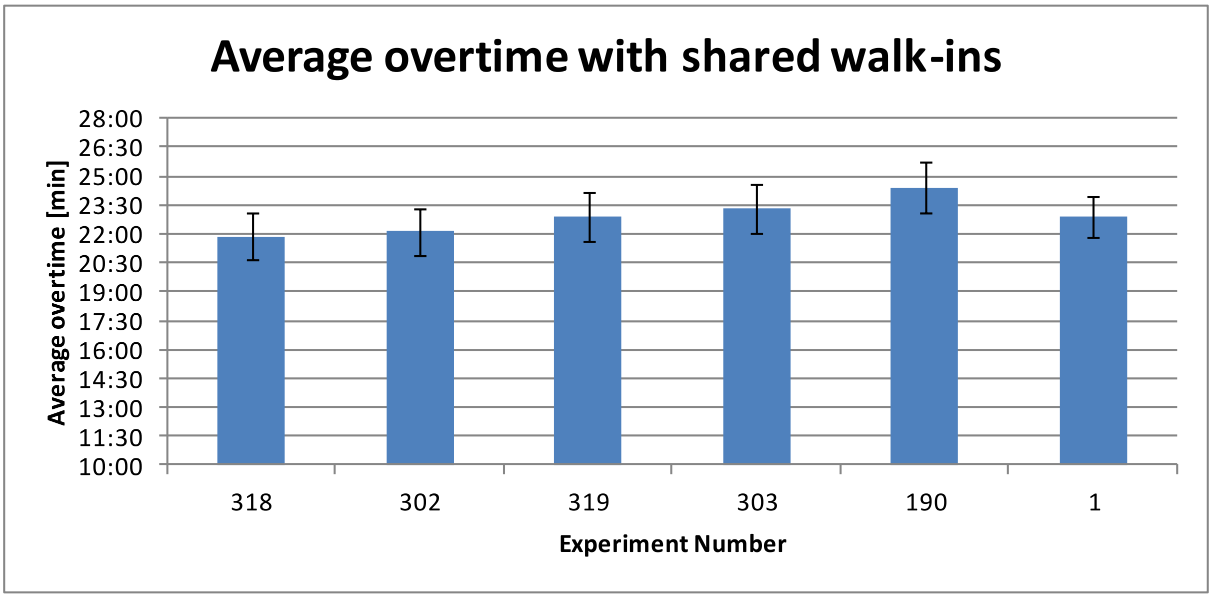


Figure 26: The five best performing configurations with shared walk-in patients for overtime. The base scenario is included for comparison. The black brackets show the 95% confidence interval.

Patient-Doctor Trade-off

Figure 22 shows a graph that plots the average waiting time of patients (relative to the waiting time in the base scenario) versus the, previously explained, RDP. In order to compare the results on average waiting time and RDP, we plot the efficient frontier as is shown in Figure 27. From this, we see that four different configurations are 100% efficient. These are shown in Table 17, along with the base scenario for comparison.

There are only two experiments that, in spite of the reduced capacity caused by the lack of a walk-in doctor, are able to best the base scenario both in terms of RDP and waiting time. These are configuration 320, which is also on the efficient frontier, and configuration 304, which is basically the same as configuration 320, but without the medical student appointments.

In all fully efficient scenarios the walk-in waiting time is lower than that of the base scenario, even though walk-in waiting time was not a criterion. This is not strange, since more than 75% of the scenarios with shared walk-in patients have lower walk-in waiting times than the base scenario.

Just as with the experiments without shared walk-in patients, we see, from Table 22, the more balanced experiments are those with improved appointment intervals. Also, the late new patient pools appear to dominate the left part of the efficient frontier, where the relative doctor's performance is best.

The two groups of dots on the right side of Figure 22 show that some of the interventions do not have a great impact on the output for all configurations. The group on the utmost right consists of experiments with an early new patient pool, base appointment rule, and doctors that arrive on time. The group of dots to the left of that also consists of experiments with an early new patient pool and base appointment rule, but there doctors arrive according to the current situation.

Table 22: The five fully efficient experiments with sharing walk-in patients. The base scenario is included for comparison

EN	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over	Walk-in wait	RDP
319	BW	NPP Late	True	Impr.	False	True	True	13:15	27:58	22:56	10:49	84%
318	Dome	NPP Late	True	Impr.	False	True	True	11:48	31:13	21:53	09:10	85%
320	IAI	NPP Late	True	Impr.	False	True	True	09:27	31:41	25:53	09:02	95%
380	IAI	NPP Mid	True	Impr.	True	True	True	08:43	39:07	26:50	09:02	105%
252	IAI	NPP Mid	True	Impr.	True	False	True	08:38	40:09	28:01	08:08	109%
1	Base	Base	False	Current	False	False	False	09:44	42:16	22:55	11:51	100%

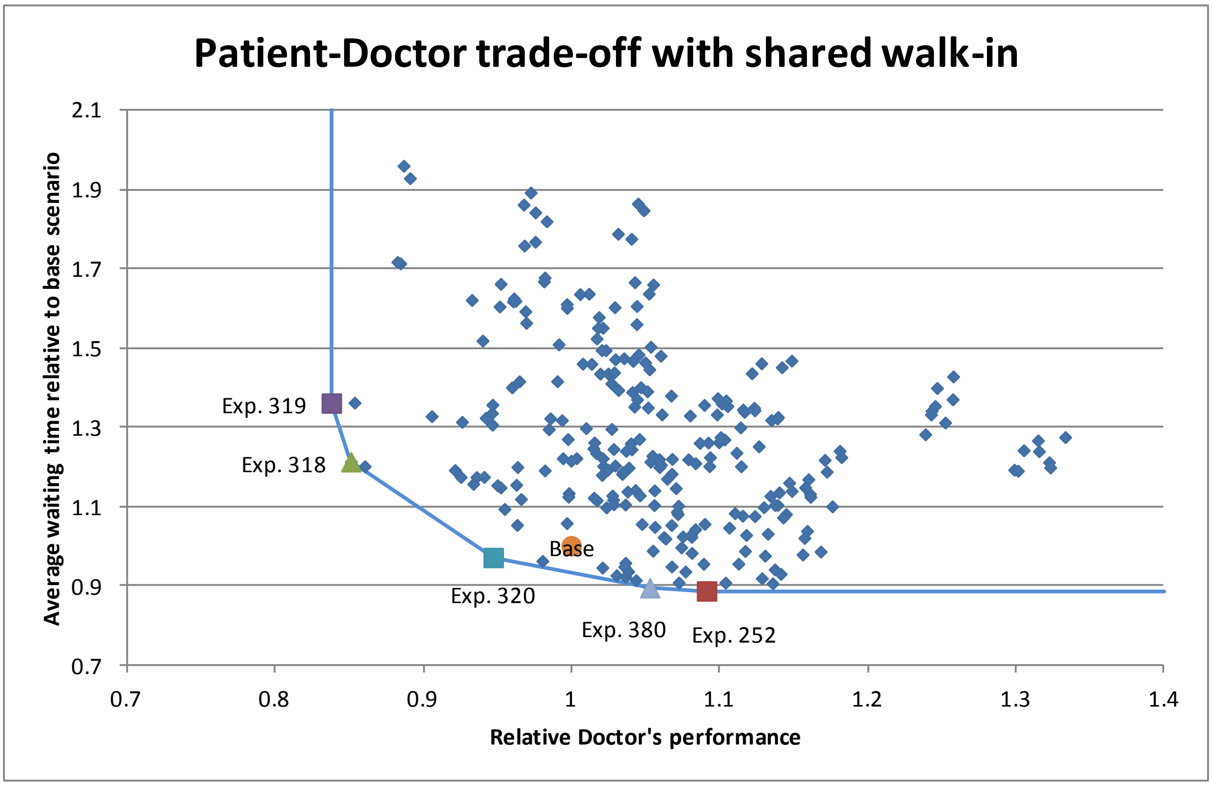


Figure 27: The efficient frontier of experiments 129 to 384. The base scenario is included for comparison.

5.2.5. *EFFECTS PER INTERVENTION*

This section explores the effects on the outpatient clinic's performance for all interventions. We do this based on averages, as they are shown in Table 23, and on interesting two-way interactions between interventions that we found during the analysis, that are shown in Table 24.

Table 23 shows the average outcome of all configurations that employ the mentioned interventions. However, in order to compare the values for patients sequences, appointment rules, sharing of new patients, doctor's punctuality, and medical student appointments fairly to the base scenario (intervention type none), we do not incorporate the configurations that share walk-in patients in these averages (e.g., the value for Shared new patients True is the average of the outcome of configurations 65 to 128 (see also Appendix D)). The averages for shared walk-in patients naturally do incorporate the configurations with shared walk-ins.

Table 23: Average outcomes for all studied interventions.

Intervention type	Invervention	Wait	Idle	Over
None	None	0:09:44	0:42:16	0:22:55
Appointment rule	Base	0:08:52	0:45:46	0:23:09
	BW	0:11:14	0:35:47	0:20:32
	Dome	0:09:39	0:41:34	0:19:59
	IAI	0:08:08	0:43:53	0:21:11
Patient Sequence	Base	0:09:18	0:43:01	0:20:29
	NPP Early	0:09:18	0:43:44	0:21:45
	NPP Mid	0:09:01	0:44:09	0:20:41
	NPP Late	0:10:16	0:36:06	0:21:57
Share new patients	False	0:09:42	0:42:11	0:20:24
	True	0:09:14	0:41:19	0:22:02
Doctor's punctuality	Impr.	0:08:08	0:45:52	0:20:12
	Current	0:10:48	0:37:38	0:22:14
Med. student appointments	False	0:09:25	0:41:56	0:21:21
	True	0:09:31	0:41:34	0:21:05
Share walk-in patients	False	0:09:28	0:41:45	0:21:13
	True without empty slots	0:12:32	0:34:36	0:30:22
	True with empty slots	0:12:21	0:33:39	0:28:49

Table 24: Average outcomes of combined interventions, showing the effects of noteworthy two-way interactions of interventions.

Interaction	First intervention	Second intervention	Wait	Idle	Over
A	NPP Late	SNP True	0:10:32	0:37:55	0:19:17
	NPP Late	SNP False	0:10:00	0:34:16	0:24:37
B	NPP Late	Base AR	0:09:45	0:38:35	0:23:22
	NPP Late	BW	0:12:29	0:31:20	0:21:56
	NPP Late	Dome	0:10:42	0:33:59	0:19:49
	NPP Late	IAI	0:08:06	0:40:30	0:22:40
C	Base PS	SNP True	0:09:21	0:43:00	0:19:52
	Base PS	SNP False	0:09:16	0:43:02	0:21:05
D	NPP Late	MSA True	0:10:19	0:35:50	0:21:45
	NPP Late	MSA False	0:10:12	0:36:21	0:22:09

Table 23 shows, just as we realized in Section 5.2.2, that the choice of appointment rule has a more pronounced effect on clinic performance than the choice for patient sequence. Of the appointment rules, improved appointment intervals yield the biggest improvements on waiting time. Bailey-Welch and the Dome rule improve the system for doctor-related performance measures idle time and overtime, but respectively deteriorate and do not improve the patients' waiting time.

The patient sequences yield small changes to patient waiting time, with an early and mid new patient pool improving on the current situation, and a late new patient pool performing worse than the current situation. That the late new patient pool performs worse on waiting time is probably caused by return patients being scheduled at the beginning of the session with appointment intervals shorter than their average service duration, which effectively creates a buffer of patients at the beginning of the session, thus increasing waiting times and decreasing idle times. That the late new patient pool scores worst on overtime has to do with sharing new patients. See Interaction A in Table 24 for a comparison of this two-way interaction. When new patients are shared among doctors, and new patients are scheduled at the end of the clinic session, then any imperfections in determining when doctors are allowed to leave become clearly visible. We expect that this is the reason for this interaction.

Interestingly, the late new patient pool performs worst on waiting time for all appointment rules, except for the improved appointment intervals, see Interaction B in Table 24 and the average performances in Table 23 for a comparison of this interaction. This strengthens the assumption that the bad average performance of the late new patient pool on waiting time is caused by the effect of the short appointment intervals for return patients.

As mentioned in Section 5.2.3, sharing new patients can lead to significant improvements on waiting time. However, the best improvements caused by sharing new patients happen with configurations that are not efficient, and so have a lot of improvement possibilities. Compare for instance the waiting time of configurations 7 and 23 (both approximately 14 minutes) with their counterparts that do share new patients, configurations 71 and 87 (see Appendix D). These configurations combine the Bailey-Welch rule with an early new patient pool, and achieve reductions in waiting time of respectively 13% and 12% when sharing new patients.

Sharing new patients has no significant effect on overtime when the new patients are scheduled in the beginning or in the middle of the clinic session. However, as Interaction A in Table 24 shows, sharing new patients greatly increases overtime when all new patients are scheduled at the end of the clinic session. Interaction C shows that this effect also holds when one new patient is scheduled near the end of the clinic session with the base patient sequence.

Improving the doctor's punctuality has, just as Babes & Sarma (1991), Liu & Liu (1998), and Cayirli and Veral (2003) report, a significant effect on the patient's waiting time. In addition to the effect on waiting time, we also find that improving the doctor's punctuality has, on average, distinct effects on the doctor's idle time and overtime.

As Table 23 shows, the medical student appointments have, on average, only very small effects. The most obvious reason for this is that only a small percentage of patients (3% for configurations with a new patient pool, 7% for the base patient sequence) get medical student appointments. However, while configurations with a late new patient pool only have 3% of patients that get medical student appointments, these configurations do show improved overtime and idle times from medical student appointments, as Interaction D in Table 24 shows. The larger effect of medical student appointments on late new patient pools has to do with the fact that any delay or improvement to the appointment finish time has a more direct effect on the doctor's overtime, because patients with a medical student appointment are scheduled at the end of the session. Reducing the session's final completion time naturally also reduces the doctor's idle time.

The effect that sharing walk-in patients among general doctors has on waiting time, idle time and overtime is obvious from Table 23. That the difference between the outcomes of configurations with and without empty slots for walk-in patients is so small seems to imply that the configuration of empty slots is suboptimal. Perhaps either more, or differently spread out empty slots would have a better effect.

5.2.6. CONCLUSIONS

There are three configurations that stand out, based on that they are on the efficient frontier and that they offer balanced improvements to both the RDP and waiting times. From the experiments without sharing walk-in patients, these are experiments 62 and 64, and from the experiments with sharing walk-in patients, this is experiment 320.

Of the two intervention types that change only the appointment schedule, appointment rules and patient sequences, the appointment rules have the most distinct effect on clinic performance. This is in contrast to the findings of Cayirli et al. (2006). We expect that this difference with the literature is caused by the low percentage of new patients in the schedules we studied.

Sharing new patients achieves rather large benefits, of up to 18%, for waiting times. However, the configurations that gain the biggest improvements from sharing new patients are the configurations that do not perform that well on waiting time. The best performing waiting times generally improve less than half a minute from sharing new patients. As for idle time and overtime, sharing new patients only has a large effect on configurations with a late new patient pool, where it shows improvements of approximately 4 minutes to idle time, but also increases overtime by on average 5 minutes. This means that, although it does offer improvements, sharing new patients improves configurations near the efficient frontier only marginally. This may also have to do with the fact that the schedule only has 4 new patients per 18 appointment slots, so only a small percentage of patients can be shared among doctors.

Having the doctor arrive on time is, in general, beneficial for the waiting time and overtime, with average improvements over the whole of the data of 2 to 3 minutes for both waiting time and overtime. However, if the doctor arrives early, this also leads to increased idle times.

5.3. SENSITIVITY ANALYSIS

With the sensitivity analysis, we test the sensitivity of the model outcome to changes in our assumptions, or to changes in (estimated) model parameters. We use the most balanced experiments on the efficient frontiers of the experiments with and without sharing walk-in patients, as well as the base scenario, for the sensitivity analyses. These are experiments number 62, 64 and 320, and number 1 as base scenario. These are the experiment numbers from Appendix D. Table 25 recapitulates on the settings of these experiments.

Table 25: Configurations of the experiments used in the sensitivity analysis. Experiment 1 is the base scenario.

EN	AR	PS	SNP	DPu	MSA	SWiP	ESWiP
62	Dome	NPP Late	False	Impr.	True	False	False
64	IAI	NPP Late	False	Impr.	True	False	False
320	IAI	NPP Late	False	Impr.	True	True	True
1	Base	Base	False	Current	False	False	False

We consider only first-order effects, so we examine the sensitivities for each factor individually. In order to reduce output variability and find more significant results, each experiment is run for 2500 replications for the sensitivity analyses.

The following sections elaborate on the environmental factors chosen for the sensitivity analyses. Table 26 shows a summary of the changes to the parameters, along with a number for recognition in following figures. Section 5.3.12 deals with the sensitivity of the model output to the calculation of RDP.

Table 26: Alterations to environmental factors used in the sensitivity analysis. Number F will not be used for experiment 70, since its scheduled utilization cannot be increased by 10%.

	Change in value	Number
No-show rate	- 50%	A
	+ 50%	B
Walk-in arrivals	- 25%	C
	+ 25%	D
Scheduled utilization	- 10%	E
	+ 10%	F
Number of doctors	- 1	G
	+ 1	H
Probability of medical students attending a clinic session	- 50%	I
	+ 50%	J
DICT	- 25%	K

5.3.1. *NO-SHOW RATE*

Since there are no valid historical records of the number of no-shows at the outpatient clinic, we used the no-show data from 3 weeks of data gathering. It is entirely possible that these data over- or underestimate the actual value. Therefore we decide to examine the effect of reducing and increasing the no-show rate by half to 3.5% and 10.5%.

5.3.2. *NUMBER OF DAILY WALK-IN PATIENT ARRIVALS*

It is quite possible that the walk-in session will increase or decrease in popularity in the future. Therefore we will test the effect of a 25% decrease and a 25% increase in walk-in patient arrivals.

5.3.3. *SCHEDULED UTILIZATION*

The scheduled utilization of doctors can be altered in two ways: either the number of consultation sessions per week is changed, or the outpatient department receives more or fewer appointment requests. We decide to test changes to the average utilization of 10%, to 67.5% and 82.5% in the base-scenario. However, because experiment 70 has less appointment slots, it is already at 99% utilization. This means that we cannot increase its scheduled utilization.

5.3.4. *NUMBER OF DOCTORS*

The number of doctors present differs per half weekday. We expect the amount of doctors to be important to the effect of sharing patients. An increase in doctors will also increase the number of patients for the counter-employees, thus also increasing the waiting time at the counter. We test the sensitivity for number of doctors by reducing and increasing the number by 1, to respectively 2 and 4 doctors. When changing the number of doctors, the number of scheduled patients per doctor remains constant.

5.3.5. *PROBABILITY OF MEDICAL STUDENT JOINING THE CONSULTATION SESSION*

There are no historical records of the number of consultation sessions attended by medical students, so the 30% used in the model was based on a small sample. Moreover, the amount of medical students at the ENT-outpatient center changes almost weekly. Therefore we examine the effect of a change to 15% and 45%.

5.3.6. *REDUCING DESIRABLE INTERCONSULTATION TIME*

During data gathering, the consultation sessions had an average of 10.8 minutes of DICT. This time includes useful activities, such as arranging things with medical assistants, or consulting with the doctor on supervision duty. However, it also includes for instance time to get coffee, waiting for the printer to work, or taking a toilet break. It is possible that the measured average DICT is incorrect, or even that the amount of disturbances will change in the future because of, for instance, better technical support. Therefore we test the sensitivity of the outcome to reducing the amount of DICT by 25%.

5.3.7. *WAITING TIME*

Figure 28 shows the waiting time sensitivity for the environmental factors.

What stands out is the effect of changes E and F, respectively reducing and increasing the scheduled utilization by 10%. This shows that the realized patient's waiting time is rather dependent on the scheduled utilization.

What is unexpected is the rather small and non-significant effect of changes G and H, which alter the number of doctors, for experiment 320. Because in this experiment walk-in patients are shared among doctors, we assumed that more, or less, doctors would introduce a significant change in waiting time for patients. But, apparently, this effect is much smaller than expected. This may have to do with the relatively low number of patients that are shared; on average approximately only 2.3 walk-in patients per day.

Another unexpected turn is provided by experiments C and D. While experiment 320 reacts as expected to the reduced and increased walk-in rates, experiments 1, 62, and 64 show higher waiting times for lower walk-in rates and vice versa. Given that these effects are rather small and not significant, we expect that they stem from variability in model output.

Reducing the probability of DICT occurring by 25% reduces waiting times by only 5 to 8 percent in these experiments, corresponding to approximately 30 to 45 seconds.

Although the variations in no-show rates cause significant effects for all configurations, experiment number 62, 64 and 320 all seem to be more robust for an increase in no-show rates than the base-scenario.

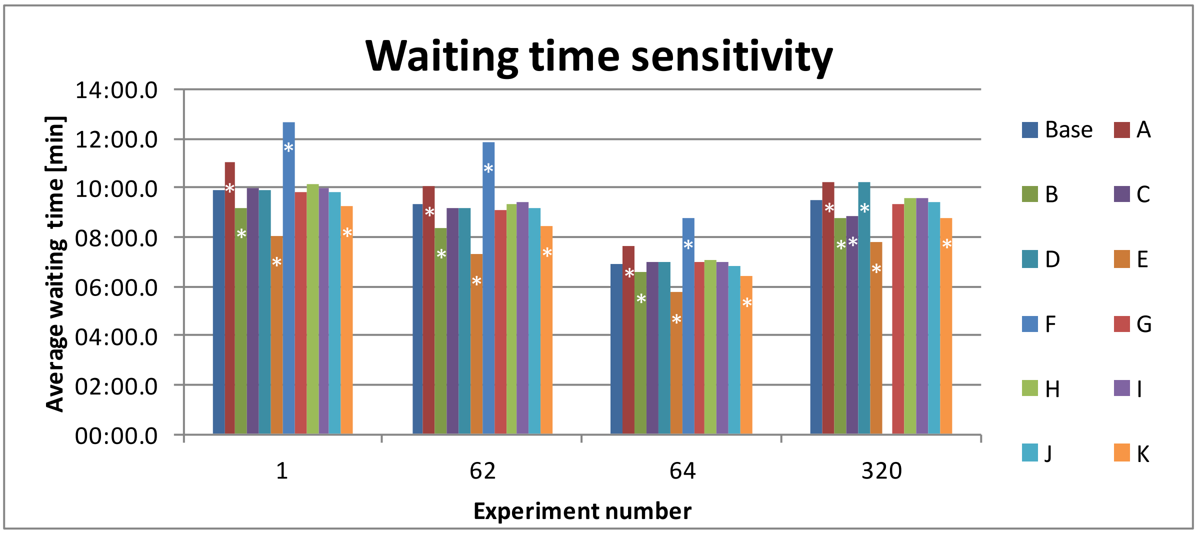


Figure 28: Waiting times for the various changes in environmental factors. Effects that are significant at a 95% confidence level are marked with a white asterisk.

5.3.8. Walk-in patient waiting time

Figure 29 shows the walk-in patient's waiting time sensitivity for the environmental factors.

Experiment numbers 1, 62, and 64 are barely sensitive to all changes, except for the change in walk-in arrival rate. That they are insensitive to changes in number of general doctors and their scheduled utilization suggests that the assumption is correct that the effects of higher utilization on waiting time at the counter are negligible.

When walk-in patients are shared among doctors, like in experiment 320, the walk-in patient's waiting time is more susceptible to changes. However, it seems that the configuration with shared walk-in patients is much more robust for increase in walk-in patient rates. This suggests that, if the outpatient clinic were to try to increase the walk-in session's popularity, it would be wise to share walk-in patients among doctors.

Experiment 320 is especially sensitive to the reduced scheduled utilization of change E, as is to be expected. This also suggests that, in the current situation, when days occur that doctors have low scheduled utilizations and the walk-in doctor is unable to attend the walk-in session (e.g. due to illness), general doctors should easily be able to take over from the walk-in doctor during their consultation sessions.

The number of doctors is important for the walk-in patient's waiting time in experiment 320. Having one fewer doctor increases waiting time by 24 percent.

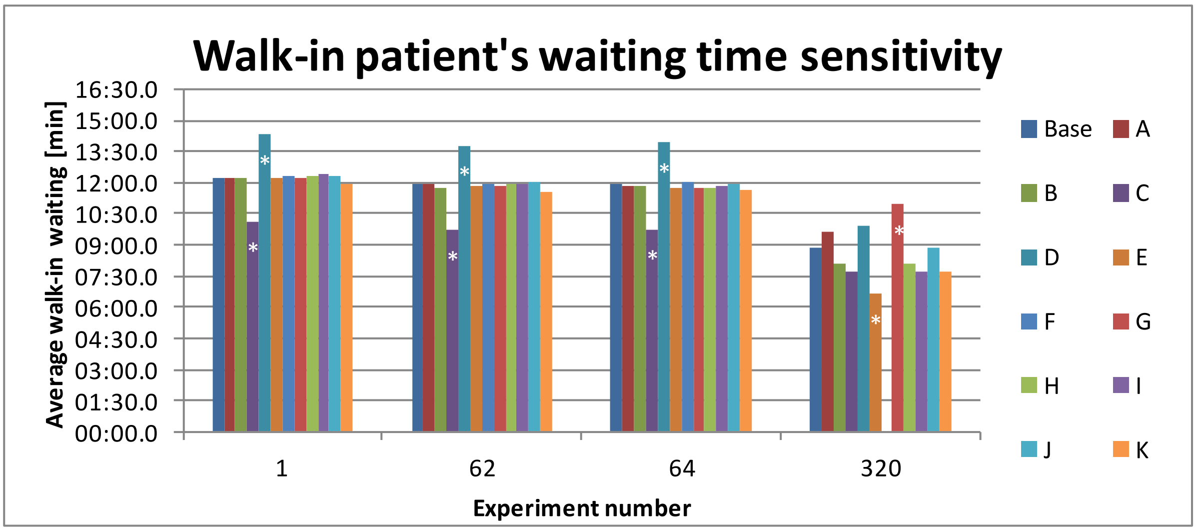


Figure 29: Walk-in patient waiting times for the various changes in environmental factors. Effects that are significant at a 95% confidence level are marked with a white asterisk.

5.3.9. IDLE TIME

Figure 30 shows the sensitivities of the configurations' idle times to the changes in assumptions and environmental factors.

The sensitivities in terms of idle time are mostly similar between experiments 1, 62, and 64. The only small difference is when it comes to the number of doctors (changes G and H). The base scenario has a slightly higher idle time when more doctors are present, we expect that this comes from marginally increased waiting times for patients at the counter.

Naturally, in contrast to experiments 1, 62, and 64, experiment 320 is somewhat sensitive to the walk-in rates. If there are less walk-in patients to see, doctors have less to do. More walk-in patients mean more work to do and less idle time.

A 25% reduction in DICT (roughly 2.5 minutes) only has small effects on the idle times, of 2 to 4%, or approximately 1 to 1.5 minutes. This shows that part of the desirable interconsultation times takes place during moments where the doctor could otherwise be idle.

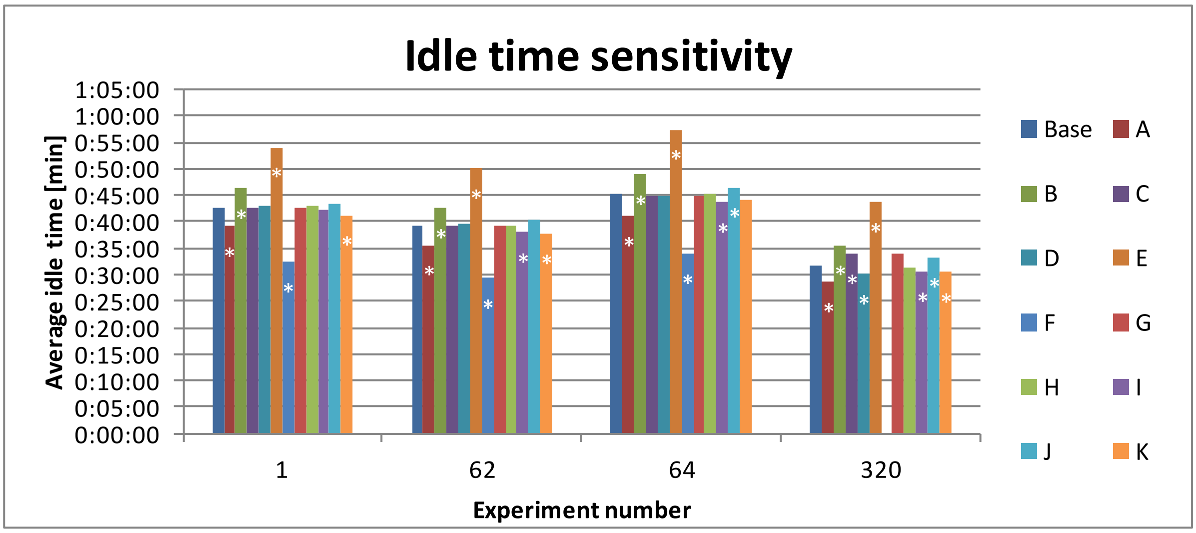


Figure 30: Idle times for the various changes in environmental factors. Effects that are significant at a 95% confidence level are marked with a white asterisk.

5.3.10. *Overtime*

In Figure 31 we show the configurations' overtime sensitivities for changes in the environmental factors. Experiment 64 appears to be the most robust in terms of overtime.

Experiments 62, 64 and 320 are more sensitive to changes in medical students attending clinic sessions than the base scenario. This appears to be a direct consequence of the late new patient pool used in these experiments. Because all new patients are grouped at the end of the clinic session, every minute that medical students delay these patients has a direct effect on the doctor's overtime.

Experiments 64 and 320 appear to be less sensitive for changes in scheduled utilization. We expect that this has to do with the appointment rules used; improved appointment intervals leave more room to make up for an increase in scheduled utilization during the consultation session.

Experiment 320 seems to be, although the effect is not significant, more sensitive to changes in walk-in patient rates. This would make sense, since experiment 320 is the only one of the four where general doctors treat walk-in patients.

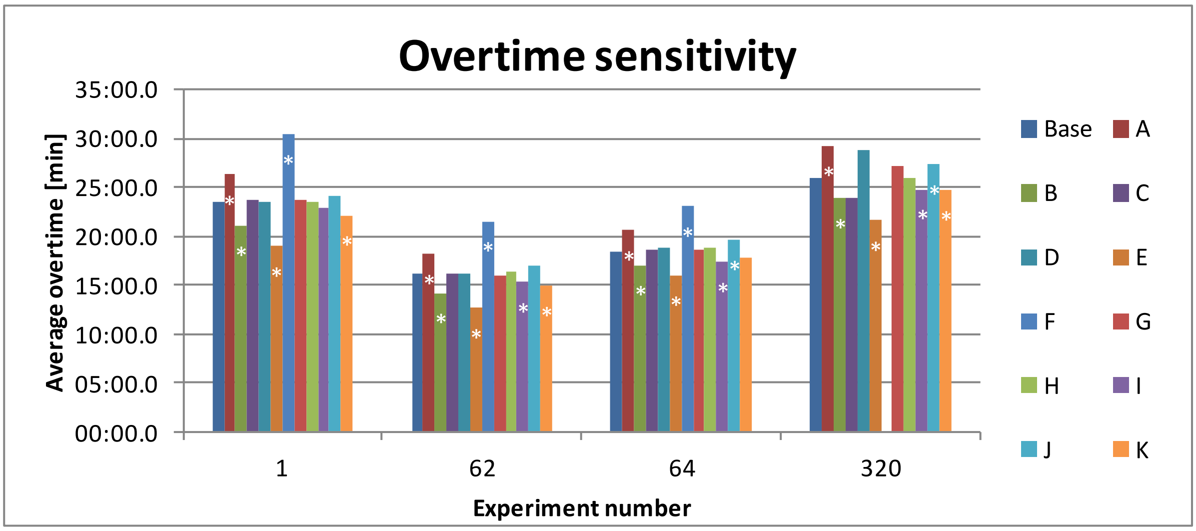


Figure 31: Overtimes for the various changes in environmental factors. Effects that are significant at a 95% confidence level are marked with a white asterisk.

5.3.11. DOCTOR-PATIENT TRADE-OFF

Figure 32 and Figure 33 show the patient-doctor trade-off graphs used in Section 5.2, but annotated with the results of the sensitivity tests.

The most noteworthy about these figures is that none of the sensitivity data points lie far from the efficient frontier. The general trend is from the upper left of the graph to the lower right, which means that if the waiting time increases, the relative doctor's performance decreases and vice versa.

The only times that experiment 62 does not outperform the base scenario on both waiting time and RDP, is when the number of patients to treat increases, with tests A and F. Experiment 64 is only outperformed by the base scenario when the scheduled utilization decreases by 10%, this is due to the increased idle times. Experiment 320 also outperforms the base scenario in all cases, except when the number of patients to see increases, with tests A and D.

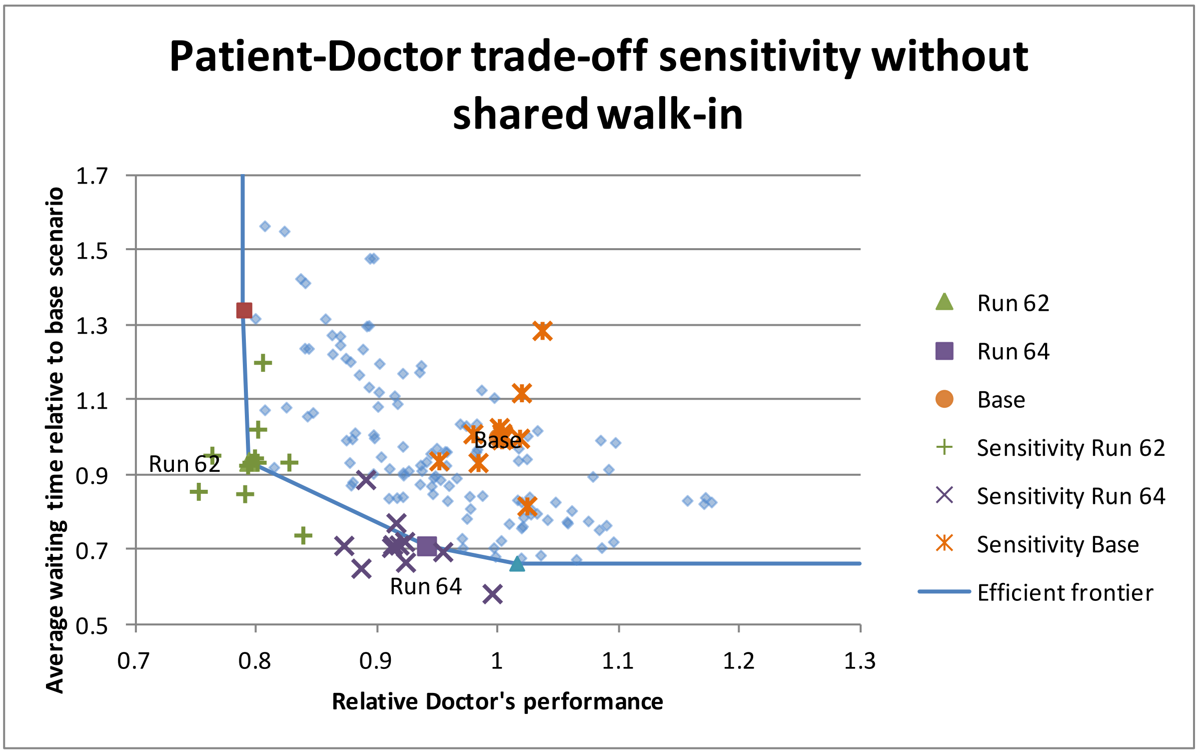


Figure 32: Patient-Doctor trade-off showing the results of the sensitivity tests for scenarios without shared walk-ins. Notice that data points from the sensitivity analyses of experiments 62 and 64 do not become much less efficient.

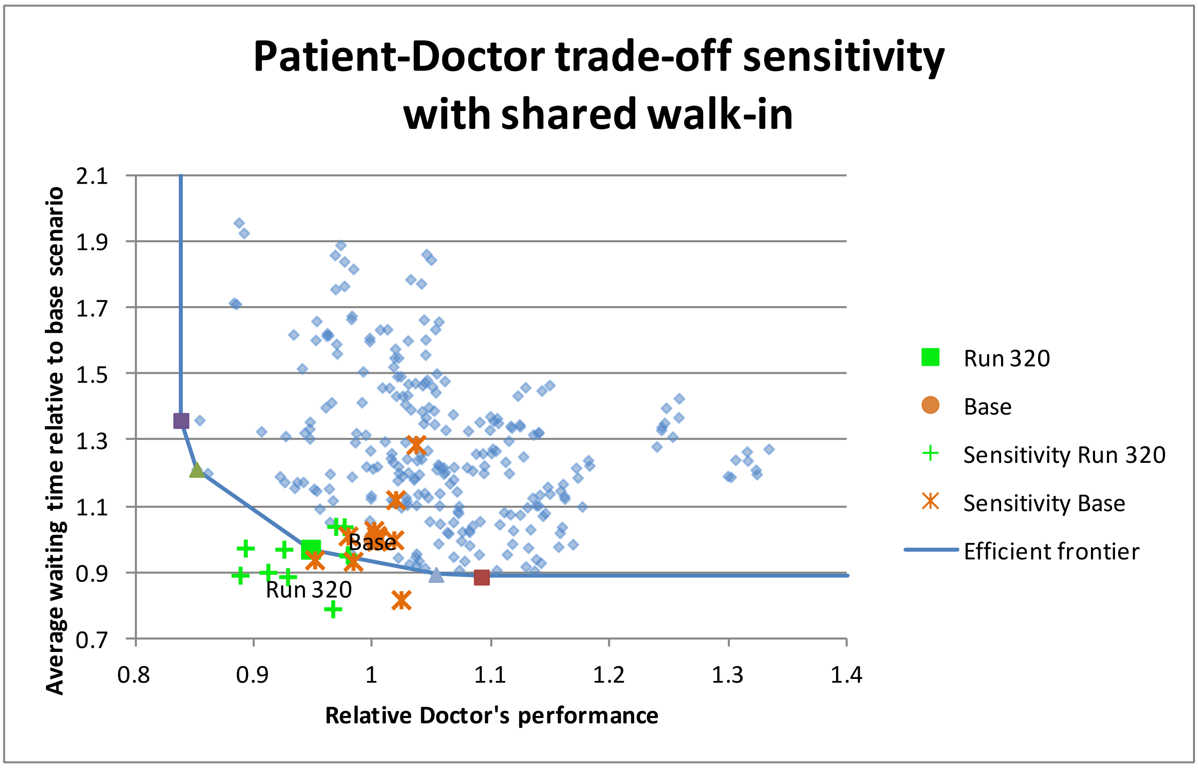


Figure 33: Patient-Doctor trade-off showing the results of the sensitivity tests for the scenario with shared walk-ins and the base scenario. Notice that data points from the sensitivity analyses of experiments 320 do not become much less efficient.

5.3.12. SENSITIVITY OF CALCULATION OF RDP

In this analysis we determine which scenarios are the best, based partially on the RDP. However, different people may have different opinions about the relative weights for idle time and overtime that should be used in the calculation of the RDP. In this section, we explore the effect of changing the relative weights of idle time and overtime in the RDP to the outcome of which configurations are the best. In order to keep the size of the chapter limited, this section presents only the analysis for configurations without sharing walk-in patients. The analysis we performed for configurations with shared walk-in patients shows similar results.

We use the combinations of weights as presented in Table 27.

Table 27: Combinations of weights for different calculations of Relative Doctor's Performance.

Test	Weight idle time	Weight overtime
Base case	1	2
Case I	1	1
Case II	2	1
Case III	1	3

The graphs in Figure 34 show the patient doctor trade-offs of experiments 1 to 128, all configurations without sharing walk-in patients, for these four different RDPs. In these figures, experiments that are new to the efficient frontier are marked with an orange circle.

Experiments that are noteworthy but are not fully efficient have their label centered on top of the corresponding data point. These experiments are the Base experiment and experiments that are fully efficient in the base RDP calculation, but are not fully efficient when the RDP calculation is altered.

Since experiment 108 is fully efficient because it has the lowest waiting time, and the only factor that changes in the graphs in Figure 34 is the RDP, it is clear that experiment 108 remains fully efficient in all of these cases.

Figure 34 shows that experiment 30 is fully efficient in the base case and in Case I, but that it stops being fully efficient with cases II and III. This is because experiment 30 performs well on both idle time and overtime, but it is not a top performer on either of these performance indicators. This means that when either idle time or overtime is considered to be much more important, experiment 30 loses on RDP to the top performing configurations of that performance indicator.

All of the experiments that become fully efficient when idle time becomes more important (cases I and II) utilize a late new patient pool. This shows that the late new patient pools have a beneficial effect on the idle time.

Another striking point that comes forward from Figure 34 is the shape change of the cloud of data points when idle time becomes more important than overtime in the RDP calculation. If idle time is given more weight in the RDP calculation, then the cloud of data points appears to become more of a line of data points. This is because the correlation between idle time and waiting time (correlation coefficient of -0.84) is stronger than the correlation between overtime and waiting time (correlation coefficient of 0.18).

As for experiments 62 and 64, the most balanced fully efficient experiments, Figure 34 shows that they remain fully efficient when idle time and overtime are considered equally important (case I) and that they also thrive when overtime is considered to be even more important (case III). In case II, where idle time has double the weight of overtime, experiments 62 and 64 are not part of the efficient frontier anymore. However, both experiments remain close to the efficient frontier. This indicates that experiment 62 and experiment 64 achieve results that remain efficient even if opinions about the relative importance of overtime and idle time change.

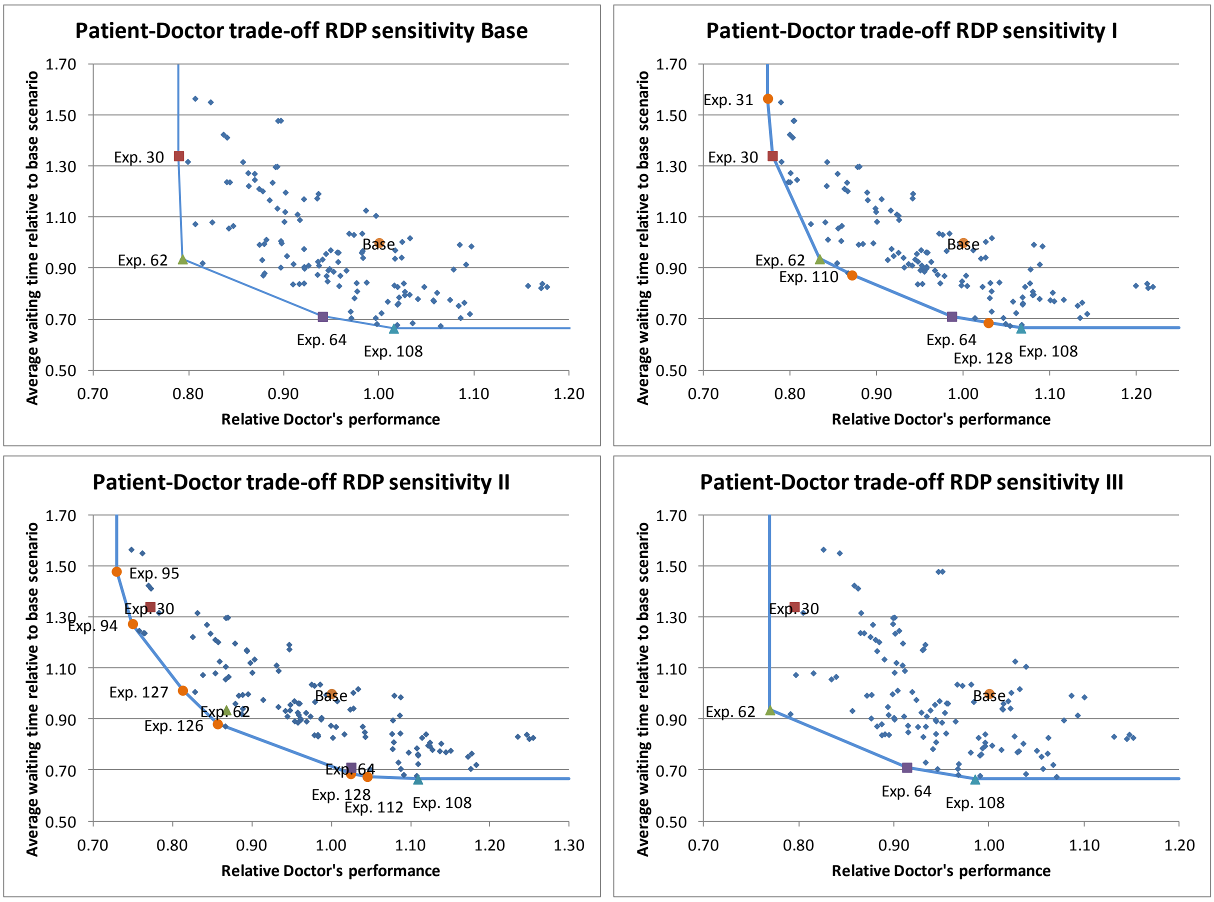


Figure 34: Effects of changes in calculation of RDP on the patient-doctor trade-offs of experiments without shared walk-in patients.

5.3.13. *CONCLUSIONS*

For the efficient experiments without shared walk-ins that we examined for sensitivity, experiment 62 and 64, we notice that while they are sensitive to changes in environmental factors, this sensitivity does not make them stray far from the efficient frontier. Changes that increase waiting times simultaneously decrease the doctor's performance and vice versa. This mostly just sends the outcome to another part of the efficient frontier.

The sensitivity results of experiments 1 and 320 appear to be more perpendicular to the efficient frontier, although most changes seem to improve the efficiency of experiment 320.

Experiment 64 performs better in terms of overtime than both the base scenario and experiment 62 under changes in scheduled utilization. This most likely has to do with the improved appointment intervals that better spread any increases in utilization.

Since general doctors treat walk-in patients in experiment 320, this configuration is more sensitive to changes in walk-in rates than both other configurations.

Because of the late new patient pools utilized in experiments 62, 64, and 320, they are more sensitive to changes in medical students attending clinic sessions. This is especially true for overtime, with changes of approximately 5% for experiments 62 and 320, up to an increase of 7% in overtime for experiment 64 when more medical students attend the sessions. Experiment 320's walk-in patient waiting time is also especially sensitive to the attendance of medical students; a 15 percentage point reduction in medical student attendance leads to a 16% reduction in walk-in patient waiting time.

Both configuration 62 and 64 remain efficient if the calculation of the relative doctor's performance changes. This means that their performance does not rely solely on the perceived importance of either idle time or overtime.

5.4. Conclusions

In this chapter, we did a full factorial analysis of the interventions, and thus tested 384 different combinations of experimental factors. We divided the analysis into two different stages; 128 configurations without sharing walk-in patients, and 256 configurations with sharing walk-in patients. Table 28 recapitulates on the most balanced and efficient scheduling systems that were tested. It also shows the base scenario for comparison.

When only the appointment rule and patient sequence are varied with respect to the base scenario, the appointment rule has the largest impact on the output. Of the four appointment rules, improved appointment rules show the most balanced and beneficial performance. The Dome-rule leads to the best improvements on doctor's performance, while it generally leads to less increased waiting times than the Bailey-Welch rule.

In general, improved appointment intervals tend to lead to balanced results, improving both on waiting time and doctor's performance, but those configurations do not lead to the most extreme improvements on the doctor's performance. The biggest improvements to doctor's performance are achieved by configurations that use either the Bailey-Welch or Dome-rule.

Medical student appointments only have minor effects on the output. The effect of sharing new patients depends largely on the configuration. For configurations that use a late new patient pool, sharing new patients increases overtime by roughly 4 minutes on average, but for configurations that use an early or mid new patient pool, the average overtime slightly improves. For configurations that utilize a Bailey-Welch rule combined with an early or mid new patient pool, sharing new patients can save up to two minutes of waiting time for patients.

For the patients' waiting time and overtime, the most certain way to gain improvements is to have the consultation sessions start on time, with average improvements of 2 to 3 minutes to waiting time and overtime.

The sensitivity analysis shows that experiments 62 and 64 tend to stay close to the efficient frontier with changes in environmental factors. This means that these configurations also perform well in a changing environment. Both experiment 62 and 64 also perform well under changes in the relative importance of idle time and overtime in the calculation of RDP. Since general doctors treat walk-in patients in experiment 320, this configuration is more sensitive to changes in walk-in rates than both other configurations.

Table 28: Most balanced and efficient scheduling systems. The upper part of the table shows the input for the configurations, the lower side of the table shows the output.

	EN	AR	PS	SNP	DPu	MSA	SWiP	ESWiP
Input	**62**	Dome	NPP Late	False	Impr.	True	False	False
	64	IAI	NPP Late	False	Impr.	True	False	False
	320	IAI	NPP Late	False	Impr.	True	True	True
	1	*Base*	*Base*	*False*	*Current*	*False*	*False*	*False*
	EN	**% Wait < 15 min.**	**Wait**	**Idle**	**Over**	**Walk-in wait**	**RDP**	**RW**
Output	**62**	77%	09:07	38:49	15:32	11:19	79%	94%
	64	84%	06:55	45:47	18:33	11:58	94%	71%
	320	77%	09:27	31:41	25:53	09:02	95%	97%
	1	*75%*	*09:44*	*42:16*	*22:55*	*11:51*	*100%*	*100%*

6. Conclusions, recommendations and implementation

This chapter starts by presenting the conclusions of this research, followed by recommendations for ENT's management and for further research in Section 6.2. Section 6.3 discusses some issues about the practical implementation of the recommended interventions.

6.1. Conclusions

This research set out to achieve the following goal:

The goal of this research is to analyze the current scheduling process, the consultation schedules and the scheduling constraints, and identify and prospectively assess ways to improve these, at the outpatient center of the ENT department of the UMCU.

From the analysis of the current situation, it turns out that combined consultations with the function center rarely present any problems for the outpatient clinic. Because of the daily walk-in session, access times are practically 0 for new patients. The access times for return patients are also well within any limits set by the Treeknormen (RIVM, n.d.). So the function center and access times have been left out of further analyses.

The simulation model shows that there are various possibilities for successfully improving the efficiency of the outpatient clinic trough interventions in the scheduling, schedules and constraints. We have identified the combinations of interventions that result in the most efficient and balanced improvements to patient waiting time, doctor's idle time and overtime for the current situation where walk-in patients are seen by a walk-in doctor and a situation where walk-in patients are shared among regular doctors.

In case the outpatient clinic will continue to utilize a separate walk-in doctor, we identified two different but useful improvement methods. The first configuration, experiment 62, is able to reduce waiting times by 6%, idle times by 8% and it achieves a 32% reduction in overtime. The second configuration, experiment 64, reduces waiting time by 29% and overtime by 19%, but does so at a cost of an 8% increase in idle time. Table 29 shows the configurations of these experiments.

An added bonus of implementing configuration 64 is that the clinic's performance becomes less sensitive to an increase in average scheduled utilization. However, since new patients are scheduled at the end of the consultation session, medical students do tend to influence overtime when they see new patients.

In case the walk-in doctor will be made obsolete, and walk-in patients will be shared among doctors that already have a consultation session, the patient waiting times can be reduced by 3%, while reducing walk-in patient waiting times to 9 minutes, reducing idle time by 25% and accepting an increase of overtime by 13%, by using the configuration of experiment 320, which is shown in Table 29. If this configuration will be implemented for sessions during walk-in times, other sessions outside of walk-in times can easily be held with configuration 64, since configuration 320 and 64 are identical in all but the way of treating walk-in patients.

Table 29: Configurations of the most balanced and efficient improvements to the scheduling system.

Experiment number	Appointment Rule	Patient Sequence	Share New Patients	Doctor's Punctuality	Med. Student Appointments	Share Walk-ins	Empty Slots for Walk-ins
62	Dome	NPP Late*	False	Impr.	True	False	False
64	IAI**	NPP Late*	False	Impr.	True	False	False
320	IAI**	NPP Late*	False	Impr.	True	True	True

Implementing one of these interventions changes the sensitivity of the performance of the outpatient clinic to various environmental factors. A decrease in no-show rate will have a less dramatic effect than in the current situation. A change in medical student attendance of consultations does show a larger effect to idle times and overtimes of doctors. And, of course, changes in walk-in rates have a larger effect on the performance of regular consultation sessions for experiment 320.

Though the abovementioned sets of interventions all include medical student appointments, this intervention only offers a rather limited improvement of up to 3% on idle time and up to 5% on overtime. This means that disregarding the medical student appointments would not make a large difference.

Sharing new patients only achieves substantial improvements (up to 18%) on waiting time for configurations that perform poorly on waiting time in the first place. Configurations that perform well on waiting time gain only small improvements or even none at all from sharing new patients. As for idle time and overtime, sharing new patients only has large effects on configurations that include a late new patient pool. With those configurations, idle time decreases by approximately 4 minutes, but overtime increases by on average 5 minutes. The combination of only improving poorly performing waiting times, and the double effect on idle time and overtime ensures that sharing new patients does not substantially improve configurations close to the efficient frontier.

There is one draw-back to using the improved appointment intervals, especially in combination with empty appointment slots for walk-in patients. Both these interventions cost appointment slots to implement; it is possible to see the same amount of patients as is currently the case, but then 99% of the appointments will have to be utilized if the same amount of consultation sessions is kept. This means that a (sudden) increase in patient numbers can only be compensated by scheduling extra consultation hours and it might cause an increase in access times.

6.2. Recommendations

We recommend the management and doctors of the ENT outpatient clinic of UMCU the following:

In view of ENT's goal of reducing waiting times and overtimes and being able to cope with increasing utilization, we recommend implementing configuration 64. This configuration uses improved appointment intervals and a late new patient pool, has an improved doctor's punctuality and uses medical student appointments. This configuration reduces waiting times by 29% and reduces overtime by 19%. It is also more robust for an increase in utilization. However, it comes with a slight drawback, namely that consultation schedules that employ the improved appointment intervals have 25% fewer appointment slots for return patients. But, since the current average scheduled utilization of consultation sessions is approximately 75%, this reduction in return patient appointment slots does not create a need for an increase in consultation sessions.

If ENT instead prefers to focus on improving the doctor's performance and reduce overtime by 32% and idle time by 8%, we recommend implementing the system of configuration 62, which utilizes the Dome appointment rule, combined with a late new patient pool, has sessions that start on time, and uses medical student appointments. This system also slightly improves patients' waiting time at the outpatient clinic. Since the effect of medical student appointments is rather small, this could be omitted.

Moreover, if ENT prefers to stop using a dedicated walk-in doctor, this can be accomplished by experiment 320, which also uses improved appointment intervals with a late new patient pool, has an improved doctor's punctuality, uses medical student appointments, and it also uses some empty slots for walk-in patients. This system offers a small improvement to waiting time, a 25% reduction in doctor's idle time, but does so at the cost of a 13% increase in overtime. This configuration also has the disadvantage of decreasing the maximum production. If the empty slots for walk-in patients are shared among three doctors, consultation sessions have to be utilized at 99% to achieve the current production levels. This would mean that the morning sessions will probably also get a higher utilization (since the walk-in sessions are in the afternoon). Since configuration 64 and 320 are identical in configuration in all but the way to treat walk-in patients, we recommend using configuration 64 for all sessions where there will be no walk-in patients, if configuration 320 is implemented. If management decides to implement this configuration, we also recommend to change the walk-in session times such that they completely overlap with the general consultation session times.

If ENT implements one of the recommended configurations, we recommend regularly repeating the measurements of waiting time and overtime, in order to monitor the system's performance and ensure that the implemented configurations achieve the expected improvements.

In general, but especially if ENT implements one of the configurations with improved appointment intervals, we recommend to repeat the consultation duration measurements regularly. This in order to ensure that the scheduled consultation durations still reflect actual consultation durations.

From the measurements of the current situation, it became clear that doctors are not very punctual with starting clinic sessions. The data collected with these measurements show that starting on time offers significant improvements to both waiting time and overtime. The findings from the simulations support this conclusion. Therefore we recommend doctors of ENT to improve their punctuality, and we recommend management of ENT to reinforce this behavior. For a further discussion on methods of improving doctor's punctuality we refer the interested reader to Section 6.3.5.

We recommend implementing the following improvement to the hospital's electronic care information system (EZIS). Besides the "green checkmark" that is added to a patient at check-in at the counter, we recommend adding a sign that the doctor can add to the patient upon calling the patient in for the consultation. Apart from reducing the probability of doctors forgetting a patient in the waiting room, this system can easily be used to continuously monitor patient's waiting times in all outpatient clinics. We also recommend improving EZIS with an option that doctors can select, which shows a pop up the moment that the doctor's next patient is checked in at the counter. With this option, doctors can concentrate better on other work and do not have to check EZIS regularly to see whether a new patient has arrived.

During the research, it became clear that there is a significantly reduced demand during summer months. This reduction in demand does not stem from a reduction in capacity. We recommend using scheduling fewer consultation sessions, or reducing consultation session durations, to ensure that doctors can use their time efficiently. The extra time that this creates could be put to use by giving the employees courses in, for instance, time management or typing.

Furthermore, part of the aim of this research is to decrease patients' actual waiting times. However, as Thompson, Yarnold, Williams and Adams (1996) conclude from their research, managing patients' expectations has a larger effect on patient satisfaction than actually decreasing waiting times. De Man, Vandaele and Gemmel (2004) strongly recommend going a step further and explaining to patients why they have to wait. They find this to be "the single most effective waiting perception management technique" related to patients' perception of reliability. Therefore, in addition to the recommendations following from this research, we recommend to introduce an (automated) method of notifying patients of their expected waiting times, as well as giving the reason for the waiting times.

For further research, we have the following recommendations:

The algorithms used for determining which doctor sees which patient when sharing new or walk-in patients do not take into account the doctors' further schedules. We expect that taking this factor into account in these algorithms could improve the system's performance. A further study on this decision making process might show that sharing patients offers better improvements. Aside from the decision making process, we believe that further research on the effect of the percentage of shareable patients on the effect of sharing patients might also give better insight into the potential benefits of sharing patients.

In the modeling part of this study, we did not take access times into account because the current access times turned out to be perfectly acceptable. However, two of the recommended configurations cause a decrease in available appointment slots. This might increase access times. A further study on the effect of this decrease in available appointment slots on access times could offer more insight into this effect.

In this study, we made the assumption that a doctor's service times do not depend on the size of the queue of waiting patients for a doctor. All doctors we consulted for this research said that they do shorten service times when presented with a large queue or even a busy schedule. This is also mentioned in other research (Westeneng, 2007; Cayirli et al., 2006). However, we found no research that actually supports this claim based on real-life data for outpatient centers. A further study on the habit of doctors increasing their service rates upon observing congestion in the waiting area, and on the effect this has on session performance might improve future research on the performance of outpatient clinics.

6.3. IMPLEMENTATION

This section examines possible difficulties with the practical implementation of the recommended interventions. We start by inspecting the appointment rules, followed by patient sequencing, sharing of walk-in patients, medical student appointments, and finish with how to improve the doctor's punctuality.

6.3.1. APPOINTMENT RULES

The recommended configurations have two appointment rules: Improved appointment intervals and the Dome rule. Both of these appointment rules can easily be implemented by updating the schedules in the administration program (EZIS). This only entails scheduling appointments on different moments.

The improved appointment intervals that we proposed are based on consultation durations that were averaged over several doctors. Naturally, some doctors work faster than the average and do not need this extra time. One method to overcome this is to start by giving every doctor the improved appointment intervals. Then, if they turn out not to need it, they can switch back to the current appointment times. In order to facilitate this possible switch back, we recommend scheduling appointments as much as possible on appointment times that are a multiple of 10 minutes. If this is done carefully, the current appointment intervals can be reinstated without rescheduling any appointments.

For the Dome rule, it might happen that employees or patients protest the difference in appointment intervals ("Why is this patient scheduled for 5 minutes and this similar patient for 15 minutes?"). If this happens, it should be explained to them that this does not mean that the patient with a 5 minute appointment interval will only be seen for 5 minutes. They should see it more as if the next patient(s) just arrive a bit early so that the doctor is not kept waiting.

6.3.2. PATIENT SEQUENCING

All recommended configurations use a late new patient pool, where all new patients are scheduled at the end of the clinic session. Since this patient sequence basically entails just a small change to the schedule, the practical implementation can be done by some small changes in EZIS.

While presenting the proposed interventions to the hospital staff, the issue arose that scheduling new patients together might lead to congestion at the check-in counter. This issue has been taken into account in the model, and the conclusion is that the difference is very small. See Table 30 for the effects on using the base scenario and two of the new patient pools on the average waiting times at the counter and the average of daily maximum waiting times at the counter. A partial explanation for the small effect of the new patient pools on waiting times is that, although the process duration at the counter is longer for new patients, new patients also have longer appointment durations, which means that they have longer inter-arrival times.

Table 30: The effects of various appointment rules and patient sequences on waiting time at the counter.

Appointment rule	Patient sequence	# Doctors	Average wait at counter [mm:ss]	Avg. daily max. wait at counter [mm:ss]
Base	Base	7	00:48	05:22
Bailey-Welch	NPP Early	7	00:47	05:24
Bailey-Welch	NPP Mid	7	00:48	05:43

6.3.3. Sharing walk-in patients

Sharing walk-in patients will change the doctors' way of working. This might come with some transitional difficulties, such as doctors that give low priority to seeing walk-in patients, or walk-in patients that are accidentally forgotten in the waiting room. In order to prevent these problems from occurring, we recommend making someone responsible for determining which doctor sees which patient. This could be one of the counter-employees, one of the doctors that also share patients, or the supervising doctor. The advantage of giving responsibility to one specific person is that it will reduce the possibility of doctors avoiding to see walk-in patients. If the responsibility is shared by the doctors on a rotating basis, this might create ownership of the process and improve willingness to cooperate and see the walk-in patients.

Ensuring that patients are not forgotten can be done by, for instance, putting their name and arrival time in a jar on the counter, and taking it out when they are called in by the doctor.

We also recommend to determine the best way to schedule empty slots for the walk-in patients. The way that was used in the model is based on patients with evenly distributed arrival rates, but in practice, walk-in patients appear to have a tendency of arriving at the start of the walk-in session. So perhaps it would be wise to schedule some more empty slots at the beginning of a consultation session.

Since walk-in patients will be treated during regular consultation sessions, we recommend changing walk-in times such that they completely overlap with regular consultation times. Currently, afternoon sessions are from 13:00 to 16:00 and walk-in sessions are from 12:30 to 15:00. We recommend changing the start of the walk-in sessions to 13:00. If it is deemed necessary, the end of the session can also be changed to a later time. The advantage of having walk-in times overlap completely is that doctors do not have to be available for a walk-in patient outside of their regular consultation hours. These changes in walk-in times should be clearly communicated to general practitioners that refer patients to the walk-in session.

When sharing walk-in patients, we recommend sending all walk-in patients to the same waiting room, so there will be no confusion about the whereabouts of patients. We also recommend placing all doctors that share these patients in rooms close to this waiting room, to avoid unnecessary travel times.

We recommend keeping the walk-in session in the afternoon, since this has the advantage of giving patients that visit their general practitioner in the morning the opportunity to attend the walk-in session on the same day.

6.3.4. *Medical student appointments*

Implementing medical student sessions should not be too much trouble. It would only entail that medical students call the patients that they like to see on a session a number of days in advance to ask them whether they can arrive a little earlier at the outpatient clinic. In the computer model, we set the medical student appointments at 10 minutes prior to the original appointment. This had to do with patients being an average of 10 minutes early, so this should let patients arrive on average 20 minutes prior to the original appointment.

It seems important for patient satisfaction that if a patient arrives early to be seen by a medical student, they are not kept waiting by the student. Practically, this means that patients with a medical student appointment are given priority by the medical student. This also means that medical students should communicate any agreements with patients clearly to counter employees, and that counter employees should clearly communicate about the arrival of these patients.

6.3.5. *Improving doctor's punctuality*

The doctor's punctuality may be improved in several ways. First, creating awareness among doctors of the importance of being on time is expected to increase the priority doctors place on being on time. It should also be clear that a doctor is not on time if he arrives at the exact moment of the first appointment, since it takes some time to get started.

Second, for morning sessions, the morning hand-off can cause doctors to be late. This can happen because the hand-off runs late, but it also has its effect that the location is roughly a 5 minute walk from the outpatient clinic. Possible improvements include improving the hand-off's efficiency, scheduling more time between the start of the hand-off and start of the consultation sessions, or changing the location of the hand-off.

Doctors often work during the lunch break. A possible improvement to the doctor's punctuality in the afternoon is to let doctors work at the outpatient clinic during their lunch break, so underestimating their travel time to the outpatient clinic has a smaller effect on the start time of the session.

The doctors' punctuality could, in general, be improved by giving them a course in time management. A perfect time for this course is during the summer, when there are few patients to see and doctors have more time they can spend on extra courses.

Literature

Babes, M., & Sarma, G. V. (1991). Outpatient queues at the Ibn-Rochd Health Center. *Journal of the Operational Research Society*. 42(10), 845-855

Bailey, N. (1952). A study of queues and appointment systems in hospital out-patient departments, with special reference to waiting-times. *Journal of the Royal Statistical Society*, *14*(2), 185–199.

Berg, B. P., Denton, B. T., Ayca Erdogan, S., Rohleder, T., & Huschka, T. (2014). Optimal booking and scheduling in outpatient procedure centers. *Computers & Operations Research*, *50*, 24–37.

Cardoen, B., Demeulemeester, E., & Beliën, J. (2010). Operating room planning and scheduling: A literature review. *European Journal of Operational Research*, *201*(3), 921–932.

Cayirli, T., & Gunes, E. D. (2013). Outpatient appointment scheduling in presence of seasonal walk-ins. *Journal of the Operational Research Society*, *65*(4), 512–531.

Cayirli, T., & Veral, E. (2003). Outpatient Scheduling in Health Care: a Review of Literature. *Production and Operations Management*, *12*(4), 519–549.

Cayirli, T., Veral, E., & Rosen, H. (2006). Designing appointment scheduling systems for ambulatory care services. *Health Care Management Science*, *9*(1), 47–58.

Cayirli, T., Veral, E., & Rosen, H. (2008). Assessment of patient classification in appointment system design. *Production and Operations Management, 17*(3), 338–353.

Cayirli, T., Yang, K. K., & Quek, S. A. (2012). A Universal Appointment Rule in the Presence of No-Shows and Walk-Ins. *Production and Operations Management*, *21*(4), 682–697.

CBO (2004). *Meetplan werken zonder wachtlijst*. Utrecht: CBO Kwaliteitsinstituut voor de Gezondheidszorg.

De Man, S., Vandaele, D., Gemmel, P. (2004). *The waiting experience and consumer perception of service quality in outpatient clinics.* Universiteit Gent, Faculteit economie en bedrijfskunde. Working paper.

Denton, B. T., & Gupta, D. (2003). A sequential bounding approach for optimal appointment scheduling. *IIE Transactions*. Vol. 35, 1003-1016

Günal, M. M., & Pidd, M. (2010). Discrete event simulation for performance modelling in health care: a review of the literature. *Journal of Simulation*, *4*(1), 42–51.

Hans, E. W., Van Houdenhoven, M., & Hulshof, P. J. H. (2012). A Framework for Healthcare Planning and Control. In *Handbook of Healthcare System Scheduling,* 303–320.

Harper, P. R., & Gamlin, H. M. (2003). Reduced outpatient waiting times with improved appointment scheduling: a simulation modelling approach. *OR Spectrum*, *25*(2), 207–222.

Ho, C., & Lau, H. (1992). Minimizing total cost in scheduling outpatient appointments. *Management Science.* Vol. 38, 1750-1764

Jun, J. B., Jacobson, S. H. and Swisher, J. R. (1999). Application of Discrete-Evente Simulation in health care clinics: A survey. *The Journal of the Operational Research Society*, Vol. 50, No. 2, 109–123.

Kaandorp, G. C., & Koole, G. (2007). Optimal outpatient appointment scheduling. *Health Care Management Science*, *10*(3), 217–229.

Klassen, K. J., & Rohleder, T. R. (1996). Scheduling outpatient appointments in a dynamic environment. *Journal of Operations Management*, *14*(2), 83–101.

Law, A. M. (2007). *Simulation modeling and analysis, fourth edition*. New York: McGraw-Hill.

Liu, L., & Liu, X. (1998). Block appointment systems for outpatient clinics with multiple doctors. *Journal of the operational research society*. 49(12), 1254-1259

Mondschein, S. V., & Weintraub, G. Y. (2003). Appointment policies in service operations: a critical analysis of the economic framework. *Production and Operations Management*, *12*(2), 266–286.

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

RIVM (n.d.). *Het Treekoverleg: Streefnormen wachttijden curatieve sector*. Retrieved from http://www.zorgatlas.nl/thema-s/wachtlijsten/wachtlijsten-ziekenhuiszorg/het-treekoverleg-streefnormen-wachttijden-curatieve-sector on 13 November 2014.

Robinson, L. W., Chen, R. R. (2003). Scheduling doctors' appointments: Optimal and empirically-based heuristic policies. *IIE Transactions*. Vol. 35, 295-307

Rohleder, T. R., & Klassen, K. J. (2002). Rolling Horizon Appointment Scheduling : A Simulation Study. *Health Care Management Science*, *5*(3), 201–209.

Rouppe van der Voort, M. B. V. (2014). *Optimising delays in access to specialist outpatient clinics.* Tilburg: Rouppe van der Voort.

Thompson, D. A., Yarnold, P. R., Williams, D. R., & Adams, S. L. (1996). Effects of actual waiting time, information delivery, and expressive quality on patient satisfaction in the emergency department. *Annals of emergency medicine*, 28(6). 657–665.

UMCU (2013). *Directieverslag 2012*. Utrecht: Universitair Medisch Centrum Utrecht.

Vissers, J. (1979). Selecting a suitable appointment system in an outpatient setting. *Medical Care*. 17(12), 1207-1220

Wang, P. P. (1997). Optimally scheduling N customer arrival times for a single-server system. *Computers & Operations Research*. Vol. 24, 703-716

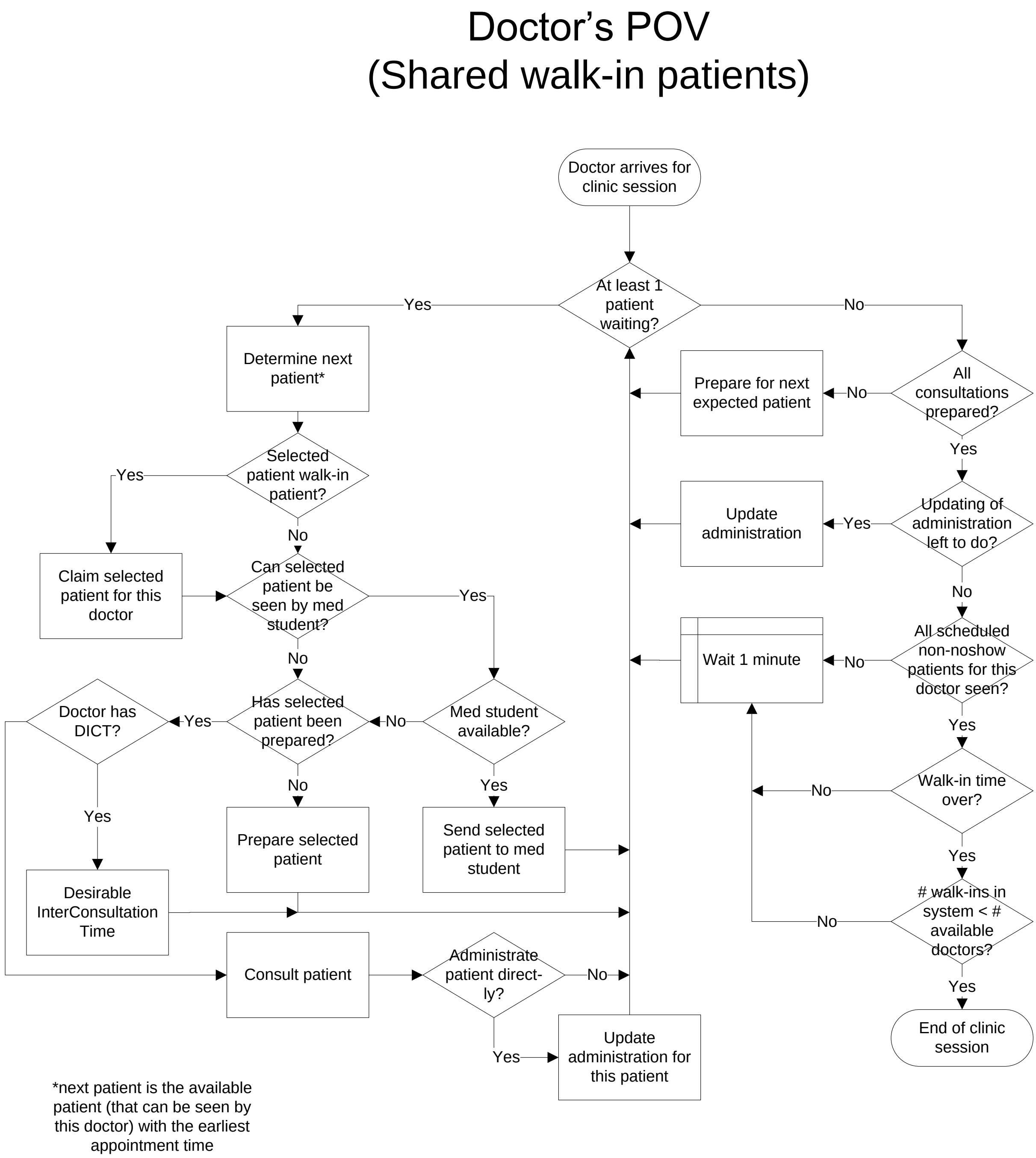
Westeneng, J. (2007). *Outpatient appointment scheduling: An evaluation of alternative appointment systems to reduce waiting times and underutilization in an ENT outpatient clinic*. Enschede: Universiteit Twente.

Wijewickrama, A., & Takakuwa, S. (2006). Simulation analysis of an outpatient department of internal medicine in a university hospital. *Proceedings of the 2006 Winter Simulation Conference,* 425–433.

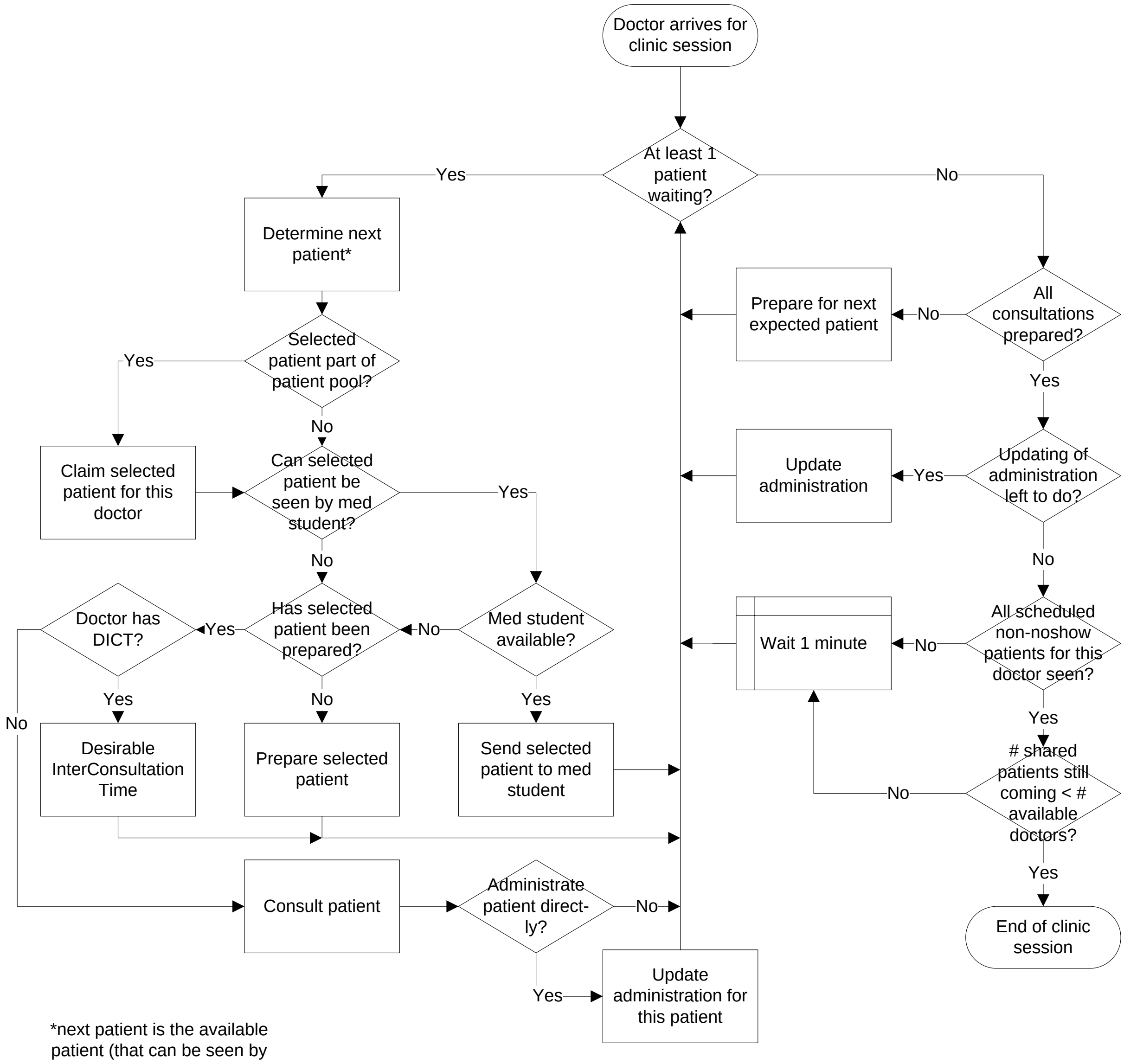
APPENDICES

APPENDIX A: PROCESS CHARTS FOR INTERVENTIONS

The figures below represent the altered Doctor's and medical student's processes for several interventions.

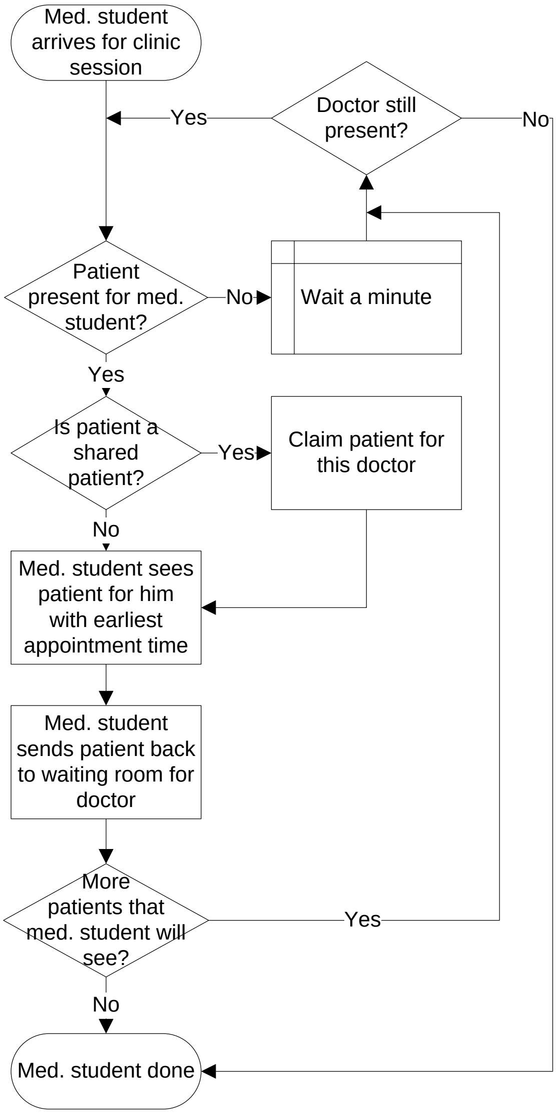


Doctor’s POV
(Shared new patients)

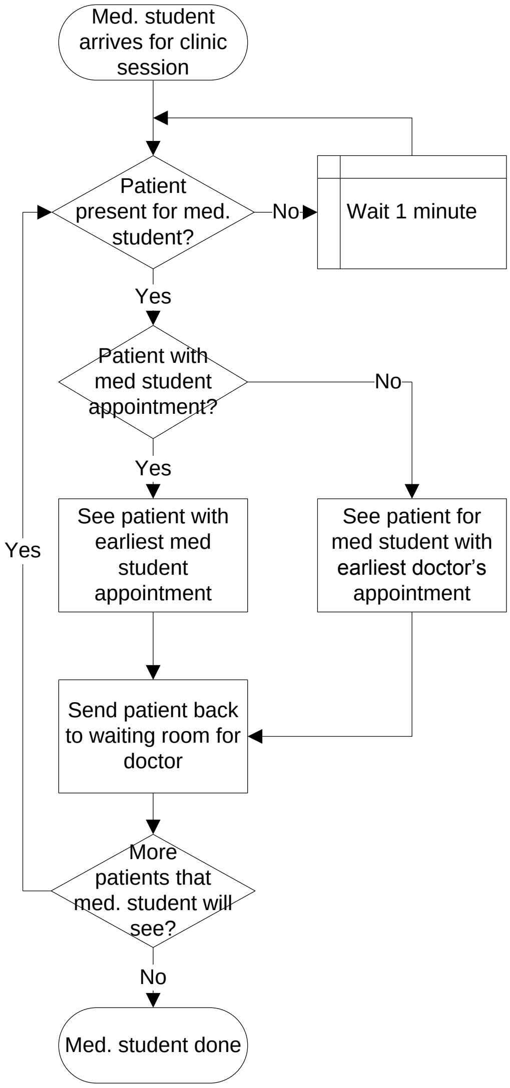


*next patient is the available patient (that can be seen by this doctor) with the earliest appointment time

Med. student's POV (shared walk-ins and shared new patients)



Med. student's POV (med student appointments)

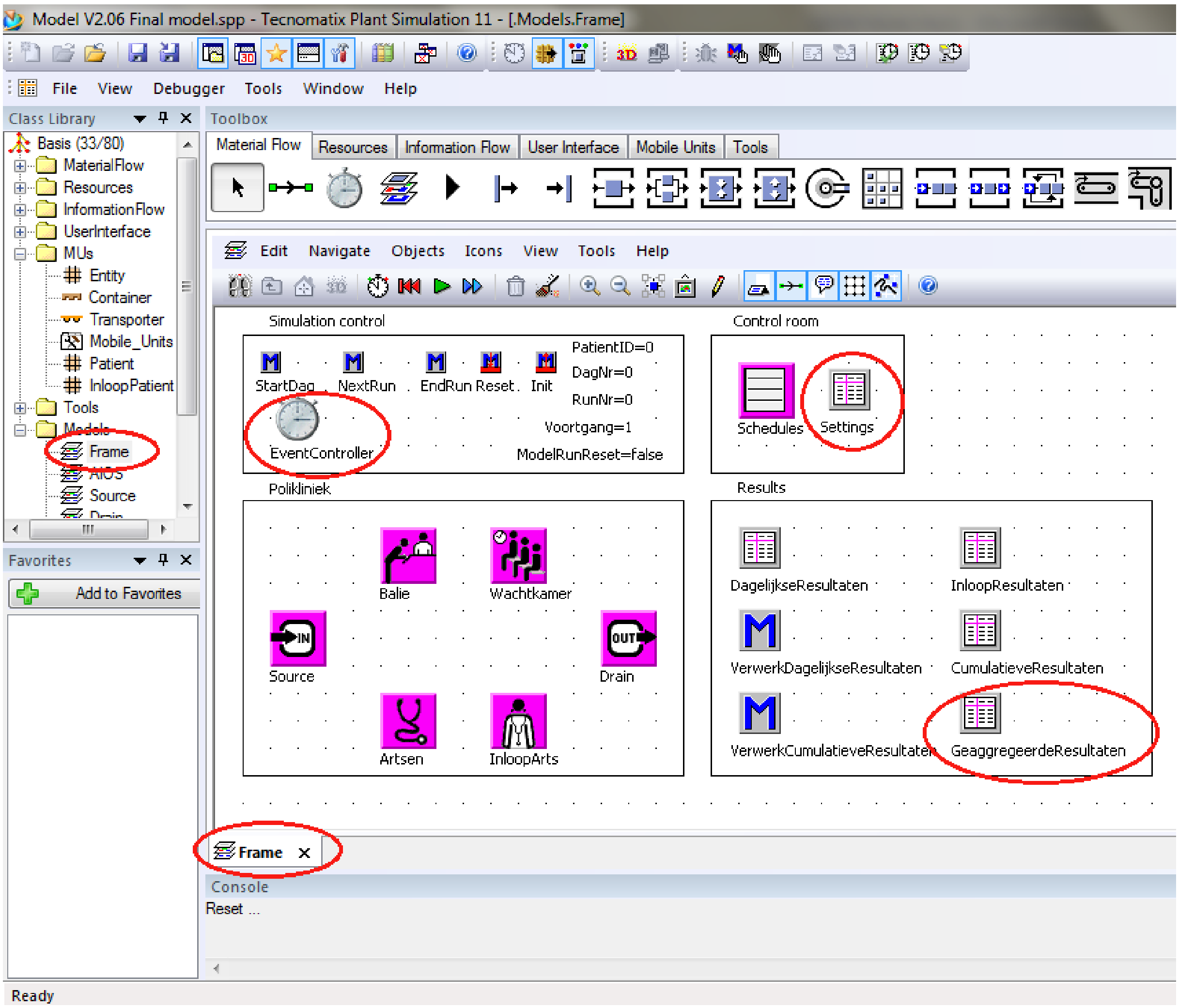


APPENDIX B: DESCRIPTION SIMULATION MODEL

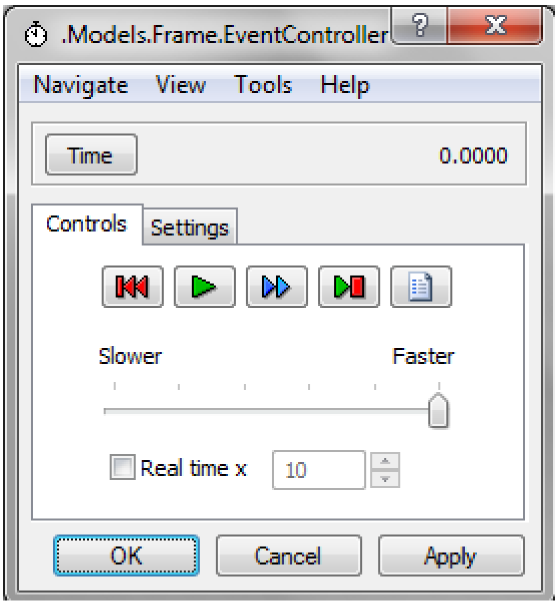
In order to run the simulation model, you will need a computer with Siemens Plant Simulation 11 and a valid user license. A (free) student license for the software has enough capabilities to use or add to the model.

To use the model, open the model file. The figure on the next page shows a screenshot of the model, with the most important parts we discuss here marked with a red circle. Open the frame "Frame". If the "Frame" is not opened in the main screen, it can be found in the Class Library under Models. Once in the "Frame", the model's settings can be set in the tablefile Settings (in the "Control room"-box). One row in the Settings corresponds to one experiment in the model, so multiple experiments can be performed sequentially by filling out multiple rows in the Settings. Make sure that all settings are filled out in a single row. The various settings are:

- "Rooster", which schedule should be used (should be a path-reference to a schedule in the frame "Schedules");
- "NoshowProb", the no-show rate. Should be between 0 and 1;
- "Volgeplandheid", the average scheduled utilization. Should be between 0 and 1;
- "AantalAIOS", the number of doctors that will simultaneously have consultation sessions;
- "Inloop", what happens with walk-in patients. Entering "Inlooparts" calls a walk-in doctor, "Delen" shares new patients. If walk-in patients are not important for your simulation, entering anything that is not "Inlooparts" or "Delen" will ignore walk-in patients entirely;
- "RunLength", the number of replications for the experiment;
- "DoctorPunctuality", different options for the doctor's punctuality. "Current" gives the current punctuality, "Exact" lets the session start exactly on time, "Low" lets the session start early with probability distribution N~(-5,3) in minutes. Entering something else will result in an error;
- "CoAssKans", the probability of a medical student attending a consultation session.
- "BeginInloop", the start time of the walk-in session. Keep in mind that the regular consultation sessions are from 08:20 to 12:00 in the model;
- "EindeInloop", the latest time that walk-in patients can enter the system;
- "DeelNieuwePatienten", decide whether new patients are shared among doctors or not. Value either True or False;
- "MetZnAllenWachten", if this is true than all doctors will wait for each other. Was not used in the experiments;
- "P(DICT)", the probability of a doctor having Desirable InterConsultation Time before seeing a patient. Can be anywhere from 0 to 1;
- "Lege Plekken voor Inlopers", values can be True or False. If both this value and "DeelNieuwePatienten" are set to true then the schedule will have empty slots for new patients;
- "MedStudentSessions", can be either True or False. Setting it to True will let medical students schedule earlier appointments with selected new patients;
- "P(direct administreren)" determines the probability of the doctor updating the patients' administration directly after the consultation session. Values can be 0 to 1.



Once all settings have been entered, double click on the EventController in the “Frame”, in the Simulation control-box. This opens the EventController, which looks like this:



Make sure the model is reset by pressing the reset-button in the EventController. Now we are ready to perform the experiment(s).

If you want to view the animations (there are not a lot of them) in the model of the first experiment, click the play-button (the green triangle) in the EventController. You can slow down or speed up the simulation with the slider below the buttons. If you do not want to view any animations and just want the experiments to go swiftly, press the "start simulation without animations"-button (the double blue triangles) in the EventController and wait until the simulation is finished. The "Frame" shows the progress throughout multiple experiments with the variable "Voortgang".

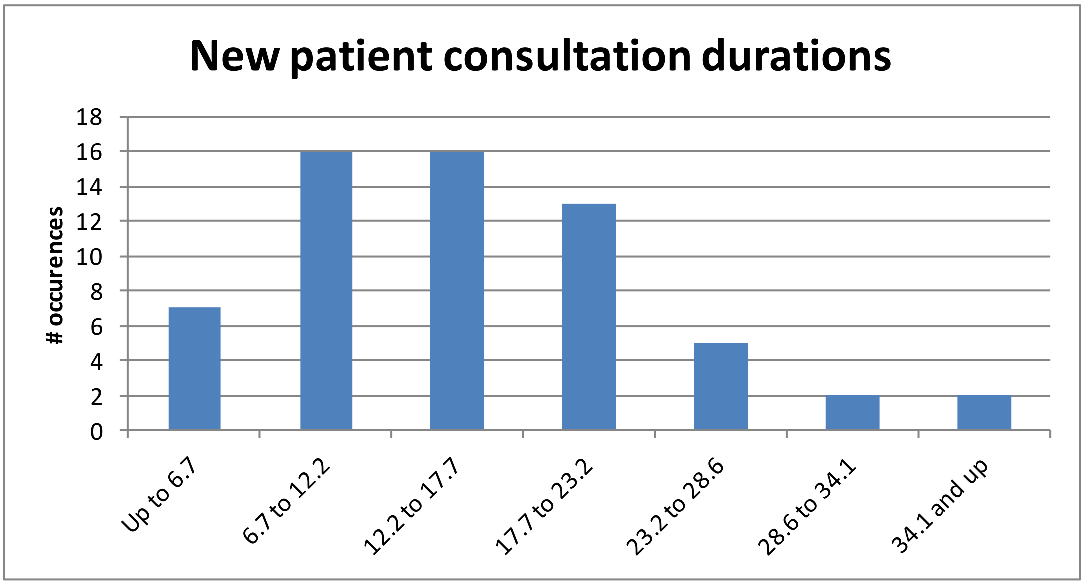
Once the simulation is finished, the experiments' results are shown in the tablefile "GeaggregeerdeResultaten" on the "Frame". To save the results, you can either select "save as […]" on the file menu (of the table, not of the main-screen) and choose the filetype you want to use to save the results, or copy and paste the data manually.

APPENDIX C: DETERMINING A PROBABILITY DISTRIBUTION

This appendix shows an example of how we distill a probability distribution from a set of measured data, we do this for the new patient consultation durations. We do this in four steps: hypothesizing, parameter estimation, checking fit with plots, and a goodness of fit test.

HYPOTHESIZING

At first glance, the histogram shown in the figure below seems to resemble that of a gamma-distribution. The coefficient of variation (0.51) is not close to one, which is also consistent with a gamma distribution.



PARAMETER ESTIMATION

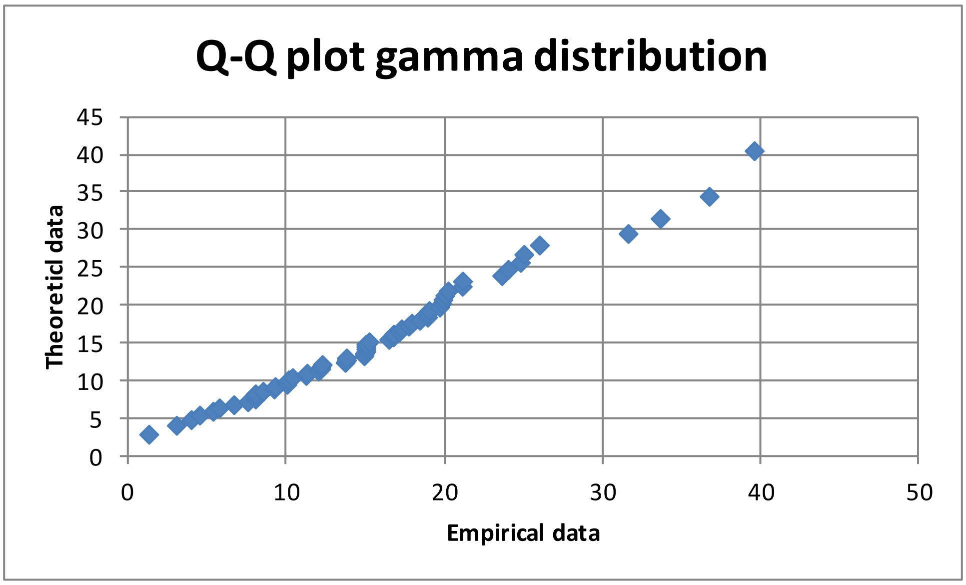
The gamma-distribution uses an alpha and a beta-parameter. These are estimated from the data sample as follows:

$$\alpha = \left(\frac{\bar{x}}{s}\right)^2 \qquad\qquad \beta = \frac{\bar{x}}{\alpha}$$

In our data, the sample mean $\bar{x}$ equals 15.544, and the sample standard deviation s equals 7.885. This gives: $\alpha = 3.886$ and $\beta = 4.000$.

CHECKING FIT WITH PLOTS

The Quantile-Quantile plot in the following figure of the empirically found data versus the theoretical data from the hypothesized gamma distribution with $\alpha = 3.886$ and $\beta = 4.000$, mostly shows a straight line with y = x. This means that is quite likely that the observed data is taken from the expected distribution. Only three of the data points on the right do not seem to correspond with the hypothesized distribution, so the hypothesized distribution probably slightly underestimates high values.



GOODNESS-OF-FIT-TEST

To test the goodness-of-fit of the data, we perform a χ^2-test as shown in the following table. For this test, we define:

H_0: Data is of gamma distribution with $\alpha = 3.886$ and $\beta = 4.000$

H_a: Data is not of gamma distribution with $\alpha = 3.886$ and $\beta = 4.000$

Bin	Lower value bin	Upper value bin	Observed	Expected	(O-E)²/E
1	0.00	7.67	8	8.71	0.06
2	7.67	10.41	10	8.71	0.19
3	10.41	12.93	6	8.71	0.85
4	12.93	15.62	10	8.71	0.19
5	15.62	18.90	9	8.71	0.01
6	18.90	23.80	10	8.71	0.19
7	23.80	inf	8	8.71	0.06
				Total:	1.54

At confidence level 0.95 ($\alpha = 0.05$) and 6 degrees of freedom, H_0 should not be rejected if χ^2 < 1.635. The test value of the χ^2-test is 1.54, so H_0 should not be rejected. So, at confidence level 0.95, it has not been proven that the data is not of a gamma distribution with $\alpha = 3.886$ and $\beta =$ 4.000.

APPENDIX D: INPUT AND OUTPUT OF EXPERIMENTS

The table below presents the settings of all experiments, along with the output on average waiting time of non-walk-in patients, average idle time and average overtime. To keep a clear overview, we use the following abbreviations:

- EN Experiment Number
- Ut Utilization
- AR Appointment Rule
- PS Patient Sequence
- SNP Shared New Patients
- DPu Doctor's Punctuality
- MSA Medical Student Appointments
- SWiP Shared Walk-in Patients
- ESWiP Empty Slots for Walk-in Patients
- BW Bailey-Welch rule
- IAI Improved Appointment Intervals
- NPP New Patient Pool
- Impr. Improved (Doctor's Punctuality)

EN	Ut	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over
1	0.75	Base	Base	False	Current	False	False	False	09:44	42:16	22:55
2	0.75	Dome	Base	False	Current	False	False	False	11:03	38:27	20:07
3	0.75	BW	Base	False	Current	False	False	False	12:23	34:50	20:52
4	0.86	IAI	Base	False	Current	False	False	False	09:02	41:05	20:40
5	0.75	Base	NPP Early	False	Current	False	False	False	09:37	45:39	25:29
6	0.75	Dome	NPP Early	False	Current	False	False	False	10:03	41:30	22:08
7	0.75	BW	NPP Early	False	Current	False	False	False	13:46	30:38	21:41
8	0.87	IAI	NPP Early	False	Current	False	False	False	09:23	40:33	21:50
9	0.75	Base	NPP Mid	False	Current	False	False	False	09:47	43:31	23:21
10	0.75	Dome	NPP Mid	False	Current	False	False	False	11:27	40:22	21:00
11	0.75	BW	NPP Mid	False	Current	False	False	False	12:39	36:02	21:19
12	0.87	IAI	NPP Mid	False	Current	False	False	False	09:07	40:15	21:18
13	0.75	Base	NPP Late	False	Current	False	False	False	11:25	36:55	22:06
14	0.75	Dome	NPP Late	False	Current	False	False	False	12:50	32:34	18:55
15	0.75	BW	NPP Late	False	Current	False	False	False	15:07	30:22	21:04
16	0.87	IAI	NPP Late	False	Current	False	False	False	09:31	38:24	21:22
17	0.75	Base	Base	False	Current	False	False	True	10:06	41:45	22:23
18	0.75	Dome	Base	False	Current	False	False	True	11:23	38:00	19:58
19	0.75	BW	Base	False	Current	False	False	True	12:50	34:20	20:34
20	0.86	IAI	Base	False	Current	False	False	True	09:15	40:18	19:38
21	0.75	Base	NPP Early	False	Current	False	False	True	09:40	45:27	25:03
22	0.75	Dome	NPP Early	False	Current	False	False	True	10:06	41:23	21:58
23	0.75	BW	NPP Early	False	Current	False	False	True	13:53	30:31	21:35
24	0.87	IAI	NPP Early	False	Current	False	False	True	09:28	40:23	21:36
25	0.75	Base	NPP Mid	False	Current	False	False	True	09:55	43:42	23:37

EN	Ut	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over
26	0.75	Dome	NPP Mid	False	Current	False	False	True	11:37	40:18	21:05
27	0.75	BW	NPP Mid	False	Current	False	False	True	12:39	35:55	21:17
28	0.87	IAI	NPP Mid	False	Current	False	False	True	09:19	40:11	21:30
29	0.75	Base	NPP Late	False	Current	False	False	True	11:40	36:25	21:30
30	0.75	Dome	NPP Late	False	Current	False	False	True	13:04	32:04	18:45
31	0.75	BW	NPP Late	False	Current	False	False	True	15:15	29:51	20:36
32	0.87	IAI	NPP Late	False	Current	False	False	True	09:44	37:44	20:40
33	0.75	Base	Base	False	Impr.	False	False	False	07:31	50:54	21:08
34	0.75	Dome	Base	False	Impr.	False	False	False	08:17	46:51	18:14
35	0.75	BW	Base	False	Impr.	False	False	False	08:48	42:28	18:15
36	0.86	IAI	Base	False	Impr.	False	False	False	07:04	50:00	19:09
37	0.75	Base	NPP Early	False	Impr.	False	False	False	08:11	54:52	24:10
38	0.75	Dome	NPP Early	False	Impr.	False	False	False	08:12	50:02	20:10
39	0.75	BW	NPP Early	False	Impr.	False	False	False	10:24	37:27	18:34
40	0.87	IAI	NPP Early	False	Impr.	False	False	False	07:40	49:21	20:18
41	0.75	Base	NPP Mid	False	Impr.	False	False	False	07:20	52:08	21:39
42	0.75	Dome	NPP Mid	False	Impr.	False	False	False	08:14	48:51	19:02
43	0.75	BW	NPP Mid	False	Impr.	False	False	False	08:50	43:40	18:45
44	0.87	IAI	NPP Mid	False	Impr.	False	False	False	06:39	48:51	19:31
45	0.75	Base	NPP Late	False	Impr.	False	False	False	08:29	44:17	19:28
46	0.75	Dome	NPP Late	False	Impr.	False	False	False	08:58	39:35	16:05
47	0.75	BW	NPP Late	False	Impr.	False	False	False	10:32	36:55	17:52
48	0.87	IAI	NPP Late	False	Impr.	False	False	False	06:52	46:36	19:28
49	0.75	Base	Base	False	Impr.	False	False	True	07:46	50:03	20:26
50	0.75	Dome	Base	False	Impr.	False	False	True	08:12	45:44	17:42
51	0.75	BW	Base	False	Impr.	False	False	True	09:05	41:42	17:47
52	0.86	IAI	Base	False	Impr.	False	False	True	07:07	49:10	18:08
53	0.75	Base	NPP Early	False	Impr.	False	False	True	08:06	54:29	23:42
54	0.75	Dome	NPP Early	False	Impr.	False	False	True	08:04	49:52	19:58
55	0.75	BW	NPP Early	False	Impr.	False	False	True	10:18	37:19	18:25
56	0.87	IAI	NPP Early	False	Impr.	False	False	True	07:30	48:57	19:58
57	0.75	Base	NPP Mid	False	Impr.	False	False	True	07:28	52:17	21:51
58	0.75	Dome	NPP Mid	False	Impr.	False	False	True	08:13	48:25	18:47
59	0.75	BW	NPP Mid	False	Impr.	False	False	True	08:46	43:37	18:47
60	0.87	IAI	NPP Mid	False	Impr.	False	False	True	06:52	48:37	19:34
61	0.75	Base	NPP Late	False	Impr.	False	False	True	08:32	44:06	19:08
62	0.75	Dome	NPP Late	False	Impr.	False	False	True	09:07	38:49	15:32
63	0.75	BW	NPP Late	False	Impr.	False	False	True	10:28	36:18	17:23
64	0.87	IAI	NPP Late	False	Impr.	False	False	True	06:55	45:47	18:33
65	0.75	Base	Base	False	Current	True	False	False	09:28	42:16	23:39
66	0.75	Dome	Base	False	Current	True	False	False	10:33	38:01	20:39
67	0.75	BW	Base	False	Current	True	False	False	12:03	34:36	21:48
68	0.86	IAI	Base	False	Current	True	False	False	09:26	41:16	22:39
69	0.75	Base	NPP Early	False	Current	True	False	False	08:55	45:44	25:12
70	0.75	Dome	NPP Early	False	Current	True	False	False	09:01	41:13	21:32

EN	Ut	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over
71	0.75	BW	NPP Early	False	Current	True	False	False	12:04	29:59	22:09
72	0.87	IAI	NPP Early	False	Current	True	False	False	08:41	41:01	22:01
73	0.75	Base	NPP Mid	False	Current	True	False	False	09:09	43:27	23:03
74	0.75	Dome	NPP Mid	False	Current	True	False	False	10:37	39:55	20:25
75	0.75	BW	NPP Mid	False	Current	True	False	False	11:43	35:36	20:51
76	0.87	IAI	NPP Mid	False	Current	True	False	False	08:42	40:30	21:26
77	0.75	Base	NPP Late	False	Current	True	False	False	10:47	32:48	27:30
78	0.75	Dome	NPP Late	False	Current	True	False	False	12:09	28:43	23:56
79	0.75	BW	NPP Late	False	Current	True	False	False	14:24	26:02	26:21
80	0.87	IAI	NPP Late	False	Current	True	False	False	09:10	34:44	25:56
81	0.75	Base	Base	False	Current	True	False	True	09:42	41:46	23:10
82	0.75	Dome	Base	False	Current	True	False	True	10:56	37:49	20:47
83	0.75	BW	Base	False	Current	True	False	True	11:55	33:45	21:08
84	0.86	IAI	Base	False	Current	True	False	True	09:22	40:38	21:51
85	0.75	Base	NPP Early	False	Current	True	False	True	08:44	45:30	24:44
86	0.75	Dome	NPP Early	False	Current	True	False	True	08:45	41:01	21:15
87	0.75	BW	NPP Early	False	Current	True	False	True	12:04	30:00	22:00
88	0.87	IAI	NPP Early	False	Current	True	False	True	08:39	40:37	21:37
89	0.75	Base	NPP Mid	False	Current	True	False	True	09:11	43:33	23:19
90	0.75	Dome	NPP Mid	False	Current	True	False	True	10:50	39:48	20:22
91	0.75	BW	NPP Mid	False	Current	True	False	True	11:48	35:27	20:46
92	0.87	IAI	NPP Mid	False	Current	True	False	True	08:53	40:08	21:12
93	0.75	Base	NPP Late	False	Current	True	False	True	10:59	32:33	27:10
94	0.75	Dome	NPP Late	False	Current	True	False	True	12:25	28:21	23:48
95	0.75	BW	NPP Late	False	Current	True	False	True	14:25	25:53	26:33
96	0.87	IAI	NPP Late	False	Current	True	False	True	09:22	34:06	26:11
97	0.75	Base	Base	False	Impr.	True	False	False	07:34	50:50	21:54
98	0.75	Dome	Base	False	Impr.	True	False	False	08:06	46:33	18:55
99	0.75	BW	Base	False	Impr.	True	False	False	08:53	42:32	19:31
100	0.86	IAI	Base	False	Impr.	True	False	False	07:33	50:22	21:22
101	0.75	Base	NPP Early	False	Impr.	True	False	False	08:04	55:17	24:10
102	0.75	Dome	NPP Early	False	Impr.	True	False	False	07:53	50:21	20:04
103	0.75	BW	NPP Early	False	Impr.	True	False	False	09:40	37:34	19:43
104	0.87	IAI	NPP Early	False	Impr.	True	False	False	07:36	50:10	20:45
105	0.75	Base	NPP Mid	False	Impr.	True	False	False	06:53	52:19	21:39
106	0.75	Dome	NPP Mid	False	Impr.	True	False	False	07:38	48:32	18:38
107	0.75	BW	NPP Mid	False	Impr.	True	False	False	08:10	43:22	18:22
108	0.87	IAI	NPP Mid	False	Impr.	True	False	False	06:28	49:37	19:55
109	0.75	Base	NPP Late	False	Impr.	True	False	False	08:04	40:59	25:38
110	0.75	Dome	NPP Late	False	Impr.	True	False	False	08:30	36:14	20:33
111	0.75	BW	NPP Late	False	Impr.	True	False	False	09:49	32:57	23:01
112	0.87	IAI	NPP Late	False	Impr.	True	False	False	06:34	43:37	25:05
113	0.75	Base	Base	False	Impr.	True	False	True	07:50	50:23	21:32
114	0.75	Dome	Base	False	Impr.	True	False	True	08:29	46:16	19:07
115	0.75	BW	Base	False	Impr.	True	False	True	08:56	41:57	19:06

EN	Ut	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over
116	0.86	IAI	Base	False	Impr.	True	False	True	07:23	49:31	20:08
117	0.75	Base	NPP Early	False	Impr.	True	False	True	08:01	55:08	23:59
118	0.75	Dome	NPP Early	False	Impr.	True	False	True	07:45	50:21	20:04
119	0.75	BW	NPP Early	False	Impr.	True	False	True	09:42	37:46	19:50
120	0.87	IAI	NPP Early	False	Impr.	True	False	True	07:26	49:28	20:12
121	0.75	Base	NPP Mid	False	Impr.	True	False	True	07:02	52:32	21:59
122	0.75	Dome	NPP Mid	False	Impr.	True	False	True	07:54	48:33	18:45
123	0.75	BW	NPP Mid	False	Impr.	True	False	True	08:10	43:29	18:36
124	0.87	IAI	NPP Mid	False	Impr.	True	False	True	06:37	49:24	20:11
125	0.75	Base	NPP Late	False	Impr.	True	False	True	08:07	40:34	24:28
126	0.75	Dome	NPP Late	False	Impr.	True	False	True	08:35	35:31	20:59
127	0.75	BW	NPP Late	False	Impr.	True	False	True	09:52	32:18	22:40
128	0.87	IAI	NPP Late	False	Impr.	True	False	True	06:41	42:58	24:06
129	0.75	Base	Base	True	Current	False	False	False	13:02	34:10	32:07
130	0.75	Dome	Base	True	Current	False	False	False	14:19	31:13	29:45
131	0.75	BW	Base	True	Current	False	False	False	15:36	28:23	31:09
132	0.86	IAI	Base	True	Current	False	False	False	12:06	32:54	29:24
133	0.75	Base	NPP Early	True	Current	False	False	False	13:54	38:34	36:08
134	0.75	Dome	NPP Early	True	Current	False	False	False	14:08	34:59	32:49
135	0.75	BW	NPP Early	True	Current	False	False	False	18:09	26:19	32:53
136	0.87	IAI	NPP Early	True	Current	False	False	False	13:10	33:19	32:02
137	0.75	Base	NPP Mid	True	Current	False	False	False	12:50	34:54	32:34
138	0.75	Dome	NPP Mid	True	Current	False	False	False	14:24	32:29	30:28
139	0.75	BW	NPP Mid	True	Current	False	False	False	15:38	29:04	31:28
140	0.87	IAI	NPP Mid	True	Current	False	False	False	11:54	32:03	30:29
141	0.75	Base	NPP Late	True	Current	False	False	False	14:22	29:44	31:07
142	0.75	Dome	NPP Late	True	Current	False	False	False	15:37	26:31	28:40
143	0.75	BW	NPP Late	True	Current	False	False	False	17:43	25:01	30:49
144	0.87	IAI	NPP Late	True	Current	False	False	False	12:07	30:23	30:07
145	0.75	Base	Base	True	Current	False	False	True	13:14	33:46	31:39
146	0.75	Dome	Base	True	Current	False	False	True	14:33	30:39	29:45
147	0.75	BW	Base	True	Current	False	False	True	15:56	27:50	30:40
148	0.86	IAI	Base	True	Current	False	False	True	12:01	32:16	28:39
149	0.75	Base	NPP Early	True	Current	False	False	True	13:37	38:21	35:46
150	0.75	Dome	NPP Early	True	Current	False	False	True	14:17	35:05	33:04
151	0.75	BW	NPP Early	True	Current	False	False	True	17:59	26:38	32:53
152	0.87	IAI	NPP Early	True	Current	False	False	True	13:12	32:48	31:37
153	0.75	Base	NPP Mid	True	Current	False	False	True	12:54	34:50	32:47
154	0.75	Dome	NPP Mid	True	Current	False	False	True	14:26	32:09	29:59
155	0.75	BW	NPP Mid	True	Current	False	False	True	15:56	29:14	31:45
156	0.87	IAI	NPP Mid	True	Current	False	False	True	11:52	32:06	30:37
157	0.75	Base	NPP Late	True	Current	False	False	True	14:38	30:01	31:25
158	0.75	Dome	NPP Late	True	Current	False	False	True	15:47	26:01	28:05
159	0.75	BW	NPP Late	True	Current	False	False	True	17:56	24:45	30:37
160	0.87	IAI	NPP Late	True	Current	False	False	True	12:08	30:01	29:42

EN	Ut	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over
161	0.75	Base	Base	True	Impr.	False	False	False	10:31	41:55	29:29
162	0.75	Dome	Base	True	Impr.	False	False	False	11:07	38:30	26:43
163	0.75	BW	Base	True	Impr.	False	False	False	11:42	34:57	27:32
164	0.86	IAI	Base	True	Impr.	False	False	False	09:42	40:47	26:56
165	0.75	Base	NPP Early	True	Impr.	False	False	False	12:20	47:15	34:19
166	0.75	Dome	NPP Early	True	Impr.	False	False	False	12:04	43:02	30:31
167	0.75	BW	NPP Early	True	Impr.	False	False	False	14:21	32:51	29:12
168	0.87	IAI	NPP Early	True	Impr.	False	False	False	11:05	41:30	29:52
169	0.75	Base	NPP Mid	True	Impr.	False	False	False	10:06	42:34	29:47
170	0.75	Dome	NPP Mid	True	Impr.	False	False	False	10:43	39:48	27:20
171	0.75	BW	NPP Mid	True	Impr.	False	False	False	11:30	35:39	27:45
172	0.87	IAI	NPP Mid	True	Impr.	False	False	False	09:18	39:59	28:00
173	0.75	Base	NPP Late	True	Impr.	False	False	False	10:59	36:41	27:45
174	0.75	Dome	NPP Late	True	Impr.	False	False	False	11:26	32:48	24:50
175	0.75	BW	NPP Late	True	Impr.	False	False	False	12:43	30:49	26:18
176	0.87	IAI	NPP Late	True	Impr.	False	False	False	08:59	37:32	26:54
177	0.75	Base	Base	True	Impr.	False	False	True	10:29	41:08	28:35
178	0.75	Dome	Base	True	Impr.	False	False	True	10:51	37:19	26:09
179	0.75	BW	Base	True	Impr.	False	False	True	11:53	34:26	26:59
180	0.86	IAI	Base	True	Impr.	False	False	True	09:37	40:25	26:16
181	0.75	Base	NPP Early	True	Impr.	False	False	True	12:05	47:02	34:00
182	0.75	Dome	NPP Early	True	Impr.	False	False	True	11:51	42:41	30:15
183	0.75	BW	NPP Early	True	Impr.	False	False	True	13:58	32:51	28:43
184	0.87	IAI	NPP Early	True	Impr.	False	False	True	10:58	41:00	29:29
185	0.75	Base	NPP Mid	True	Impr.	False	False	True	09:56	42:22	29:49
186	0.75	Dome	NPP Mid	True	Impr.	False	False	True	10:44	39:17	26:53
187	0.75	BW	NPP Mid	True	Impr.	False	False	True	11:40	35:39	27:56
188	0.87	IAI	NPP Mid	True	Impr.	False	False	True	09:06	39:31	27:42
189	0.75	Base	NPP Late	True	Impr.	False	False	True	11:04	36:21	27:33
190	0.75	Dome	NPP Late	True	Impr.	False	False	True	11:36	32:24	24:24
191	0.75	BW	NPP Late	True	Impr.	False	False	True	12:53	30:34	26:14
192	0.87	IAI	NPP Late	True	Impr.	False	False	True	09:19	37:38	26:51
193	0.75	Base	Base	True	Current	True	False	False	12:52	34:35	32:54
194	0.75	Dome	Base	True	Current	True	False	False	14:04	31:31	30:37
195	0.75	BW	Base	True	Current	True	False	False	15:11	28:30	31:45
196	0.86	IAI	Base	True	Current	True	False	False	11:52	33:22	30:51
197	0.75	Base	NPP Early	True	Current	True	False	False	13:20	38:47	36:01
198	0.75	Dome	NPP Early	True	Current	True	False	False	13:08	34:33	32:13
199	0.75	BW	NPP Early	True	Current	True	False	False	16:13	25:35	33:09
200	0.87	IAI	NPP Early	True	Current	True	False	False	12:21	33:25	31:54
201	0.75	Base	NPP Mid	True	Current	True	False	False	12:01	34:18	31:49
202	0.75	Dome	NPP Mid	True	Current	True	False	False	13:34	31:43	29:36
203	0.75	BW	NPP Mid	True	Current	True	False	False	14:33	28:22	30:47
204	0.87	IAI	NPP Mid	True	Current	True	False	False	11:31	32:34	30:45
205	0.75	Base	NPP Late	True	Current	True	False	False	13:59	27:51	35:30

EN	Ut	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over
206	0.75	Dome	NPP Late	True	Current	True	False	False	15:06	24:52	32:33
207	0.75	BW	NPP Late	True	Current	True	False	False	17:17	23:11	34:15
208	0.87	IAI	NPP Late	True	Current	True	False	False	11:42	28:54	34:40
209	0.75	Base	Base	True	Current	True	False	True	13:05	33:55	32:12
210	0.75	Dome	Base	True	Current	True	False	True	14:00	30:37	30:01
211	0.75	BW	Base	True	Current	True	False	True	15:21	27:44	31:01
212	0.86	IAI	Base	True	Current	True	False	True	11:57	32:50	30:03
213	0.75	Base	NPP Early	True	Current	True	False	True	12:58	38:29	35:31
214	0.75	Dome	NPP Early	True	Current	True	False	True	13:04	34:30	32:16
215	0.75	BW	NPP Early	True	Current	True	False	True	16:09	25:59	33:30
216	0.87	IAI	NPP Early	True	Current	True	False	True	12:16	33:01	31:37
217	0.75	Base	NPP Mid	True	Current	True	False	True	12:11	34:36	32:20
218	0.75	Dome	NPP Mid	True	Current	True	False	True	13:44	31:36	29:27
219	0.75	BW	NPP Mid	True	Current	True	False	True	14:50	28:13	30:42
220	0.87	IAI	NPP Mid	True	Current	True	False	True	11:23	32:23	30:43
221	0.75	Base	NPP Late	True	Current	True	False	True	14:13	27:45	35:50
222	0.75	Dome	NPP Late	True	Current	True	False	True	15:06	24:21	32:40
223	0.75	BW	NPP Late	True	Current	True	False	True	17:24	22:59	33:57
224	0.87	IAI	NPP Late	True	Current	True	False	True	11:55	28:25	33:58
225	0.75	Base	Base	True	Impr.	True	False	False	10:43	42:36	30:31
226	0.75	Dome	Base	True	Impr.	True	False	False	11:09	39:02	27:39
227	0.75	BW	Base	True	Impr.	True	False	False	11:48	35:37	28:36
228	0.86	IAI	Base	True	Impr.	True	False	False	10:02	41:53	28:57
229	0.75	Base	NPP Early	True	Impr.	True	False	False	12:24	48:02	34:44
230	0.75	Dome	NPP Early	True	Impr.	True	False	False	11:55	43:17	30:27
231	0.75	BW	NPP Early	True	Impr.	True	False	False	13:32	32:37	30:00
232	0.87	IAI	NPP Early	True	Impr.	True	False	False	11:01	42:10	30:04
233	0.75	Base	NPP Mid	True	Impr.	True	False	False	09:32	42:34	29:39
234	0.75	Dome	NPP Mid	True	Impr.	True	False	False	10:12	39:22	26:51
235	0.75	BW	NPP Mid	True	Impr.	True	False	False	10:52	35:26	27:35
236	0.87	IAI	NPP Mid	True	Impr.	True	False	False	08:50	40:33	28:22
237	0.75	Base	NPP Late	True	Impr.	True	False	False	10:41	35:00	32:17
238	0.75	Dome	NPP Late	True	Impr.	True	False	False	10:55	31:25	29:01
239	0.75	BW	NPP Late	True	Impr.	True	False	False	12:17	29:06	30:12
240	0.87	IAI	NPP Late	True	Impr.	True	False	False	08:49	36:27	31:49
241	0.75	Base	Base	True	Impr.	True	False	True	10:56	42:12	30:04
242	0.75	Dome	Base	True	Impr.	True	False	True	11:06	38:19	27:22
243	0.75	BW	Base	True	Impr.	True	False	True	12:04	35:08	28:07
244	0.86	IAI	Base	True	Impr.	True	False	True	10:00	41:28	28:32
245	0.75	Base	NPP Early	True	Impr.	True	False	True	12:04	47:35	34:11
246	0.75	Dome	NPP Early	True	Impr.	True	False	True	11:34	42:56	30:11
247	0.75	BW	NPP Early	True	Impr.	True	False	True	13:09	32:35	29:38
248	0.87	IAI	NPP Early	True	Impr.	True	False	True	10:44	41:25	29:29
249	0.75	Base	NPP Mid	True	Impr.	True	False	True	09:36	42:48	30:05
250	0.75	Dome	NPP Mid	True	Impr.	True	False	True	10:16	39:10	26:34

EN	Ut	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over
251	0.75	BW	NPP Mid	True	Impr.	True	False	True	10:58	35:26	27:33
252	0.87	IAI	NPP Mid	True	Impr.	True	False	True	08:38	40:09	28:01
253	0.75	Base	NPP Late	True	Impr.	True	False	True	10:45	34:52	32:41
254	0.75	Dome	NPP Late	True	Impr.	True	False	True	11:02	30:47	28:35
255	0.75	BW	NPP Late	True	Impr.	True	False	True	12:22	28:51	29:32
256	0.87	IAI	NPP Late	True	Impr.	True	False	True	08:57	36:09	31:39
257	0.84	Base	Base	True	Current	False	True	False	12:58	32:05	30:42
258	0.83	Dome	Base	True	Current	False	True	False	14:12	29:56	29:41
259	0.84	BW	Base	True	Current	False	True	False	15:45	26:47	28:56
260	0.93	IAI	Base	True	Current	False	True	False	11:37	33:08	28:35
261	0.83	Base	NPP Early	True	Current	False	True	False	13:10	38:31	35:37
262	0.83	Dome	NPP Early	True	Current	False	True	False	13:22	33:51	31:29
263	0.83	BW	NPP Early	True	Current	False	True	False	17:12	25:42	30:08
264	0.95	IAI	NPP Early	True	Current	False	True	False	12:22	32:31	29:49
265	0.83	Base	NPP Mid	True	Current	False	True	False	12:17	35:05	30:54
266	0.82	Dome	NPP Mid	True	Current	False	True	False	14:15	32:29	30:01
267	0.83	BW	NPP Mid	True	Current	False	True	False	15:45	28:17	28:15
268	0.97	IAI	NPP Mid	True	Current	False	True	False	11:53	30:55	29:32
269	0.82	Base	NPP Late	True	Current	False	True	False	13:47	29:42	28:47
270	0.83	Dome	NPP Late	True	Current	False	True	False	16:41	25:29	26:14
271	0.84	BW	NPP Late	True	Current	False	True	False	18:46	23:05	27:43
272	0.99	IAI	NPP Late	True	Current	False	True	False	12:52	25:59	30:27
273	0.84	Base	Base	True	Current	False	True	True	13:08	31:54	30:23
274	0.83	Dome	Base	True	Current	False	True	True	14:41	29:15	29:03
275	0.84	BW	Base	True	Current	False	True	True	16:10	26:36	28:39
276	0.93	IAI	Base	True	Current	False	True	True	11:53	32:20	27:38
277	0.83	Base	NPP Early	True	Current	False	True	True	13:03	38:26	35:34
278	0.83	Dome	NPP Early	True	Current	False	True	True	13:18	34:01	31:39
279	0.83	BW	NPP Early	True	Current	False	True	True	17:07	25:28	29:55
280	0.95	IAI	NPP Early	True	Current	False	True	True	12:15	32:24	29:37
281	0.83	Base	NPP Mid	True	Current	False	True	True	12:16	34:41	30:32
282	0.82	Dome	NPP Mid	True	Current	False	True	True	14:17	32:20	29:43
283	0.83	BW	NPP Mid	True	Current	False	True	True	15:49	28:14	28:14
284	0.97	IAI	NPP Mid	True	Current	False	True	True	11:50	30:25	28:50
285	0.82	Base	NPP Late	True	Current	False	True	True	13:47	29:14	27:54
286	0.83	Dome	NPP Late	True	Current	False	True	True	16:43	25:25	26:10
287	0.84	BW	NPP Late	True	Current	False	True	True	19:04	22:50	27:39
288	0.99	IAI	NPP Late	True	Current	False	True	True	13:00	25:00	29:12
289	0.84	Base	Base	True	Impr.	False	True	False	09:58	39:37	27:50
290	0.83	Dome	Base	True	Impr.	False	True	False	10:41	37:07	26:32
291	0.84	BW	Base	True	Impr.	False	True	False	11:26	33:03	24:56
292	0.93	IAI	Base	True	Impr.	False	True	False	09:14	41:25	26:20
293	0.83	Base	NPP Early	True	Impr.	False	True	False	11:36	47:05	33:42
294	0.83	Dome	NPP Early	True	Impr.	False	True	False	11:17	42:09	29:28
295	0.83	BW	NPP Early	True	Impr.	False	True	False	13:38	32:01	26:17

EN	Ut	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over
296	0.95	IAI	NPP Early	True	Impr.	False	True	False	10:17	40:46	27:38
297	0.83	Base	NPP Mid	True	Impr.	False	True	False	09:30	43:01	28:19
298	0.82	Dome	NPP Mid	True	Impr.	False	True	False	10:31	40:03	27:12
299	0.83	BW	NPP Mid	True	Impr.	False	True	False	11:14	35:09	24:51
300	0.97	IAI	NPP Mid	True	Impr.	False	True	False	08:54	38:33	26:42
301	0.82	Base	NPP Late	True	Impr.	False	True	False	10:18	36:43	25:34
302	0.83	Dome	NPP Late	True	Impr.	False	True	False	11:42	31:33	22:08
303	0.84	BW	NPP Late	True	Impr.	False	True	False	13:15	28:36	23:18
304	0.99	IAI	NPP Late	True	Impr.	False	True	False	09:22	32:45	26:49
305	0.84	Base	Base	True	Impr.	False	True	True	10:15	39:16	27:24
306	0.83	Dome	Base	True	Impr.	False	True	True	10:57	36:19	25:48
307	0.84	BW	Base	True	Impr.	False	True	True	11:26	32:33	24:29
308	0.93	IAI	Base	True	Impr.	False	True	True	09:12	40:02	24:58
309	0.83	Base	NPP Early	True	Impr.	False	True	True	11:35	47:11	33:45
310	0.83	Dome	NPP Early	True	Impr.	False	True	True	11:03	42:00	29:14
311	0.83	BW	NPP Early	True	Impr.	False	True	True	13:12	31:37	25:54
312	0.95	IAI	NPP Early	True	Impr.	False	True	True	10:00	40:33	27:20
313	0.83	Base	NPP Mid	True	Impr.	False	True	True	09:18	42:28	27:47
314	0.82	Dome	NPP Mid	True	Impr.	False	True	True	10:34	40:07	27:09
315	0.83	BW	NPP Mid	True	Impr.	False	True	True	11:10	34:47	24:34
316	0.97	IAI	NPP Mid	True	Impr.	False	True	True	09:01	38:17	26:16
317	0.82	Base	NPP Late	True	Impr.	False	True	True	10:15	35:51	24:31
318	0.83	Dome	NPP Late	True	Impr.	False	True	True	11:48	31:13	21:53
319	0.84	BW	NPP Late	True	Impr.	False	True	True	13:15	27:58	22:56
320	0.99	IAI	NPP Late	True	Impr.	False	True	True	09:27	31:41	25:53
321	0.84	Base	Base	True	Current	True	True	False	12:58	33:13	31:47
322	0.83	Dome	Base	True	Current	True	True	False	13:58	29:57	29:56
323	0.84	BW	Base	True	Current	True	True	False	15:35	27:56	29:58
324	0.93	IAI	Base	True	Current	True	True	False	11:40	33:37	29:52
325	0.83	Base	NPP Early	True	Current	True	True	False	12:46	38:57	35:42
326	0.83	Dome	NPP Early	True	Current	True	True	False	12:39	34:29	31:51
327	0.83	BW	NPP Early	True	Current	True	True	False	15:55	25:26	31:36
328	0.95	IAI	NPP Early	True	Current	True	True	False	11:52	33:23	30:22
329	0.83	Base	NPP Mid	True	Current	True	True	False	11:42	35:04	30:38
330	0.82	Dome	NPP Mid	True	Current	True	True	False	13:31	32:20	29:42
331	0.83	BW	NPP Mid	True	Current	True	True	False	14:47	27:44	27:33
332	0.97	IAI	NPP Mid	True	Current	True	True	False	11:33	31:30	29:50
333	0.82	Base	NPP Late	True	Current	True	True	False	13:26	27:40	33:11
334	0.83	Dome	NPP Late	True	Current	True	True	False	16:14	23:50	31:19
335	0.84	BW	NPP Late	True	Current	True	True	False	18:07	21:04	32:06
336	0.99	IAI	NPP Late	True	Current	True	True	False	12:37	24:32	32:59
337	0.84	Base	Base	True	Current	True	True	True	12:56	32:43	31:13
338	0.83	Dome	Base	True	Current	True	True	True	14:13	29:30	29:39
339	0.84	BW	Base	True	Current	True	True	True	15:30	26:54	29:15
340	0.93	IAI	Base	True	Current	True	True	True	11:43	32:54	28:54

EN	Ut	AR	PS	SWiP	DPu	SNP	ESWiP	MSA	Wait	Idle	Over
341	0.83	Base	NPP Early	True	Current	True	True	True	12:29	38:34	35:18
342	0.83	Dome	NPP Early	True	Current	True	True	True	12:25	34:08	31:26
343	0.83	BW	NPP Early	True	Current	True	True	True	15:40	25:09	31:21
344	0.95	IAI	NPP Early	True	Current	True	True	True	11:44	33:15	30:06
345	0.83	Base	NPP Mid	True	Current	True	True	True	11:46	34:45	30:22
346	0.82	Dome	NPP Mid	True	Current	True	True	True	13:38	32:31	29:52
347	0.83	BW	NPP Mid	True	Current	True	True	True	15:13	28:32	28:27
348	0.97	IAI	NPP Mid	True	Current	True	True	True	11:29	31:07	29:25
349	0.82	Base	NPP Late	True	Current	True	True	True	13:20	27:20	32:21
350	0.83	Dome	NPP Late	True	Current	True	True	True	16:20	23:33	31:29
351	0.84	BW	NPP Late	True	Current	True	True	True	18:25	21:03	32:19
352	0.99	IAI	NPP Late	True	Current	True	True	True	12:38	23:51	32:34
353	0.84	Base	Base	True	Impr.	True	True	False	10:26	41:27	29:38
354	0.83	Dome	Base	True	Impr.	True	True	False	10:45	37:25	26:57
355	0.84	BW	Base	True	Impr.	True	True	False	11:35	34:16	26:08
356	0.93	IAI	Base	True	Impr.	True	True	False	09:37	42:20	28:03
357	0.83	Base	NPP Early	True	Impr.	True	True	False	11:47	48:02	34:16
358	0.83	Dome	NPP Early	True	Impr.	True	True	False	11:22	42:51	29:41
359	0.83	BW	NPP Early	True	Impr.	True	True	False	12:49	31:59	27:47
360	0.95	IAI	NPP Early	True	Impr.	True	True	False	10:28	42:00	28:31
361	0.83	Base	NPP Mid	True	Impr.	True	True	False	09:03	43:31	28:32
362	0.82	Dome	NPP Mid	True	Impr.	True	True	False	09:57	39:56	26:50
363	0.83	BW	NPP Mid	True	Impr.	True	True	False	10:39	34:59	24:34
364	0.97	IAI	NPP Mid	True	Impr.	True	True	False	08:50	39:34	27:28
365	0.82	Base	NPP Late	True	Impr.	True	True	False	10:09	35:11	30:09
366	0.83	Dome	NPP Late	True	Impr.	True	True	False	11:14	29:44	26:59
367	0.84	BW	NPP Late	True	Impr.	True	True	False	12:47	26:48	27:24
368	0.99	IAI	NPP Late	True	Impr.	True	True	False	09:07	31:36	29:57
369	0.84	Base	Base	True	Impr.	True	True	True	10:32	40:34	28:38
370	0.83	Dome	Base	True	Impr.	True	True	True	10:46	36:57	26:50
371	0.84	BW	Base	True	Impr.	True	True	True	11:41	33:36	25:39
372	0.93	IAI	Base	True	Impr.	True	True	True	09:34	41:18	26:59
373	0.83	Base	NPP Early	True	Impr.	True	True	True	11:40	48:04	34:16
374	0.83	Dome	NPP Early	True	Impr.	True	True	True	11:10	42:48	29:37
375	0.83	BW	NPP Early	True	Impr.	True	True	True	12:36	31:40	27:33
376	0.95	IAI	NPP Early	True	Impr.	True	True	True	10:11	41:36	27:57
377	0.83	Base	NPP Mid	True	Impr.	True	True	True	09:10	43:18	28:28
378	0.82	Dome	NPP Mid	True	Impr.	True	True	True	09:58	40:24	27:10
379	0.83	BW	NPP Mid	True	Impr.	True	True	True	10:53	35:17	24:55
380	0.97	IAI	NPP Mid	True	Impr.	True	True	True	08:43	39:07	26:50
381	0.82	Base	NPP Late	True	Impr.	True	True	True	09:55	34:27	29:38
382	0.83	Dome	NPP Late	True	Impr.	True	True	True	11:16	29:22	26:27
383	0.84	BW	NPP Late	True	Impr.	True	True	True	12:55	26:08	26:50
384	0.99	IAI	NPP Late	True	Impr.	True	True	True	09:14	31:13	30:01