UNIVERSITY OF TWENTE.

Faculty of Behavioural,
Management & Social Sciences

Block planning in the outpatient clinic of Gastroenterology

How dedicated time-slots and care pathways can improve timeliness

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In this version we removed organization sensitive information. In the sections involved, we removed the information and added [Confidential information]

Management summary

The UMC Utrecht experiences an increase of outpatient clinic visits, due to the focus on a short length of stay. The outpatient clinic of Gastroenterology also experiences such developments. The patients at the clinic often do not receive care at the desired moment. The access time of new patients is higher than desired, namely 88 days compared to the norm of 28 days. The short term check-up consultations are often scheduled later than the desired moment, as the schedule is already filled with other consultations. To deal with these problems, we formulated the next goal:

Develop and prospectively assess a method on a tactical level that helps to deliver care within the desired time-interval for various consultation types within the outpatient clinic of Gastroenterology.

Context analysis

We performed a context analysis, in which we studied the clinical sessions of Inflammatory Bowel Disease (IBD) and general population. An important finding in the scheduling process is that only *new* and *check-up* consultation types are distinguished, while in reality *emergency* and *periodic* consultations take place as well. As an infinite planning horizon is used, the schedule is being filled with long term periodic consultations, such that no time is left for the short-term check-up consultations. Furthermore, we analysed the probability of receiving care at the desired moment. An overview of the data for IBD can be observed in Table 1.

Table 1 - Performance IBD *CONFIDENTIAL INFORMATION*

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Based on this table, we observe that the timeliness of care is compromised for the new consultations and check-up consultations. The general clinic showed a similar performance but even with lower probabilities for new patients of receiving timely access.

Solution approach

Based on the literature study, we propose a block planning that reserves time for various consultation types. The goal is to develop a method that is demand induced, where access time and utilization are important. Therefore, we developed a three step method:

Step 1. To determine the number of slots needed such that new patients receive care in time, we applied the analytical queuing model of Kortbeek (2012). The arrival distribution based on the historical arrival data of 2015 is used as input. The model returns the number of slots required to meet the 'Treeknorm' for IBD and general clinic.

Step 2. To validate the analytical model, we use a simple queuing simulation model. Based on the exact historical arrival of new patients in 2015, it checks if the patients receive timely access, while using the calculated number of slots from Step 1.

Step 3. To prospectively assess the effects of the frequency and desired time-interval for check-up consultations on timeliness, we analysed several interventions using a simulation study. As no historical data is available on check-up consultations, care pathways are used to show the effect on timeliness of care.

Results

We conclude that the outpatient clinic of Gastroenterology will benefit from reserving a number of slots per consultation type. With a four week cycle, the 'Treeknorm' can be met if the IBD clinic reserves 15 slots for new patients and the general clinic reserves 59 slots for new patients. A simulation is used to test these results, and shows that for the general clinic 59 slots were sufficient to meet the access time norm. For the IBD clinic 16 slots were needed.

In order to improve the timeliness for check-up consultations, we evaluated the effect of decreasing the number of check-up consultations by using care pathways. The simulation showed for the IBD that an increasing probability of a patient exiting the system, results in less consultations and in an increase of the timeliness of the check-up consultations. However this decrease of consultations results in lowering the staff utilization. For the general population the simulation showed a similar effect.

Recommendations

Based on this research, we have the following recommendations:

- In order to improve timeliness for the various consultation types, the clinic should distinguish and register *new*, *emergency*, *check-up,* and *periodic* consultations in the agendas. This way data analyses can be performed for each separate consultation type. For each consultation the desired moment should be registered, such that the performance for each consultation type can be determined.
- Just as the 'Treeknorm' is used for new and emergency consultations, a norm for check-up and periodic consultations has to be developed. This norm should describe the probability that consultations of a certain type have to receive access at a certain moment.
- We recommend reserving 15 dedicated slots for new patients in the IBD agenda, and 59 dedicated slots for new patients in the general agenda, such that the 'Treeknorm' can be met.
- In order to increase timeliness for check-up and periodic consultations, the clinic should use a care pathway to reduce the number of recurrent visits and increase the time between two subsequent visits. However the medical staff should decide what time between these subsequent is still medical justified. This way the extra capacity can be used to schedule the check-up consultations more often at the desired moment.

- The clinic should use staff capacity effective, by not accepting simultaneous blockages in the agenda. As the staff availability is more equally spread, the consultations can be scheduled more smoothened over a period. This way bulking of consultations can be prevented, such that doctors are less over utilized. Being more mandatory in not accepting blockages on a short-term will increase patient satisfaction. This way consultations have to be cancelled or rescheduled less often. A shorter planning horizon is consistent with this goal, as slots are already blocked before consultations can be scheduled.
- As the clinic uses dedicated time-blocks for new patients, they can experiment with the use of planning rules to adapt to fluctuations in demand. Planning rules indicate releasing dedicated new slots to other consultation types, such that idle time can be prevented.

Management samenvatting

Het UMC Utrecht ervaart een toename van het aantal poliklinische consulten, door onder andere de opkomende trend van kortstondige verblijven in het ziekenhuis. De poli Maag-, Darm- en Leverziekten ervaart ook een dergelijke trend. Patiënten bij deze polikliniek ontvangen dan ook regelmatig zorg niet tijdig. De toegangstijd voor nieuwe patiënten is hoger dan gewenst, namelijk 88 dagen in plaats van de norm van 28 dagen. De kort termijn controle afspraken worden daarbij ook vaak later gepland dan gewenst, aangezien de planning al gevuld is met andere afspraken. Om met deze problemen om te gaan, hebben we het volgende doel geformuleerd:

Het ontwikkelen van een methode op een tactisch niveau dat ondersteunt om zorg frequenter binnen het gewenste tijdsinterval te leveren voor verschillende afspraaktypen op de poli Maag-, Darm- en Leverziekten.

Contextanalyse

We hebben een contextanalyse uitgevoerd, waarin we de spreekuren van de Inflammatory Bowel Disease (IBD) en algemeen (ALG) hebben bestudeerd. Een belangrijke uitkomst is dat het huidige plannignsproces alleen *nieuw* en *controle* onderscheid, terwijl er in de realiteit ook *spoed* en *periodiek* voorkwamen. Er wordt een oneindige planningshorizon gehanteerd, waardoor het schema voornamelijk gevuld wordt met lange termijn periodieke afspraken, zodat er weinig tijd voor de korte termijn controle afspraken overblijft. Een overzicht van de data voor het IBD spreekuur staat in tabel 2.

Table 2 - Prestatie IBD in 2015

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Gebaseerd op bovenstaande tabel observeren wij dat de tjidigheid van zorg in gedrang komt voor nieuwe en controle afspraken. Bij de ALG poli blijkt een vergelijkwaardige prestatie te zijn behaalt in 2015, maar met zelfs lagere kansen voor nieuwe patiënten op tijdige zorg.

Aanpak

Gebaseerd op de literatuurstudie stellen wij een blokplanning voor dat tijd reserveert voor de verschillende afspraaktypen op de poli. Het doel is om een method te ontwikkelen dat vraaggestuurd is, en waar toegangstijd en bezetting van de staf van belang zijn. We hebben daar een drie-stappen-methode voor ontwikkeld:

Stap 1. Om het benodigde aantal plekken te bepalen zodat nieuwe patiënten op tijd zorg ontvangen, hebben we een analytisch wachtrijmodel van Kortbeek (2012) toegepast. De aankomstverdeling is gebaseerd op historisch aankomst data uit 2015 en diende als input. Het model geeft het aantal plekken nodig dat nodig is om de Treeknorm voor de IBD en ALG spreekuren te behalen.

Stap 2. Om het analytische model te valideren hebben we een simpel wachtrij simulatie model gebruikt. Deze gebruikte het precieze aankomstpatroon van nieuwe patiënten zoals in 2015, en bepaalde of de patiënten tijdig zorg ontvangen, waarbij het aantal plekken wordt gebruikt zoals berekent in stap 1.

Stap 3. Om prospectief het effect van de herhaalfrequentie en het gewenste tijdsinterval voor controle afspraken op tjidigheid te evalueren, hebben we verschillende interventies getest in een simulatie studie. Aangezien er geen historische data beschikbaar was over herhaal afspraken, hebben we een zorgpad gebruikt om de tijdigheid van zorg in kaart te brengen.

Resultaten

We concluderen dat de poli MDL profijt zal hebben bij het reserveren van plekken voor verschillende afspraaktypen. Met een vierwekelijkse cyclus zal de Treeknorm behaald worden indien het IBD spreekuur 15 plekken voor nieuwe patiënten reserveert en het ALG spreekuur 59 plekken voor nieuwe patiënten reserveert. Dit aantal plekken is getest in een simulatie, en laat zien dat voor de ALG inderdaad 59 plekken voldoende waren in 2015 om de norm voor nieuwe patiënten te behalen. Voor de IBD waren er 16 plekken nodig.

Om de tijdigheid van controle afspraken te verbeteren, hebben we het effect van minder controle afspraken per patiënt getest aan de hand van een zorgpad. De simulatie heeft laten zien dat indien een IBD patiënt een grotere kans krijgt op ontslag, hij/zij minder afspraken zal hebben en de tijdigheid van controle afspraken op het IBD spreekuur zal verbeteren. Deze mindering in afspraken leidt wel tot een lagere bezetting van de staf. Bij het ALG spreekuur is een vergelijkbaar effect te zien.

Aanbevelingen

Gebaseerd op dit onderzoek hebben wij de volgende aanbevelingen:

- Om de tijdigheid voor verschillende afspraaktypen te verbeteren, zal de poli onderscheid moeten maken tussen *nieuw*, *spoed*, *controle* en *periodiek* in de agenda's. Op deze manier kan de data achteraf apart van elkaar beoordeeld worden op prestatie. Voor elk type zal het gewenste tijdsinterval beschreven moeten woredn, zodat zowel de prestatie in kaart gebracht kan worden als dat er gestuurd kan worden met deze informatie.
- Net als de Treeknorm voor nieuwe en spoed afspraken, zal er een norm voor controle en periodieke afspraken opgesteld moeten worden. Dit betekent de kans dat een afspraak van een bepaald afspraaktype zorg op het gewenste moment ontvangt.
- We raden aan om 15 toegewijde plekken voor nieuwe patiënten voor het IBD spreekuur te reserveren en 59 toegewijdde plekken voor nieuwe patiënten op het ALG spreekuur, zodat de Treeknorm wordt behaald.

- Om de tijdigheid voor controle en periodieke afspraken te verbeteren, moet de poli een zorgpad introduceren dat het aantal herhaalbezoek verminderd en de tijd tussen twee opeenvolgende herhaalconsulten verlengd. De medische staf moet hierbij betrokken worden om deze maximale duur tussen afspraken te bepalen. Op deze manier blijft er capaciteit over dat gebruikt kan worden voor controle afspraken zodat deze vaker tijdig plaatsvinden.
- De poli moet haar stafcapaciteit effectief gebruiken, door niet gelijktijdige blokkages in de agenda te accepteren. Doordat de beschikbaarheid van staf dan beter verspreid wordt, kunnen de afpraken meer verspreid worden over de periode. Op deze manier kan ophoping van afspraken voorkomen worden, zodat dokters zich minder overwerkt voelen. Ook zal de patiënttevredenheid toenemen indien korte termijn blokkades niet meer worden gehonoreerd. Een kortere planningshorizon strookt met deze doelstelling, omdat dan plekken al afgeblokt kunnnen worden voordat er patiënten op in worden gepland.
- Als de poli gebruik gaan maken van gereserveerde toegewijde plekken voor nieuwe patiënten, kunnen zij met planregels experimenteren om om te gaan met flucuaties in de aankomst. De planningregels kunnen het vrijgeven van plekken beschrijven, zodat deze beschikbaar worden voor andere afspraaktypen en zo leegstand voorkomen kan worden.

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Preface

In March 2015, I started my master thesis assignment at the UMC Utrecht. Now, seven months later, I finished my assignment which marks the end of my study. During the first four years of my study, I experienced that the Bachelor Health Sciences was not what I was hoping for. Then I did a premaster, in order to start the Master Industrial Engineering & Management with the healthcare track in 2014. This study was exactly what I expected it to be. As it was time to begin an internship for my master thesis, I used this opportunity to move from Enschede to Utrecht. The UMC Utrecht seemed a great opportunity to perform a research in a complex, difficult, and innovative organization. I have learned a lot about patient flows, planning difficulties, organization culture, and the importance of completeness of data.

As my research is completed, I hope my report provides the Division of Internal Medicine & Dermatology recommendations for their processes. Furthermore, I hope it provides insight into the current situation and possibilities for tactical planning at the clinic.

For the last seven months, I enjoyed working at the UMC Utrecht. I would like to thank the people that were involved in my project. I had interesting and sometimes difficult conversations about problem statements or solution approaches. Special thanks to Arjan, who answered all my questions and showed great interest in my project. I hope that you are pleased with the results. I would also like to thank Eva, Leon, Harald and Bas for all the interesting discussions and essential data for this research.

Furthermore I would like to thank Erwin and Ingrid for all the feedback and support during my project. As I found it difficult to combine theory and practice in my research, the meetings helped me to find new ways and give me new energy. Gréanne I would like to thank you for your rapid responses, critical and constructive feedback, and positive energy during the project.

At last I would like to thank Marjolein for her motivation and ability to calm me down. Moreover I thank my roommates, as they kept me positive and offered me company when I needed it. And last but not least I would like to thank my parents, for their continuous believe in me and their support during my study years.

I hope you will enjoy reading this report.

Joran Evers

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1 Introduction

Health care providers experience a great deal of pressure to improve their quality while constraining costs. The focus on a short length of stay makes the outpatient clinic more and more important in the healthcare delivery process (Cayirli & Veral, 2003). A part of this focus caused a great increase of visits to the outpatient clinic (Berg & Denton, 2012). The 'Universitair Medisch Centrum Utrecht' (UMC Utrecht), a large healthcare organization in the Netherlands, is also experiencing such developments. As the study of Cayirli and Veral (2003) shows, many research has been performed on patient admission planning and appointment systems for the outpatient clinic. To plan optimal and design patient schedules there are many factors to take into account, such as staff and resource levels, procedure processes, and patient characteristics as the case mix, no-shows, reschedules, and short-term appointments (Berg & Denton, 2012). This study moreover focuses on the outpatient clinic planning over various time frames, such that an outpatient clinic can allow their planning to take into account new and recurring patients.

Section 1.1 introduces and discusses the research environment, together with the selected case study and problem owner. Section 1.2 describes the research motivation and problem definition. The research objectives and scope are discussed in Section 1.3. Section 1.4 presents the research questions and sub-questions.

1.1 Research Context: University Medical Centre Utrecht

This research is commissioned by the UMC Utrecht, which is the academic medical centre in the region and city Utrecht. The UMC Utrecht is founded in 1999 with the merger of the Medical Faculty, the Wilhelmina Children Hospital (WCH) and Academic Hospital Utrecht (AHU) (Utrecht, 2015). The organization contains a total of more than 1000 beds and over 11.000 employees. Together the UMC Utrecht had a throughput of more than 300.000 outpatient visits and over 16.000 day treatments in 2015 (Utrecht, 2015). To maintain the quality of care and offer excellent care to patients, the UMC Utrecht has formulated three pillars: care, research and education. Their mission is stated as follows:

"The UMC Utrecht is an international leading university medical centre where knowledge about health, disease and care, for patients and society are developed, tested, shared and applied." (Utrecht, 2015)

To live up to this mission in a proper way, the hospital is structured with a Board of Directors, corporate staff, five directions and twelve divisions. A few examples of such divisions are Biomedical Genetics, Heart & Lungs, Internal Medicine & Dermatology, Children Centre and Cancer Centre. This research will be performed at the Division of Internal Medicine & Dermatology (DIMD). This division contains all specialties that are focused on the internal diseases and skin diseases, such as:

- Diseases of general body systems;
- Diseases of internal organs;
- Diseases of organ systems. (Utrecht, 2015)

The DIMD of the UMC Utrecht is divided into a number of different departments, where they address their outpatient patient care. In Figure 1 the organizational structure is shown.

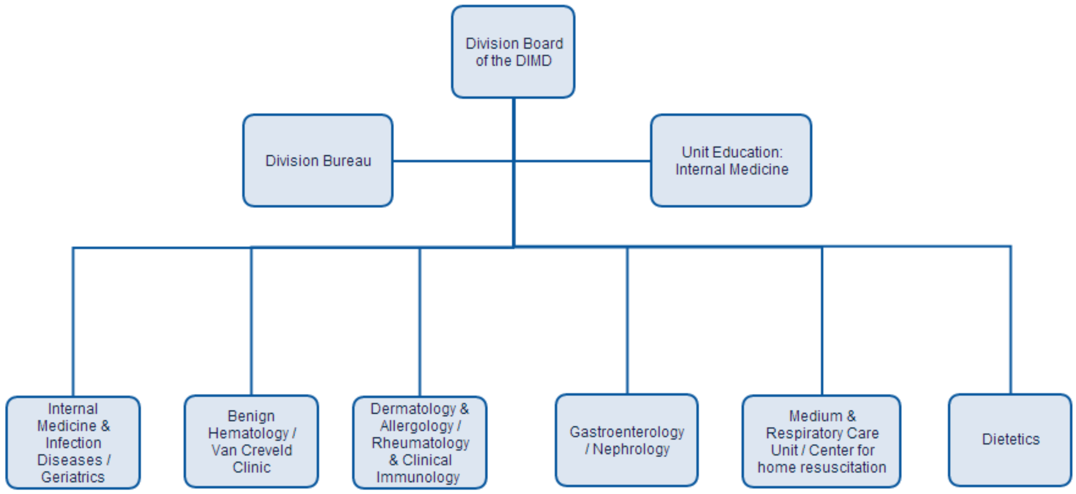

Figure 1 - Organogram of the Division Internal Medicine & Dermatology

In the Netherlands there is a national trend visible for the number of outpatient visits. There is an increase observed from 144 visits to 178 visits per 100 inhabitants over the period of respectively 2002 to 2010 (Dutch Hospital Data, 2012). This growth of outpatient clinic visits is graphical shown in Figure 2.

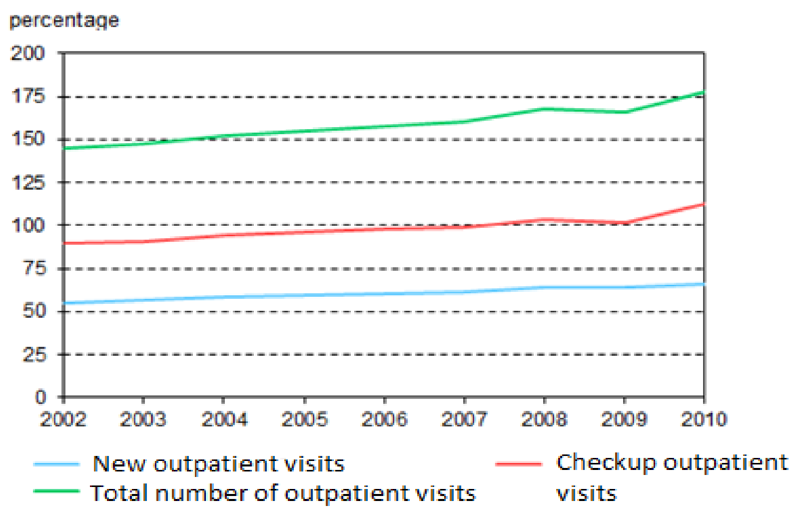

Figure 2 – Number of outpatient clinic visits annually per 100 people in the period of 2002-2010 (Gijsen & Poos, 2012)

The number of visits is divided into two types of visits. The blue line represents the first clinic visits, and shows a slight increase of approximate 10 first visits per 100 people in ten years. The red line represents the number of repeating visits or recurring patients. In ten year an increase of approximately 30 repeating visits per 100 people is observed. The green line shows the total increase of outpatient visits. The figure shows that not only the total number of visits per 100 people is increasing, but the number of recurring patients is increasing grows faster than the number of new visits (Dutch Hospital Data, 2012).

The trends gave reason for the UMC Utrecht to investigate their current patient flows and processes, such as planning procedures. As a result they started the multiannual program named ‘Poli 3.0’. Main focus points in this program are renewing the outpatient clinic structure and its functions. Main leading themes are patient-centeredness, efficacy, sustainability and innovation. The vision for care and the outpatient process is renewed, which indicates focus on health and patient empowerment in the care process. In practice this meant that care processes should be organized around the patient, where their time and availability is leading. This should eventual lead to savings in time, space, work and therefore costs (Utrecht, 2015). Another important element in this program is *Capacity management*. Although this project is in an early stage, multiple outpatient clinics of the UMC Utrecht are asked to integrate this approach in their system (Wouters & Bons, 2016). *Capacity management* can be characterized by a capacity management triangle, as shown in Figure 3.

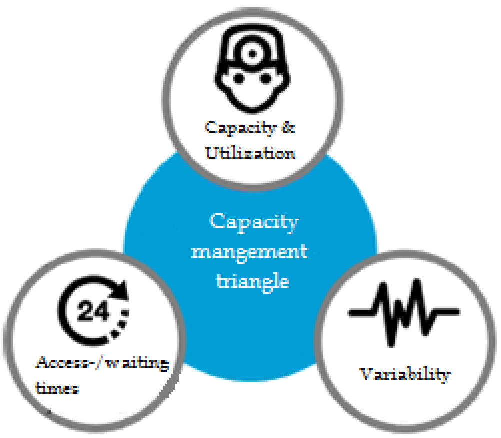

Figure 3 - Capacity management triangle (Wouters & Bons, 2016)

The triangle is focused on optimal organization of capacity, reduction of variability, and improvement of flows throughout the hospital. The last aspect is focused on access times and waiting times for patients. We define access time to be the days between a request for consultation and the date of the actual consultation. The counterpart is waiting time, which is defined as the amount of time that elapses between the patient arrival at the waiting room and the moment he gets summoned by the doctor. Together these elements are responsible for safe healthcare delivery, appropriate and effective use of capacity and optimal reliability of care delivery for the patient. This is accompanied with a control over capacity at each level in the organization.

The outpatient clinic of hospitals fulfils a special role in the chain of care delivery. As can be seen in Figure 4 the outpatient clinic influences the performance of the total hospital. Each hospital needs enough patients for its survival. Since most of the patient types enter the hospital through the outpatient department, we say that this department is essential. Also the further care path is most shaped by the outpatient clinic and therefore determines the workload further in the hospital. Since annually 350.000 outpatient clinic visitors should be able to enjoy the new structure and procedures, there is a need for a well-organized and structured outpatient clinic in the hospital (Utrecht, 2015).

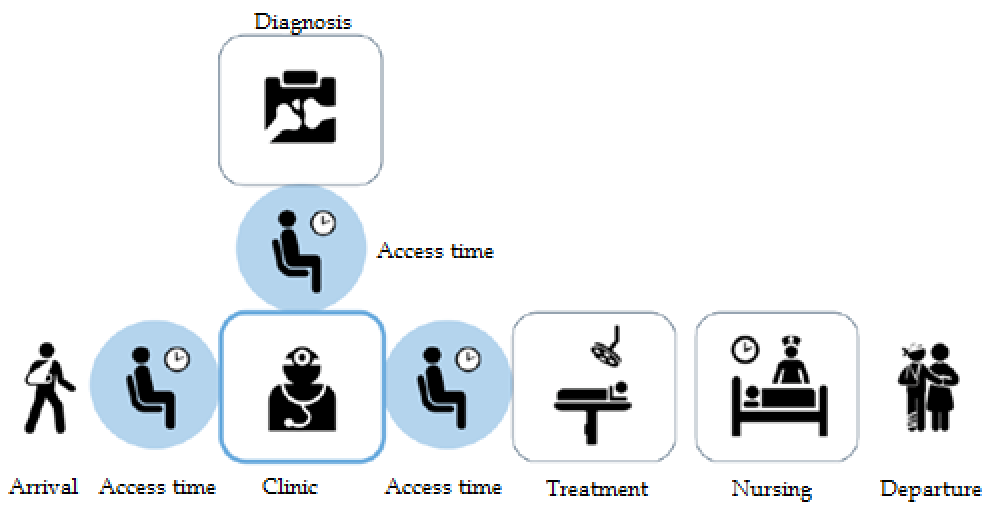

Figure 4 - Chain of care processes in hospital (Wouters & Bons, 2016)

1.1.1 Case study: Poli 3.0 - Outpatient Clinic of Gastroenterology

The *Poli 3.0* program gave motivation for this research to investigate and improve the outpatient clinic on capacity management. Scheduling short-term appointments is experienced as difficult for the outpatient clinic, as schedules are fully booked with routine periodic consultations. As periodic consultations are scheduled far in advance, the probability of patient no-show and cancellations is increased. This results in lower patient satisfaction and higher healthcare cost (Qu, Rardin, & Williams, 2011). For the outpatient clinic long access time for various consultation types are observed and a pressure on the patient schedules is experienced. With respect to access times in healthcare, the Ministry of Public Health, Welfare and Sport in the Netherlands introduced the 'Treeknormen' in 2014. This document showed the norms within healthcare delivery for the maximum acceptable access time per care sector. For the access time of new outpatients it states a maximum period of four weeks, while 80% should be seen within three weeks (Ministerie van Volksgezondheid, 2014). The outpatient clinic of Gastroenterology is currently not meeting this norm. *CONFIDENTIAL INFORMATION*

The various consultation types that take place at the outpatient clinic can be divided in new consultations, follow-up consultations and emergency consultations, which will be discussed more extensive in Section 2.1.4. The Division of Internal Medicine & Dermatology would like to reduce access times, with a focus on providing care at the desired moment for recurring patients which have a need for a short-term visit. Such short visits might be needed due to worsening of the health status of a patient or on demand of the treating doctor. The current planning method does not include reserved time-blocks for such short-term consultation types and works with an infinite planning horizon. A planning horizon is defined the maximum period of which the secretary can schedule an appointment (Hall, 2012). The clinics goal is to reorganize the planning procedure such that care delivery is more frequent within the desired time-interval for various consultation types. In this study the desired time-interval is considered as a period in which a patient is expected to be scheduled. This could be a deadline for new patients and a desired moment for recurring patients. For the latter this means that both earlier and later moments are not desirable. This research focuses at timeliness of care, so if a patient can be seen at the requested or obliged period. The focus lies at a tactical level, since the clinic would like to reinvestigate their organization of planning, use of employees, and management of processes.

1.2 Research objective, research questions and scope

The findings in Section 1.2 lead to the next research objective:

Develop a method on a tactical level that helps to deliver care within the desired time-interval for various consultation types within the outpatient clinic of Gastroenterology.

The aim of this research is to identify how the planning of the outpatient clinic of Gastroenterology can be organized effective, such that the delivered care is within the desired time-interval for various consultation types. The scope includes the IBD and general population. We formulate the next research questions and sub-questions to achieve the objective.

1. What are the current structures and processes of the outpatient clinic of Gastroenterology concerning planning and what is their current performance?
   1.1. How can the process and system be described?
   1.2. How can the resource capacity planning be described on a strategic, tactical, offline operational and online operational level?
   1.3. What stakeholders and performance indicators can be identified, and what is the current performance of the outpatient clinic of Gastroenterology?
   1.4. What bottlenecks can be identified and what is the core problem?

The second chapter answers these questions, and is focused on how the clinic is organized and its processes. By performing interviews with the secretary and members of the medical staff, data about patient groups, employees and their functions, the planning process and stakeholders is obtained. Next to this quantitative data of the outpatient clinic is obtained from KUBUS and EZIS, together with a business analyst. This dataset is based on a predetermined set of performance indicators.

2. What concepts are mentioned in the literature to organize effective planning for the outpatient clinic at a tactical level?
   2.1. What search method do we use?
   2.2. What is known about planning methods in the outpatient clinic?
   2.3. What planning models are there and how do they contribute to a solution approach?

The third chapter forms the theoretical framework. A literature study is performed in various databases, to investigate planning models and their applicability for this research. This includes searching for planning models and planning methods, which can contribute to picking a solution approach for this study.

3. How can the process be modelled and what intervention can be used to increase the probability of receiving new patients in time?

3.1. What process has to be modelled?
3.2. What model type can be used to model the situation?
3.3. What experimental settings do we use?

Chapter four discusses the model that is developed, based on the literature. The model describes the arrival and planning processes of patients at the outpatient clinic. As a result it should be able to test various experiments and influence the clinics performance.

4. How can the process be modelled and can the outcome be validated with historical data?
   4.1. What process has to be modelled?
   4.2. What model type can be used to model the situation?
   4.3. Is the model validated and verified by stakeholders?

Chapter 5 discusses a model to evaluate the outcomes of the solution approach as discussed in Chapter four. We are interested to know if the solution solves the timeliness problem in 2015 for new patients.

5. How can the process be modelled and what interventions can be used to increase the performance of the outpatient clinic of Gastroenterology?
   5.1. How can we model the process of the clinic?
   5.2. Is the model validated and verified by stakeholders?
   5.3. What experimental settings do we use?

Chapter 6 presents the results of the queue model, and of various interventions to increase timeliness of check-up consultations.

6. What is the impact of the interventions on the performance at the outpatient clinic of Gastroenterology?
   6.1. What are the experimental results of the models?

Chapter 7 describes the results of the experiments, which are the outcomes of the performance indicators. Together the performance of the interventions can be determined, and a sensitivity analysis of the parameters is done. The last chapter discusses the conclusion, as an interpretation of the results, and a discussion of the results and limitations.

1.2.1 Method

To do this in a structured way, we analyse the context analyse in Chapter 2. This includes the process and system description, planning and control, and the performance. As there are many disease types, the scope of this study includes the IBD and the general population of the outpatient department. Both are considered to have a different case-mix in terms of chronic and new patients, and elective and non-elective patients. In Chapter 3 background information about planning in outpatient clinics is searched for in literature. This should also give information about possible solution approaches for the problem. Chapters 4, 5 and 6 concerns building models that represent the processes at the outpatient clinic and give the possibility to test scenarios. These scenarios should describe various experiments, for which the performance is measured. The outcomes of these experiments are presented in Chapter 7. Eventually Chapter 8 summarizes the results into a conclusion and discussion.

1.3 Challenges

This section of the report describes possible threats to the success or validity of this study.

1.3.1 Data

A model that later on will be used in this study is dependent of data. This data should not only be sufficient in quantity, but even more important in quality. Main issue in this research will therefore be to gain valid results about frequency and numbers of various consultation types. The unplanned visits and emergency patients are expected to be sparsely registered, and will therefore be hard to obtain. If the model uses incorrect data about the frequency of this type of patient, an outcome for the tactical approach for the planning might not be valid. Next to this the desired time-interval for the consultations is often not known. This indicates that with qualitative interviews and own interpretation of data this has to be retrieved.

1.3.2 Patient care pathways

The outpatient clinic of Gastroenterology treats various diseases. Each disease has their own care pathway that strongly influences the planning and use of time within the planning horizon. The doctors and clinics are not replaceable by one another, e.g. outpatients of hepatitis cannot be treated by doctors of inflammatory bowel disease. This results in the fact that a planning method is restricted per disease type. Although this might be challenging, we expect the method to be translatable to each disease within the clinic.

2 Context analysis: structures, processes and performance

The context analysis of this report is distinguished into four sections: process and system description (Section 2.1), resource capacity planning (Section 2.2), performance (Section 2.3), and the demarcation of the core problem (Section 2.4). To gain insight into the system and functions of the outpatient clinic of Gastroenterology, interviews were conducted with the secretary at the front-office and back-office and with the medical staff. For the performance, a quantitative approach was used, where data from EZIS of the relevant periods was obtained. Together these methods gave essential input for the context analysis of this research.

2.1 Process and system description of the outpatient clinic of Gastroenterology

The first section discusses the patient groups, the decisions made in a care pathway and the various roles in the outpatient clinic team. This way the organization and its processes are discussed.

2.1.1 Patient group

The outpatient clinic of Gastroenterology involves all patients that have complaints with the gastrointestinal tract, the liver, the biliary and the pancreas and have a need for diagnoses, care or treatment (Utrecht, 2015). Examples of such diseases are hepatitis, jaundice, appendicitis and bowel cancer (Maag Lever Darm Stichting, 2015). A list of all diseases that are treated within the outpatient clinic can be found in Appendix A. Each of these diseases is treated by a specialism within the clinic. For example a patient with Crohn's disease is assigned to a doctor who is specialized in the Inflammatory Bowel Disease (IBD), while patients with Hepatitis C are assigned to a Hepatitis specialist. This distinction in patient groups strongly affects the outpatient planning and their distribution of clinical sessions for each specialism. For some of these diseases is a care pathway formulated for the associated patient group. A care pathway describes the disease type, the consultation type and frequency or consultations. For the larger part of diseases a care pathway is not formulated. As a result the number of consultations and their desired moment vary per patient. This leads to difficulties in the planning process.

To gain insight into the numbers of patients of the specialties in our scope, IBD and general population, we obtained and analysed data from EZIS in the period of 01-01-2015 to 31-12-2015. This showed a different case-mix of patients (Table 3).

Table 3 - Patients and consultations of IBD and general population in 2015

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We observe that the IBD clinic has performed more consultations in 2015 than the general clinic. However the number of unique patients is higher at the general clinic. This causes the number of new patients to be higher at the general clinic than at the IBD *CONFIDENTIAL INFORMATION* Another remark is the number of telephonic consultations at both clinics. A graph of the new, check-up and telephonic consultations of the IBD clinic in 2015 is shown in figure 5. As we discuss this with doctors, they indicate that more telephonic consultations take place than desired. Their explanation is that doctors are often eager to see a patient at a desired moment, while the schedule is fully booked with consultations. As telephonic consultations require less time, doctors request the secretary to make a telephonic appointment with the patient. Although this way doctors can consult with their patients in time, the necessary face-to-face care is not delivered.

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Figure 5 - Distribution of consultation types of the IBD patients

As we mentioned before, the number of recurring patients for both type of clinical sessions differs, as the IBD clinic relatively has less unique patients and new patients than the general clinic. To prove this we calculate the return rate per patient, which is calculated by dividing the total number of consultations by the number of unique patients. We exclude the number of telephonic consults. This results in the next formula:

$$Return\ rate = \frac{Total\ number\ of\ consultations}{Number\ of\ unique\ patients}$$

As we analysed the data obtained from EZIS, we calculated the return rate that indicates the average number of consultations per unique patient in 2015. *CONFIDENTIAL INFORMATION*

Although this research is not expected to influence the return rate, it tries to amplify the planning process such that the consultations can more frequent take place at the desired time-interval. For the IBD this indicates that, with the high number of check-up consultations compared to the number of new consultations, the schedule should take the latter group into account. As for the general population, this distribution of consultations is more balanced, such that choices have to be made what group of consultations has what priority. As we mentioned the term 'desired time-interval' often for the consultation types, we will now discuss how the decisions are made within the care process and what the various consultation types with their associated desired time-intervals are.

2.1.2 Decisions in the care pathway

The outpatient clinic of Gastroenterology treats a great amount of patients with various complaints. To deal with them in a structured manner, the secretary uses a few steps to determine in what stage of the care pathway a patient is. This includes the patient flows with regard to the planning process, the different actors in the process and the consultation type. Figure 6 shows a flowchart for a new patient that enters the system. The step of Rapid Diagnostics is more elaborated on at Appendix B.

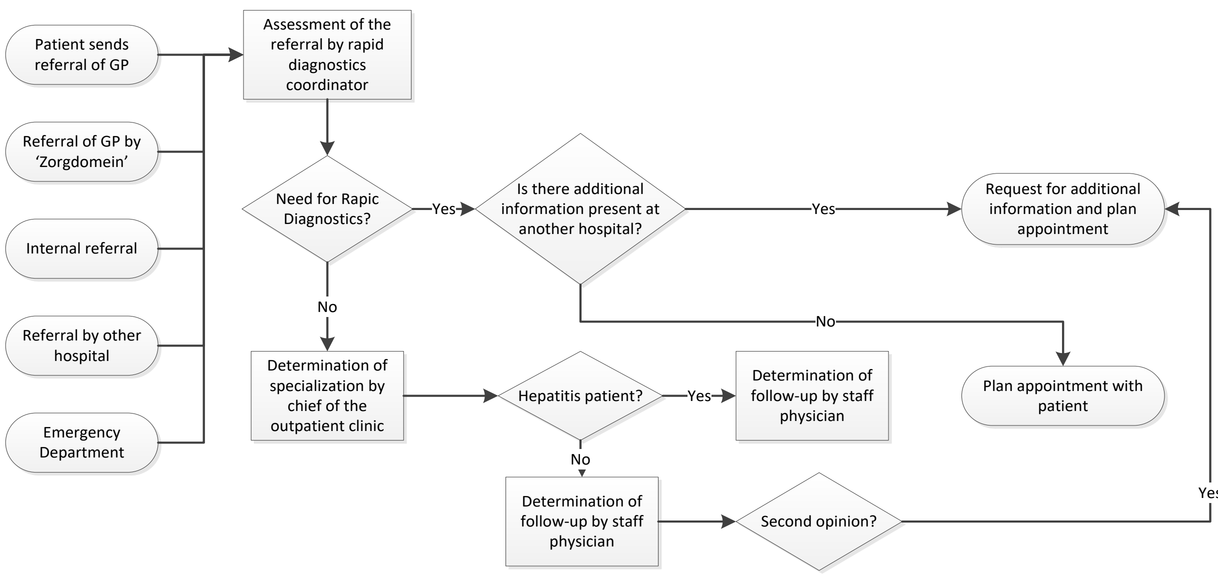

Figure 6 - Flowchart of planning process of a new patient

At first a new patient has five possible ways of entering the system: referral by a general Practitioner, referral through the 'Zorgdomein'-system, an internal referral, a referral by another hospital or by first aid. As the outpatient clinic secretary receives the letter, the rapid diagnostics coordinator first assesses the referral. If cancer is suspected, a patient is referred to the rapid diagnostics department. In this case the patient is called for an appointment at the rapid diagnostics department, and possibly additional information of the previous health institution is requested. The patient only returns to the outpatient clinic if no cancer is found but complaints are continuing. If there is no need for rapid diagnostics, the *chef de poli* assesses the referral. He determines the nature of the disease and what specialist the patient should attend to. In case of hepatitis a senior doctor will determine the follow-up and plan an appointment with the patient. In case of any other disease, a senior doctor will first determine the follow-up. Next he checks if the patient concerns a second opinion. If this is the case, he will request the previous health institution for additional information and plan an appointment, other way he will just plan an appointment.

As a new patient enters the system, a first consultation is planned. This is coupled again with a number of identical steps for patients with different diseases. In Figure 7 the flowchart of a first consultation and follow-up is shown.

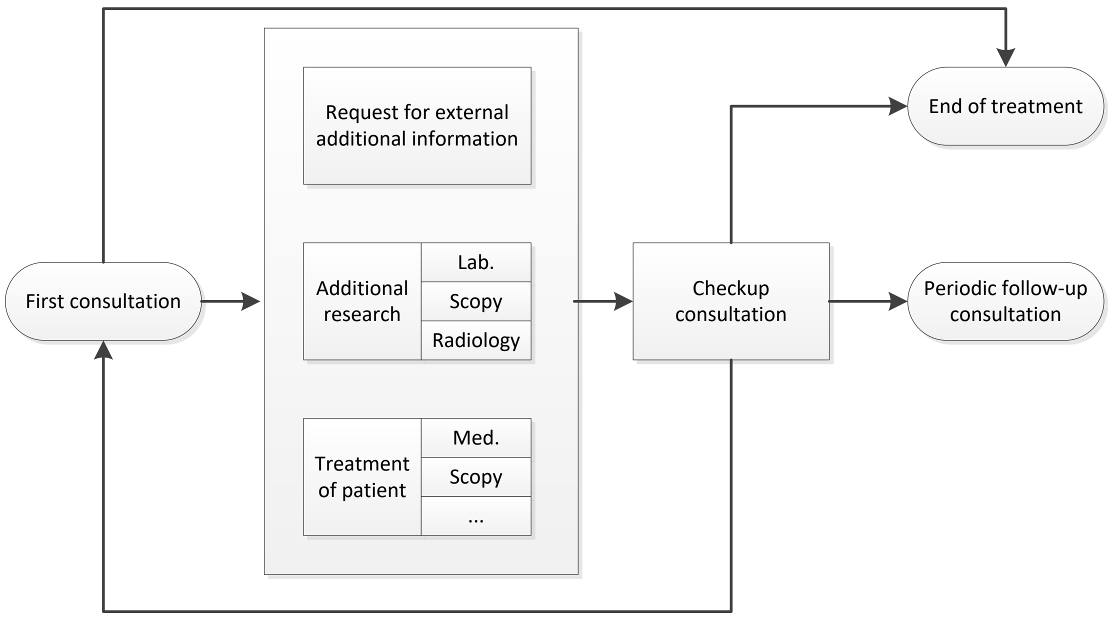

Figure 7 - First consultation and follow-up of a new patient

The second part concerns the first consultation and the possible follow-up. The doctor develops a care pathway for the patient, beginning with the first consultation of 30 minutes. Although this care pathway is unique for each patient, the steps to create one are the same. After the first consultation, the doctor and patient together decide whether there is a need for a follow-up process or that further treatment is not needed. If a follow-up is desired, the doctor decides whether there is a need for additional information on the patient, additional diagnostic research has to be performed or there is a need for treatment. For the first option the secretary will request the patient or previous health institution for additional information and schedule a check-up consultation. This can be person-to-person or telephonic. The second option includes the possibility for endoscopy or laboratory research for blood values or stool of the patient. Again this results in a check-up consultation. Last option is treatment of a patient. Same as the previous option, treatment is not performed at the outpatient clinic itself, and therefore both options have to consider the agenda of another department. After treatment or additional research a check-up appointment is planned with the doctor. The check-up consultation concerns the discussion of the previous steps. Next is to determine whether treatment is completed, periodic check-up consultation of e.g. 3, 6, 9 or 12 months is desired or that again treatment or diagnosis has to be performed.

Consultation types

The flowcharts in Figures 6 and 7 describe the several steps that determine the patient care pathway and therefore the consultation type to be planned by the secretary. So far we distinguished three consultation types, which are *new*, *check-up* and *periodic* consultations. Although not shown in the figures, the type *emergency* is added to these types. In practice this consultation type can be either new or recurring, but has a different and more pressing time-interval. Table 4 describes the four consultation types. The time-intervals related to each consultation type are important for the clinic, since it determines if the access time is in line with the desired period. Together with the number of new patients and return rate, as is shown in Section 2.1.1., this influences the pressure on the planning considerably. In Section 2.2 we will further elaborate on the desired time-interval of consultations.

Table 4 - Consultation types

Consultation type	Desired time-interval
New consultation	Within four weeks
Emergency consultation	Within two weeks
Check-up consultation	Short-term period after treatment/diagnoses
Periodic consultation	Requested by doctor

2.1.3 Various roles in the outpatient clinic team

As the patient of the outpatient clinic of Gastroenterology moves through the system, he is confronted with various members of the team that are connected with his care pathway. All of these play a different role in the care and planning process. It is essential that they work together and communicate in an effective manner, such that the processes are transparent towards a patient. The various roles in the planning and care process are shown in Table 5:

Table 5 - Key roles at the outpatient clinic of Gastroenterology

	Activity in the outpatient clinic
Supervisor or senior doctor	Performs consultations, drafting and approving of care pathways and supervision of junior doctors. Also creates an Electronic Patient Record (EPR), registration and verifying of patient record and diagnosis.
Junior doctor	Performs consultations, drafts care pathways and submits these for approval at the supervisor. Also creates an Electronic Patient Record (EPR), registration and verifying of patient record and diagnosis.
Nurse practitioner	Her function is help patients with explanation about medication, possible side effects or other information about their disease. Current only present at the IBD clinic.
'Chef de poli'	Assessment of a referral, whether patient is summoned. If yes, in what period and by what type of doctor. Next to the *chef de poli* functions as a senior doctor.
Employee of care registration	Consults and performances of at most 5 days old are checked and definitive accorded in EZIS. Main goal is connecting consults and operations such that billing can occur.
Employee of outpatient secretary	Sends letters to patient or referrer with various content, such as request for

	additional information. Checks presence of patient in EZIS, checks patient records and updates the care pathway and schedules appointments with a patient.

Each of above function plays a role in the clinic's functions. The *chef de poli* is the doctor who assesses a referral. His function is to decide whether a patient gets summoned, and if so, by what doctor and how soon. He therefore plays a key role in the process, as can be observed in Figure 6. Furthermore both the junior and senior doctors are assigned to different diseases at the clinic. There are eight senior doctors and nine junior doctors within the clinic. The senior doctors have a static distribution of what diseases they are treating, see Appendix C. The junior doctors vary in their disease specialty over time, as it is a part of their study program to treat various diseases. They can however see their own patients and develop a patient specific care pathway. A senior doctor is eventual responsible, and monitors the junior doctors on their choices. As from the first of May supervision will be performed in trios, consisting out of one senior doctor and two junior doctors. The patient and their care pathway will be discussed before the start of the day and before the afternoon session. Next to this, during the clinical sessions, there will be a moment for junior doctors to contact the supervisor.

2.2 Resource Capacity Planning

The processes and system can be described by the framework for healthcare planning and control, such that the performance of the specific healthcare sector can increase (Hans, Van Houdenhoven, & Hulshof, 2012). The planning and control can be described within healthcare for four managerial areas; medical planning, resource capacity planning, materials planning and financial planning. Next to this each managerial level can be decomposed into four hierarchal levels, which are the strategic, tactical, offline operational and online operational levels (Hans, Van Houdenhoven, & Hulshof, 2012). An overview of the various levels and areas is shown in Table 6.

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

Table 6 - Framework for health care planning and control (Hans, Van Houdenhoven, & Hulshof, 2012)

2.2.1 Managerial areas

In short the managerial area can be described as follows:

- *Medical planning*: this area concerns the role of clinicians in healthcare. It comprises decision making by clinicians regarding for example treatment, diagnosis, and triage.
- *Resource capacity planning*: it concerns the dimensioning, planning, scheduling, monitoring, and control of resources, such as staff, equipment, and capacity of facilities.
- *Materials planning*: it addresses the acquisition, storage, distribution, and retrieval of all consumable resources and materials.
- *Financial planning*: management of costs and revenues to achieve objectives within the healthcare organization. (Hans, Van Houdenhoven, & Hulshof, 2012)

This research will lie in the range of the managerial level of resource capacity planning, as we discuss the outpatient clinic on terms of planning, scheduling and staffing. As this section will show, there is just a relative small description of the tactical level when we compare with the others. This indicates that there is much to improve at this level, and therefore supports the choice of this research to focus on the tactical level.

2.2.2 Hierarchical levels

In this section we will elaborate more extensively within the four hierarchical levels.

Strategic

The strategic level of the UMC Utrecht focuses at the mission and long term goals. Their mission, as stated in Section 1.1, is translated for the outpatient clinics to focus on efficacy and innovation concerning capacity management. This is translated as improving the quality of care and make effective use of the capacity.

Quality of care

Improving quality is believed to increase by increasing the frequency of certain patient groups to gain health in time, e.g. by lowering the access time for prioritized patients and the desired time-interval can be accomplished. This gave motivation to formulate goals that referred to open the general clinic and rapid diagnostics daily, and create capacity for emergency patients. Effective communication is also believed to contribute to better quality of care. For the outpatient clinic this indicates that it is clear for all employees and patients what clinical session is opened at what moment. Furthermore care pathways for chronic care have to be developed, such that quality improvement can take place by quality control. Ultimately this form of standardization will lead to lesser variation in care delivery. The expectation is that this results in less preventable calamities and more predictability and transparency of care.

Use of capacity

In context of *Poli 3.0* the clinic seeks for connection and alignment with the developments around this project. For the capacity of the clinic this indicates that it should be efficient, such that utilization is high. Reason is that the demand for care is high, while capacity is scarce. Another goal around this subject is better supervision of junior doctors. As senior doctors are more involved in the care process, they can be more in control of the sequel. A result might be that patients will earlier be steered towards an exit, such that the outflow will increase, and the pressure on the capacity of the outpatient clinic is reduced. Next to this workload should be even distributed, such that fewer peaks will occur during the week. Connection refers to communication and alignment of the use of staff within the clinic and endoscopy department.

Production

At strategic level for the outpatient clinic of Gastroenterology there is a production agreement. This concerns the number of consultations for the patient group. We used data from EZIS to gain insight into the numbers of previous years. The production of the year 2016 should be at least equal to 2014, in

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the outpatient clinic in total. The focus lies on the number of new consultations, which.

Tactical

In terms of tactical planning this part describes the organization of operations, such as mid-term decisions about the allocation of capacity and staff. The decisions are made on a shorter planning horizon than at the strategic level.

Capacity

As from the first of May 2016 a new schedule will be used at the outpatient clinic. The schedule can be found in Appendix D, and shows which type of clinical sessions are opened at what day and moment. The opening times of the outpatient clinic during the week and the duration of the clinic sessions can be found in Appendix E. In the schedule the Rapid Diagnostics clinic is opened five times a week in the morning and the Generic clinic is opened four times a week. Emergency spots are also introduced at two slots per day for the generic clinic. These are the last spot of the morning clinic session and first spot of the afternoon clinic session, and can be used for emergency patients by referral of the GP or tertiary referral. Together the schedule with consulting hours including the nurse practitioners is distributed as can be seen in Table 7. The clinic uses *block booking* in their planning. This indicates the clinic has reserved specific time-slots on a recurring basis for a weekly schedule. Patients are then allocated to the provider who has procedure time left on a specific day.

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Table 7 - distribution of total clinic sessions at the outpatient clinic of Gastroenterology

The distribution of capacity currently does not take no-shows and emergency patients into account. So there are no fixed or variable time slots reserved for these events.

Staffing

As mentioned in Section 2.1.3 there are eight senior and nine junior doctors within the outpatient clinic. All doctors are scheduled on the basis of the before mentioned distribution of consulting hours. The new schedule includes a better distribution of workload. This indicates that the bulk is not only performed on Tuesday, but spread over the week. Next to this, since not all staff members are deployed at one moment, the possibility of an available doctor is higher such that the flexibility is increased. The schedule is to be used with a planning horizon of 10 weeks in which no adjustments can be made. In the most favourable case vacations and congresses of doctors should even be addressed approximately six months in advantage. A clinic of his speciality is then closed and no consultations can be planned. However if on a short notice there is an absence of the doctor, e.g. by illness, the secretary tries not to cancel the appointment. In this case a replacement by a junior doctor is established, since senior doctors of a different speciality cannot replace each other. As can be seen in Appendix E, each consulting hour starts with a briefing moment such that patients of the junior doctor can be discussed together with the senior doctor. The secretary will plan consulting hours in trios, such that the senior doctor has time to supervise the junior doctors. This includes creating two empty spots within each consulting hour for supervision.

Offline operational

The operational planning involves the short term decision making in the healthcare delivery process (Hans, Van Houdenhoven, & Hulshof, 2012). The 'offline' refers to planning in advance of performing operations. We describe this part on the basis of an appointment system as is outlined in the article of Cayirli and Veral (2003) and on findings of the appointment system by interviewing the secretary.

Appointment scheduling processes

A patient can request an appointment by visiting the secretary of the clinic, by phone or even by email. As the secretary receives such a request, the scheduler performs a view steps that are elaborated on next.

1. Each patient type is assumed to be homogenous and is scheduled on a First-Call, First-Appointment (FCFA) basis (Cayirli & Veral, 2003). As the patient reaches out for a consultation within the clinic, the scheduler first has to determine whether the patient is a *new patient* (N) or *recurring* patient (C). Recurring patients can concern check-up consultations, as a patient underwent treatment or diagnosis at another department, or a periodic consultation.

2. The patient's disease type is determined. The secretary searches for a doctor that treats this type of disease. This is important while consulting the static and cyclic planning, as can be observed in Appendix D, which shows the distribution of doctors per specialty over the week and their specific availability on each day.

3. The time frame in which a patient should be scheduled planned is determined next. A new patient time-interval is based on the type or referral and the current access time of the clinic. The desired time-interval of recurring patients is often induced by the doctor, and sometimes by a patient due to an emergency. For check-up patients this depends on the moment of treatment or diagnosis.

4. In this stage the secretary has to schedule the appointment in a dedicated time slot. This indicates that for a certain consultation there are various time blocks within the planning with a pre-determined length. This is based on the bisection of *new* (N) with duration of 30 minutes and *recurring* (C) with duration of 15 minutes.

The outpatient clinic categorizes timeslots for regular consultations as:

- New consultations, including oncological and rapid diagnostics (30 minutes);
- Check-up consultations, including oncological and rapid diagnostics (15 minutes);
- Telephonic consultations, regular (5 minutes);
- Telephonic consultations, long or nurse (10 minutes);

Furthermore timeslots for nurse specialist consultations are categorized as:

- New consultations (40 minutes);
- Check-up consultations (20 minutes);
- Telephonic consultations (10 minutes).

Together this step determines the *appointment interval*, which in the literature is defined as a constant or variable time between appointments (Cayirli & Veral, 2003). Since the appointments can vary in time, the appointment interval is variable and can be observed in Figure 8.

5. The final stage is to find an empty timeslot that is appropriate for the consultation type and time frame. The earliest available suitable appointment slot is then searched for. When found, the secretary can schedule the appointment. The outpatient clinic has an infinite planning horizon, such that appointments for even 14 months ahead can already be scheduled. In literature this concept is referred to as *appointment rule* which describes the *block-size (n_i)* to be scheduled in the *i*-th block. In case of the outpatient clinic of Gastroenterology, an individual block size is used. The *initial block*, which is the number of patients at an identical appointment time at the start of a clinical session, also only concerns an individual block (Cayirli & Veral, 2003). Figure 8 gives an overview of the appointment rules that are used.

Figure 8 - Appointment rule at the outpatient clinic (Cayirli & Veral, 2003)

Overbooking

In principle the outpatient clinic is trying to utilize their capacity at a maximum, although no overbooking takes place. In practice both *initial blocks* and the *remainder blocks* are individual scheduled and consultations are not planned outside the timeframe. There is one exception made, as the clinic overbooks telephonic consultations. Doctors try to perform these consultations during the clinical session or afterwards.

Patient classification

In the agenda the secretary of the clinic only distinguished the consultation types in *new* or *recurring* consultations. However patient classification is currently not performed in the appointment system of this clinic. This indicates that there are no restricted time slots within the clinical session for the various consultation types. This gives flexibility in the planning, since the number of alternative appointment times that can be offered to patient is not limited. For emergency patients there the secretary always tries to find a moment on short notice, but then again, there is no predetermined time slot available for such consultation types.

Online operational

The ‘online’ refers to reactive decision making in operational planning, so that processes can be monitored and reacting to unforeseen or unanticipated events (Hans, Van Houdenhoven, & Hulshof, 2012).

Adjustments

The clinic handles no fixed approach of dealing with no-shows in their online operational planning. This indicates that if a no-show occurs, this will lead to lost capacity on the day itself. However a note of the reason why a patient did not show up has been made. In case of three no-shows in a row, a patient will be dismissed of the outpatient care system. There is a possibility of *walk in* patients, which indicate emergency patients that have to be seen within the same or next day. In case of an emergency patient, a slot within the time frame is searched for. In case that this is found, the patient is scheduled. However if no slot is available, the doctor is asked for to take contact with the patient. Together they search for either a moment for a telephonic consult, or still schedule a consultation. This leads to overbooking for the doctor.

Now that the planning and control of the outpatient clinic is discussed in detail, we would like to know what performance is achieved with their approaches. This is discussed in the next section.

2.3 Performance

This section describes the current performance of the outpatient clinic of Gastroenterology, for the Inflammatory Bowel Disease and general population. We analyse literature on performance measures that can be used to determine the performance. Next step is to present these measures to stakeholders within the clinic, such that only relevant measures are used. The selected measures are then translated into performance indicators, which ultimately quantify the current performance of the outpatient clinic.

2.3.1 Literature

In the first stage of defining performance, we conducted a literature research at three databases. These are Orchestra, Web of Science and Scopus. In order to obtain recent results and up-to-date literature, the literature should not exceed an age of 10 years. So we search within the period of 2006 to 2016. Table 8 shows an overview of the method.

Table 8 - Databases and results for literature

Database	Search query	Subject Area	# of results	# selected after abstract	Consult date
Scopus	Outpatient AND performance AND access	Engineering	12	2	12/05/2016
ORchestra	Access	Outpatient clinics *Hierarchical level:* Tactical	4	3	12/05/2016
Web of Science	Outpatient AND performance AND access	Operations research management science	9	2	12/05/2016

In the literature, we find various performance measures that can be used to determine the performance of the outpatient clinic. Although there are many measures described, there is much overlap in them. In Appendix F an overview of performance measures found in literature is described. The most observed performance measures were waiting time (10), resource utilization (7), access time (7), overtime (7), cancellations or reschedules (3), and no-shows (3). Waiting time is considered as the patient waiting time at the day of receiving care, so the actual waiting time in the waiting room (Berg & Denton, 2012). Resource utilization refers to the usage of available time per specialism within the clinic (Kortbeek, et al., 2014). Access time is the time between a patient request for a consultation and the actual date of consultation (Qu, Rardin, & Williams, 2011). Overtime is the difference between the planned or desired completion time and the planned or actual end of service of the last patient of the day (Cayirli & Veral, 2003). Cancellation of a consultation due to overtime and patients not showing up for the appointment are both reasons for a consultation not happening, and are numerical measures.

2.3.2 Stakeholders

In Section 2.1.3 the various team members within the clinic are described. Each of them has a direct role in the functioning and performance of the clinic. Therefore they are the stakeholders that are approached for essential input for determining the appropriate performance measures. Although not mentioned before, the management team is also approached in this step. For both the outpatient clinic team as the division lead, we discussed possible performance measures to determine the performance. For all found performance measures in literature we discussed their value and appropriateness.

As all found performance measures in the literature are ought to be important, we discussed their value and appropriateness with the stakeholders. Together we agreed on using access time for new and emergency consultations, consultations within a desired time-interval for check-up and periodic consultations and staff utilization. These are the key performance measures that will be used to determine the key performance indicators. Measures such as no-shows, waiting time, and overtime are therefore excluded from this research. In the next section, we elaborate on the performance on the indicators.

2.3.3 Performance indicators

The next performance indicators are agreed on with the stakeholders:

1. Access time (days)
2. Consultations within desired time-interval (percentage)
3. Staff utilization (percentage)

Access time

Access time is often mentioned as a performance indicator for outpatient clinics in literature (Cayirli & Veral, 2003). This indicator refers to the average elapsed time in days between a request for a consultation and the actual date of the consultation for a certain consultation type.

For the formulation of the formula for access time we use the next parameters and indices:

$A_{s,t}$ = Access time	c = consultation	∈ {1,….,n}
	s = specialty	∈ {IBD, General}
	t = consultation type	∈ {New, Emergency}

The formula for the *average access time* (consultation type *t*) is:

$$A_{s,t} = \frac{\sum D'_{s,c,t} - D_{s,c,t}}{n_{s,t}}$$

$D_{s,c,t}$ = Date of consultation request

$D'_{s,c,t}$ = Actual date of consultation

$n_{s,t}$ = Total consultations

This number shows us the average access time for a certain consultation type with a predetermined disease. For access time we consider the consultation types new and emergency. The date of consultation request concerns the original request for an appointment. The actual date of consultation ignores cancellations, reschedules and no-shows, such that the realized appointment date is used.

New consultations

New patient access time is compared to the targets of the 'Treeknormen'. This norm states that 80% of the new outpatients should be seen within three weeks, and 100% in maximum four weeks (Rijksinstituut voor Volksgezondheid en Milieu, 2003). In the data, we selected consultations on their consultationtype and sub-agenda, which refers to certain doctors and their specialty. The calculated average access times are shown below in Table 9 and 10.

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This is not in line with the 'Treeknormen'.

Table 10 – Distribution of the average access time for new general patients in 2015

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Despite that the last category concerns an exception which can be considered as an outlier, this data shows that the current process results are not line with the ‘Treeknormen’.

Emergency consultations

At the clinic a bisection of emergency A and B is maintained. Emergency A patients need a consultation within the next day, while emergency B patients concern consultations within two weeks. However, at the outpatient clinic of Gastroenterology, there is a lack in registration of emergency consultations. This group of consultations is not registered proper, whereby it is neither possible to determine the number of arrival per week nor the performance in this category. Chapter 8 elaborates on this topic of interest.

Consultations within desired time-interval

The number of consultations that are within the desired time-interval can be determined by the aimed requested date for an appointment and actual date of the consultation. This requested time-interval is ordered by a doctor, and refers to the week in which a consultation should take place. This indicator concerns the average elapsed time in days between the request and actual date of consultation, and compares this with the desired moment. In formula, first the access time per specialty, per consultation and per consultation type needs to be determined:

$$A_{s,c,t} = D_{s,c,t} - D'_{s,c,t}$$

$D_{c,t}$ = Date of consultation request
$D'_{c,t}$ = Actual date of consultation

The second step is to determine whether the access time is within the desired time-interval. For the formulation of the formula for access time we use the next parameters and indices:

PCDI = Percentage of consultations within the desired time-interval	c = consultation	∈ {1,…., n}
	s = specialty	∈ {IBD, General}
	t = consultation type	∈ {Check-up, Periodic}

A consultation is within the desired time-interval if the access time equals the desired moment. The PCDI represents the percentage of consultations within the desired time-interval (for consultation type t), and is given with the next formula:

$$PCDI_{s,c,t} = \frac{\sum -x\% \leq \frac{A_{s,c,t}}{A'_{s,c,t}} \leq x\%}{n_{s,t}}$$

$A_{c,t}$ = Access time in days
$A'_{c,t}$ = Requested moment in days
$x\%$ = Percentage deviation from the desired moment

We used data from EZIS of the period of January 2015 to December 2015 to analyse on the current access time for check-up and periodic consultations with Inflammatory Bowel Disease (IBD) and the general population. To do this proper, we selected consultations on consultation type and sub-agenda, which refers to certain doctors. A time consuming element was searching for orders of doctors, in which they requested a moment. This was necessary, due to poor registration, as the option for a desired moment is not used by a doctor's order. For both IBD and general categories we analyses data from EZIS on completeness. So if we could clearly induce a desired moment from the comments in the order, we included the desired moment and the actual date of the consultation. As the desired moment varies, we calculated a percentage of deviation from the desired moment. To exclude outliers we used 95% of the two sided data, and bins were constructed. The number of bins calculated as the rounded square of the total consultations in the sample, and the bin size as the range divided by the number of bins. There is a distinction in the data between check-up consultations and periodic consultations, so both will be discussed next separate for the IBD and general population.

IBD population: check-up consultations

The desired moment as requested by a doctor varies between two and seven weeks. For IBD check-up consultations we analysed 235 samples. Figure 9 shows the frequency of consultations that are within a certain interval different from the desired moment.

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Figure 9 - Frequency of consultations within a percentage interval devious to the desired moment. Period: 01-01-2015 to 31-12-2015, n = 235.

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IBD population: periodic consultations

The desired moment as requested by a doctor varies between two and 12 months. For IBD periodic consultations we analysed 582 samples. Figure 10 shows the frequency of consultations that are within a certain interval different from the desired moment.

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Figure 10 - Frequency of consultations within a percentage interval devious to the desired moment. Period: 01-01-2015 to 31-12-2015, n = 582.

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General population: check-up consultations

We analysed 131 samples out of the EZIS data. Figure 11 shows the frequency of consultations that are within a certain interval different from the desired moment.

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Figure 11 - Frequency of consultations within a percentage interval devious to the desired moment. Period: 01-01-2015 to 31-12-2015, n = 131.

CONFIDENTIAL INFORMATION

General population: periodic consultations

We analysed 25 samples out of the EZIS data. Figure 12 shows the frequency of consultations that are within a certain interval different from the desired moment.

CONFIDENTIAL INFORMATION

Figure 12- Frequency of consultations within a percentage interval devious to the desired moment. Period: 01-01-2015 to 31-12-2015, n = 25.

CONFIDENTIAL INFORMATION

Staff utilization

As mentioned in Section 1.2 the pressure at the outpatient clinic is high with the increasing number of patients and limited resources and staff members. Utilization of both resources and staff is therefore essential. Staff utilization is the proportion that a system is operating of the available time. As in this research we aim for the planned staff utilization based on the agenda, the formula is:

$$Utilization = \frac{Number\ of\ minutes\ scheduled\ in\ agenda}{Number\ of\ available\ minutes\ in\ agenda} * 100\%$$

The formula indicates that both the minutes scheduled in de agenda should be known as the capacity in terms of available minutes for a certain period. To determine this we used data from 'Informatieportaal' in the period of January 2015 to December 2015. In total the IBD clinic had two senior doctors and three junior doctors. Table 11 and 12 shows an overview of the data of the utilisation for each IBD doctor, and for both IBD and general an overall utilisation.

Table 11- Utilization of IBD doctors in 2015

Doctor	Available capacity	Planned capacity	Utilization in 2015	Standard deviation
A	13155	13720	104%	7%
B	12255	12885	105%	10%
C	2410	1555	65%	19%
D	7395	5895	80%	18%
E	9835	8580	87%	26%
Overall	45050	42635	95%	20%

Table 12- Utilization of General doctors in 2015

Doctors	Available capacity	Planned capacity	Utilization in 2015	Standard deviation
Overall	45530	44770	98%	15%

To get a better understanding of the data, we plotted the duration of the planned consultations versus the available capacity per week in 2015. An example of this data is shown in Figures 13 and 14. The most important problem that is visualized is the blockages. For the IBD we calculated that 35% of the tactical scheme was blocked, so overall 65% of the capacity was available for scheduling. For the general clinic this percentage of blockage was even 57%.

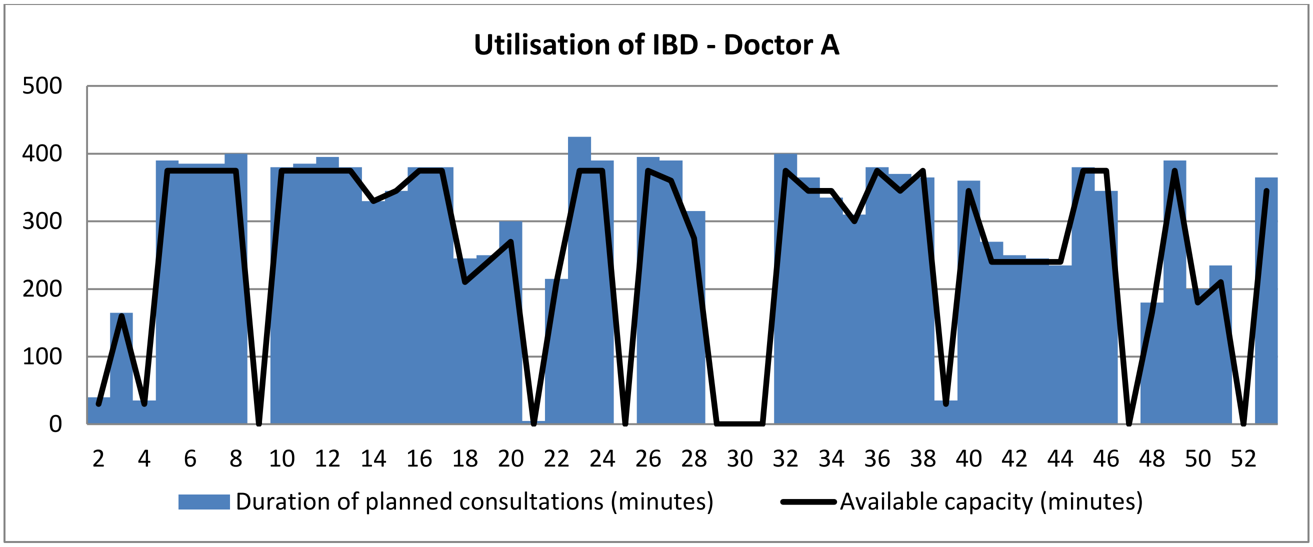

Figure 13 – Duration of planned consultations versus available capacity of the IBD staff Doctor A during the period 01-01-2015 to 31-12-2015. Source = 'Informatieportaal'

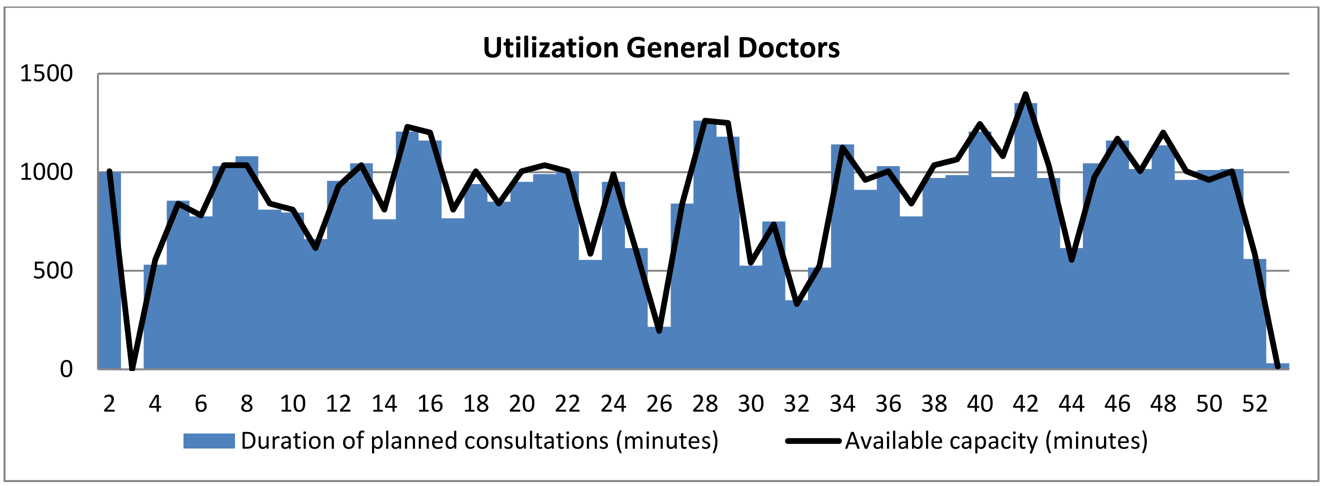

Figure 14 - Duration of planned consultations versus available capacity of the General Doctors during the period 01-01-2015 to 31-12-2015. Source = 'Informatieportaal'

Analysing this data and the data in Appendix H, we see that the image of higher utilisation of the staff doctors and lower utilisation of junior doctors is visual confirmed for the IBD. What is interesting to see is that for all doctors, both IBD and general clinic, the capacity is low or zero during the spring Break, summer vacation and towards the end of the year.

We discussed the results with the doctors and secretary. The data shows that doctors indeed have a high working pressure, as the utilization is nearly always 100%. Then again reaching such a utilization level is desired, as little staff capacity remains unused. The data shows only planned utilization, whereas no data is available of the realized utilization. The result is that no information about late shows, late starts or overworking is available. Furthermore there is no data available of no-shows, cancellations or reschedules for this specific period.

Also a sample of two months for a junior and senior IBD doctor was analysed, which can be found in Appendix I. What comes forward is that the number of periodic consultations is often higher than the remainder of consultation types. This is in confirmation with the idea of the schedule being filled with periodic consultations for the IBD population.

2.4 Demarcation of the core problem

This section discusses the most important findings of the previous sections. A cause-effect diagram of the problems is shown in Figure 15.

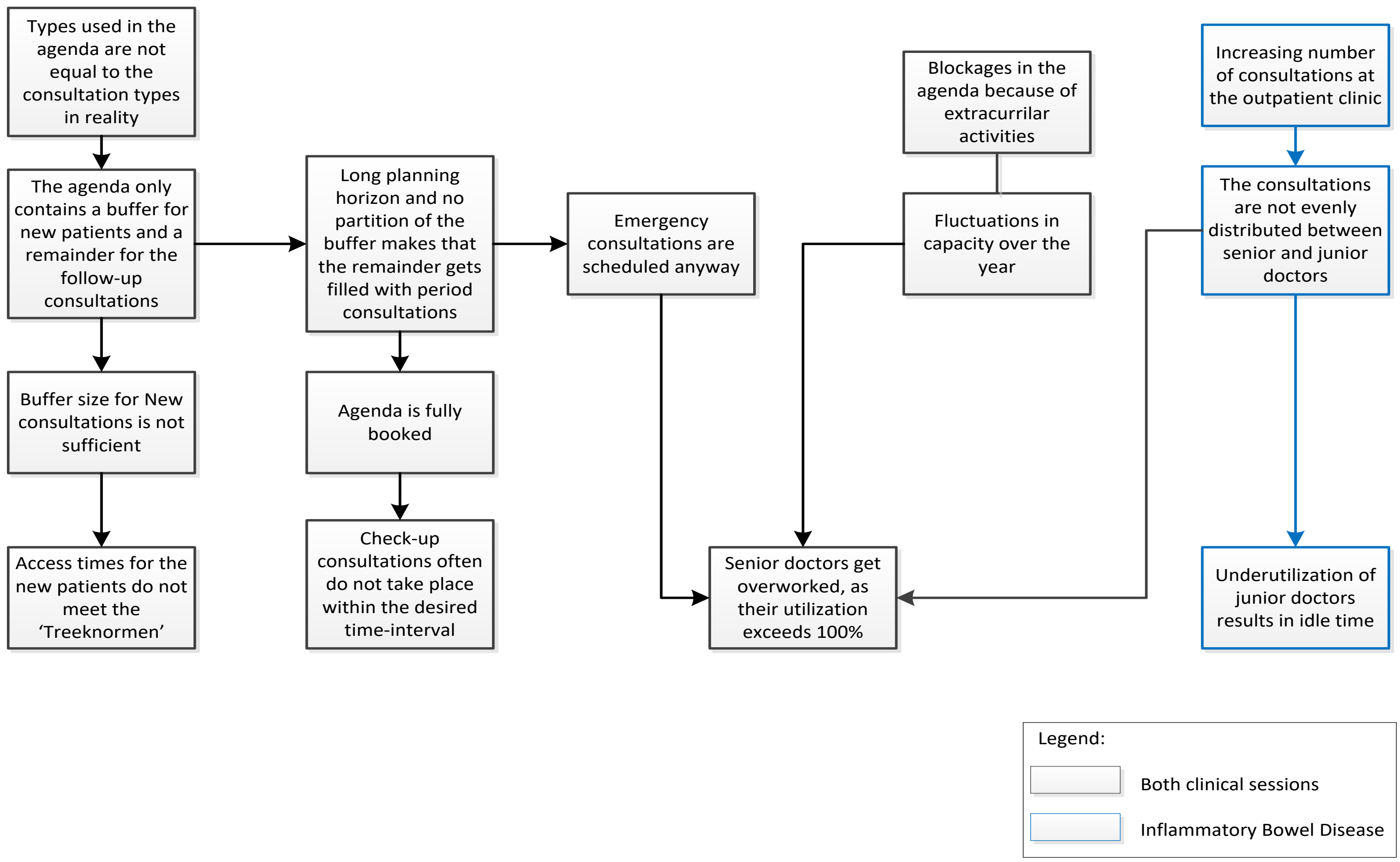

Figure 15 - Problem cluster following from the context analysis

The core problems that can be identified are:

1. Types used in the agenda are not equal to the consultation types in reality;
2. No care pathway for the follow-up is used for outpatients;
3. Extracurricular activities lead to blockages in the agenda;
4. Increasing number of consultations at the outpatient clinic.

The fourth problem lies at the strategic level, and cannot be influenced by the scope of this research. The first problem shows that the clinic uses only new and check-up consultation types, while more types are needed. Together these problems, with a long planning horizon, result in that the schedule is filled with periodic consultations, leaving no available staff minutes for check-up consultations. The second problem shows that the clinic has no insight into the frequency of check-up consultations, and their desired moment. Furthermore, emergency patients are not registered, such that the clinic has so insight in their performance of emergency consultations. In this research we will focus on the first three problems, and propose a solution approach to increase the number of consultations that are delivered within the desired time-interval.

3 Theoretical framework

Chapter 3 gives a review of literature on topics of interest in this research. We will describe in what category our problem fits, and solution approach might be applicable. In Section 3.1 we discuss the used search method. Section 3.2 discusses planning challenges in outpatient clinics. Section 3.3 discusses appointment planning in outpatient clinics. Section 3.4 discusses planning models in which the distinction is explained between analytical and simulation. Eventually Section 3.5 summarizes the found literature, and sets a basis for what type of model we can use for creating a solution approach.

3.1 Search method

Similar to Section 2.3.1 we perform a literature research, at the databases Orchestra, Web of Science and Scopus. Literature may not exceed an age of 10 years, so the period of 2007 to 2016 is used. In Table 13 an overview is given of our used search query, databases and results.

Table 13 - Databases and results for literature

Database	Search query	Subject Area	# of results	# selected after abstract	Consultation date
Scopus	Outpatient AND access AND (Appointment planning OR Waiting list)	Engineering	247	14	18/10/2016
ORchestra	Access OR Waiting list OR Appointment planning	Outpatient clinics *Hierarchical level:* Tactical	4	3	18/10/2016
Web of Science	Outpatient AND access AND (Appointment planning OR Waiting list)	Operations research management science	28	6	18/10/2016

We selected articles that included operations research of the outpatient clinic, and referred to access. This way we decreased the number of articles, and narrowed the scope, as we focus in this research on access time.

3.2 Planning in outpatient clinics

In the Netherlands an increase of the population is combined with an elderly population, such that the number of patients is increasing (Balasubramanian, Banerjee, Denton, Naessens, & Stahl, 2010). The outpatient clinic experiences the planning of these patients as difficult, due to the complex nature of the system and the multidisciplinary service. The planning in outpatient clinics becomes more important, as there is a pressure on reducing costs, combined with the expectation of the community of increasing quality of healthcare (Cayirli & Veral, 2003). As a result a trend is observed: the emphasis on short length of stay of patients in the hospital. Costs can therefore decrease, while patients can return to home as soon as possible.

To an advance of medical care and technology, procedures can take place minimally invasive. This is consistent with the short length of stay, and creates the possibility for patients to recover at home, and lower implication and infection rates. However this quick access and high throughput results in an increase of visits at the clinic, therefore putting pressure on its planning methods and use of capacity (Berg & Denton, 2012).

Another explanation for the high number of visits at the outpatient clinic is the creasing number of chronic patients (Whear et al., 2013). This group attends on a regular basis at the hospital, such as a frequency of every six, nine or twelve months. As the physician is the initiator of the appointment, it is observed that appointments commonly occur in a period when a person is feeling well, so little action is taken. This way care is ineffective, but also leads to committing the available capacity to the routine follow-up patients. If a person is not feeling well, it may become difficult to create an urgent appointment on short notice for the patient (Whear et al., 2013).

Together these events lead to challenges in the planning of the outpatient clinic and the deployment of doctors. To meet better quality and patient satisfaction, a reasonable waiting time and access time for patients at the outpatient clinic should be achieved (Cayirli & Veral, 2003). This is currently not the case, as access times for new patients are higher than desired, long waiting lists arise (Willis, et al., 2011). Furthermore check-up consultations are pushed forwards and postponed such that these consultations are not within the service targets for an appointment (Nguyen, Sivakumar, & Graves, 2015). Factors such as staffing, allocation of equipment and resources, and patient appointment schedules influence the performance of these outcomes (Berg & Denton, 2012). The focus should lie on an effective appointment planning, where utilization should be high enough and patients can be seen within a desired time-interval. Now the use of appointment planning in the outpatient clinic department is discussed.

3.3 Appointment planning in the outpatient clinic

Appointment planning is used to create appointment schedules that can deal with scheduled and unscheduled patient arrivals. An effective appointment schedule has the goal to match demand with capacity, such that staff and resource utilization increases and access time meet the norm (Kortbeek, et al., 2014). An appointment system has the objective to find an approach that optimizes a particular measure of performance in a clinical environment. For an outpatient clinic, the system can be described by a queuing system (Cayirli & Veral, 2003). The simplest case is considered when a homogeneous customer population is assumed, combined with punctual patients and doctors, and a single doctor that serves these patients with stochastic processing times. If the arrivals of patients appear to be cyclic, a Cyclic Appointment Schedule (CAS) can be described to specify a capacity cycle and day schedule (Kortbeek, et al., 2014). A system becomes more complex by the number of services, doctors, appointments per clinic session, and stochastic arrival processes, services times, and lateness and interruption level of doctors (Cayirli & Veral, 2003).

A CAS can be used to specify a capacity cycle, and create a day schedule to deal with scheduled and unscheduled patients. Now in order to create an appointment scheduling system, such as a CAS, the capacity cycle can be determined by determining an access time norm and formulating the arrival process of patients. Furthermore it is important to determine the right *booking horizon*, which describes how far into the future a scheduler is allowed to schedule appointments (Berg & Denton, 2012). Other factors that describe the queuing system such as the number of services, doctors, appointments per clinic session, and the service times, should be described in detail, as they influence outcomes as cancellations, reschedules, and no-shows (Berg & Denton, 2012). Now for creating a schedule, a choice has to be made for *block booking* or *open booking*. *Block booking* is a booking policy that reserves specific time blocks on a recurring basis for certain type of appointments. *Open booking* concerns allocating patients on a first come first serve basis, for a given day or week of service. In this case, the outpatient staff is treated as a pooled resource capacity (Berg & Denton, 2012).

In this research an appointment planning system can be used to determine the capacity needed, on a cyclic basis, to achieve the desired access time for patients. Another applicability of this approach is to develop the system as a queuing system, and run this system to retrieve outcomes on important performance measures. Now, if we would like to use a model to describe the system, we can use planning models. This subject will be discussed more extensive in Section 3.4.

3.4 Planning models

The facility or a process of interest is usually called a *system*, and is a collection of entities, such as people or machines that interact together toward the accomplishment of a logical end (Law, 2007). The state of such a system is a collection of variables necessary to describe a system on a particular time. Systems are bisected into *discrete* and *continuous*. *Discrete* refers to the state variables that change instantaneously at separated points of time. *Continuous* is where the state is changing continuously with respect to the time. Law shows different ways of studying a system, such as experimenting with the actual system or a model of the system, see in figure 16.

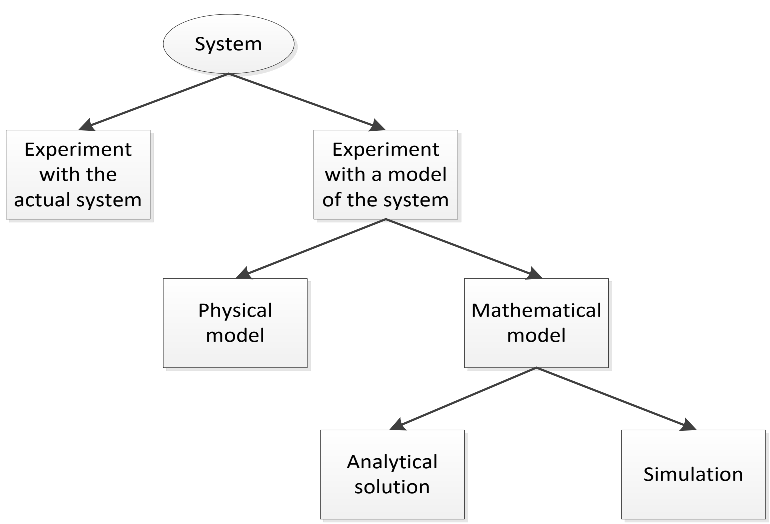

Figure 16 - Ways to study a system (Law, 2007)

Although we could experiment with the actual system, this can be too costly or be disruptive to the system. Therefore, it is desirable to use a model as a representation, and check if it is valid to represent the system. For operations research and system analysis we find it useful to use a mathematical model instead of a physical model. The model can represent a system in logical and quantitative relationships. In such a model we can experiment with various scenarios, and observe how the system would react if the system is manipulated with different inputs (Law, 2007). The last decision concerns the determination whether an analytical solution or simulation approach should be used. These two types are discussed in the next two sections.

3.4.1 Simulation models

Simulation models are mainly used when a system is too complex, such that a numerically solution cannot be achieved within polynomial time (Law, 2007). The main advantage of simulation modelling is the ability to model complex outpatient queuing systems and use other variables, such as various servers or customer-related attributes (Cayirli & Veral, 2003). As we use such a model to test various scenarios and experiment with different 'based on experience' solutions, it is not likely that a simulation model will result in an optimal solution for the problem. However it creates the possibility to experiment with the model inputs, and observe how they affect the output measures of performance (Law, 2007). A simulation model can be classified along three different dimensions: static versus dynamic, deterministic versus stochastic, and continuous versus discrete. Together these elements form several types of simulation models, such as:

- *Discrete event simulation*: modelling a system over time by which the state variables change instantaneously at separated points in time.
- *Continuous simulation*: modelling a system over time by which the state variables change continuously with respect to time.
- *Monte Carlo simulation*: a random number scheme approach, which is used for deterministic or stochastic problems. A spread sheet in Excel can be used, where the random number can be derived from some basic probability distribution. (Law, 2007)

In the literature we find that older simulation modelling studies have used a discrete event simulation with single server (Cayirli & Veral, 2003). The studies focus on appointment systems at either a tactical or operational level. Bailey (1952) was the first to analyse individual block appointment systems, where most hospitals used single-block systems. He found with a Monte Carlo simulation that a system with individual blocks and a fixed interval was most effective when the initial block contained two patients (Bailey, 1954). Another discrete event simulation model was used by Swisher et al. (2001), to investigate if decision making in outpatient clinic services was influences by patient mix, patient scheduling, and staff levels. Summarizing, a simulation can give insight into the effect of experimenting with various scenarios of factors that have an impact on the performance measures.

3.4.2 Analytical models

The mathematical model can also be constructed with an analytical approach that uses relationships and quantities for an exact solution. This construction and usage of such an model can only take place if the model is simple enough, as a too complex model is not able to be solved numerically within polynomial time (Law, 2007). Analytical approaches of studies for appointment systems include methods like mathematical programming and the queuing theory (Cayirli & Veral, 2003). For example an M/M/1 queuing model can analytically be examined. Then the steady state average delay, utilization and queuing length can be determined (Law, 2007).

We observe that most of the models in the literature assume steady-state behaviour of the process, while this is never reached in a real outpatient clinic with a small number of patients. This does not indicate that the outcome cannot give us insight into tactical choices to be made regarding resource and staff allocation. Lindley (1952) was one of the first to use an analytical approach, a G/G/1 queuing model with a single server, in which inter-arrival and service times were used. He concluded that the system improves if customer arrival times are scheduled at regular intervals, instead of random. Continuing at this path, Fries and Marathe (1981) used queuing analytical to determine the optimal block sizes (n_i) for the next determined period for which the number of assigned patients is known.

A more recent study by Elkhuizen et al. (2007) showed that in terms of access time, an analytical queuing model can be used to determine the capacity needed to meet a predetermined norm of seeing new patients at the clinic. They considered a single queuing model, with one waiting row and one service station. As a follow-up he constructed a simulation to handle with daily variations in demand and capacity scheduled. A comparable study of Van Oostrum et al. (2008) addressed a cyclic operating room schedule. This so-called Master Surgical Schedule (MSS) plans surgeries in a cyclic manner. Such an approach within the OR department could also be applicable for the outpatient clinic, where consultations can take place in a cyclic manner.

3.4.3 Queuing Models

The literature shows that capacity demand in the outpatient clinic should be demand driven, where access times and resource utilization are important performance indicators (Cayirli & Veral, 2003). In this research, we are interested to do the same at a tactical level, where the timely care delivery should be in balance with staff utilization. Although we use a deterministic duration of services, cyclic planning of consultations can also be implemented in this research to determine the required staff capacity needed.

In the literature we observe that research has been performed towards reservation of OR time for semi-urgent surgeries (Zonderland, Boucherie, Litvak, & Vleggeert-Lankamp, 2010). Zonderland et al. (2010) introduced a method to evaluate the OR capacity needed to accommodate incoming semi-urgent surgeries. A queuing model is constructed, which helped to decide what amount of reserved OR time is required to deal with a stochastic arrival process of semi-urgent patients. A trade-off was therefore made between OR utilization and cancellations. Another queuing model concerning access time evaluation was introduced by Kortbeek (2012). He constructed a queuing model were a cyclic appointment schedule and scheme was introduced, that could deal with a cyclic demand for appointment request. A Cyclic Appointment Schedule (CAS) was used, which specified the capacity cycle and day schedule, so that a pre-specified norm for a given arrival rate and capacity could be met. This concerns unplanned arrivals at the outpatient clinic. For the access time evaluation, a cyclic slotted queuing model was used, which was focused on the backlog of each day. Performance measures were expressed as the probability distribution of the access time, the expected access time, and the access time service level. The queuing methods of Zonderland et al. (2010), Kortbeek (2012) and Elkhuizen et al. (2007) for the reservation of capacity for a pre-specified norm for unplanned patients seem relevant methods for this research.

3.4.4 Interventions

In the literature we searched for solution approaches to solve the timeliness problems at the outpatient clinic. In order to solve the high access time for new patients, the system needs to match capacity to demand (Willis, et al., 2011). Then the queues will not reform and the timeliness improvements can become sustainable. In order to do so, a master schedule, which divides the operational time into slots per day, is proposed (Joustra, et al., 2010). This method is also used by Elkhuizen et al. (2007), who constructed a simple analytical queuing model to gain insight into the capacity needed to meet a pre-specified norm for the probability of receiving new patients within a certain number of weeks. We propose a similar solution approach to decrease the access time for new patients at the outpatient clinic.A more detailed overview will be described in Chapter 4.

Furthermore we are interested to know if the outcomes of the solution approach would have solved the timeliness problem of the new patients in 2015. In the literature a simulation queuing model is used, in which daily variations in demand and capacity schedules are taken into account (Elkhuizen, et al., 2007). We can use a similar method, that uses weekly variations in demand and capacity. A more detailled overview is discussed in Chapter 5.

As check-up consultations are not planned as soon as possible, we cannot use the same method as discussed before. To match the capacity of the outpatient clinic to the demand for a re-entry system, restrictions on the appointment lead times for patients are introduced (Nguyen, Sivakumar, & Graves, 2015). However this study assumes that registration and data is complete and sufficient, such that the desired time-interval of check-up patients is known. In our case study this is not the case. In the literature we find a method with slot reservations that serves regular and priority patients (Zonderland, Boucherie, Boer, & Litvak, 2012). Their model reserves slots in advance, based on a care pathway. This care pathway describes the time-interval and frequency of the expected consultations to come for each new patient. In consultation with our stakeholders we are interested in the timeliness of check-up patients, with a given capacity. We therefore propose a method that experiments with the care pathway. Chapter 6 elaborates on this method.

3.5 Summary

In this chapter we discussed the literature on planning methods for outpatient appointment planning. This section gives a short summary, and determines the solution approach for the remainder of this research.

The first part of our research question is to determine the required capacity that is needed to see new patients within a predetermined norm. If an analytical approach is possible, this approach is more favourable than a simulation. This problem can be addressed with an analytical queuing model, with a single server and single waiting row or backlog. We therefore will use and adapt the method as presented by Kortbeek (2012).

To test whether the outcomes are valid, we test the calculated capacity while introducing the use of historical arrival data. A simulation will be used to test the number of slots, while dealing with variations in demand. The model will then be extended with the use of a care pathway, which describes the frequency and time-interval for check-up patients. Experimenting with such a care pathway is purely performed to gain insight into this approach, as we have no realistic view of the follow-up of patients at the outpatient clinic of Gastroenterology.

Eventually the methods will yield results that describe the capacity size needed for new consultation types, and map the effect of using a care pathway that describes the time-interval on the timeliness of check-up consultations. Both outcomes can give us insights into possibilities of improving access time and consultations at the desired moment, while maintaining an acceptable utilization of staff.

4 Analytical model: cyclic reservation of slots

So far we discussed the context of our research, with a demarcation of the core problem in Section 2.4. In order to find a solution approach, we executed a literature study, in which solution approaches for the addressed problems are analysed and described in Chapter 3.

This chapter describes a solution approach for the number of cyclic dedicated slots for new patients. It proposes a mathematical model, and is structured in a few successive steps, which are somewhat based on the step approach of Law (2007). Section 4.1 contains the problem formulation, in which the goal is disclosed. Section 4.2 discusses the conceptual model, and how it should be interpreted. Then Section 4.3 describes the model input in terms of data and assumptions. Section 4.4 describes what the technical model looks like and shows the solution approach. Then section 4.4 shows the experimental designs.

4.1 Problem formulation

Chapter 2 presents an extensive analysis of the problems at the outpatient clinic. This chapter focuses on the problem of consultations that do not meet the access time norm. So for the consultation type 'new consultations', we want to know the number of slots needed to see new patients in time. A norm called the 'Treeknorm' is used as a target. With this approach a part of the objective, as stated in Chapter 1, can then be achieved:

"*Develop a method on a tactical level that helps to deliver care within the desired time-interval for various consultation types within the outpatient clinic of Gastroenterology."*

We perform this approach for new patients of both the general population and IBD population. This approach is not possible for emergency consultations, as no data of the arrival pattern is available.

4.2 Conceptual model

As discussed in Section 2.2, the framework by Hans et al. (2012), categorizes four hierarchal levels within the resource capacity planning. Our approach addresses the usage of staff resource with a mid-term planning at the tactical level. A closed block planning approach is used, which describes the number of outpatient clinic slots that are assigned to new consultations (Van Oostrum J. , 2009). The queue model determines the probability of receiving access time within a certain number of weeks.

The model describes a cyclic reservation of slots to be reserved for new patients. This is in line with the first phase of constructing a Master Surgical Schedule (MSS), as is mentioned in Van Oostrum et al (2008). Such a model is a cyclic surgical schedule, which specifies for each "OR-day of the planning cycle a list of recurring procedures that must be performed" (Van Oostrum et al., 2008). In their article the planning strategy has three stages, where the first stage determines the cycle length and divides capacity. A similar approach has been performed by Elkhuizen et al. (2007). They constructed an analytical model to determine what capacity was needed in the outpatient clinic to meet a predetermined norm for seeing new patients (Elkhuizen et al., 2007).

To measure the performance of the system, the performance indicator of probability of receiving access within various numbers of weeks is used. Our focus lies on the probability of receiving access within three and four weeks, such that we can observe if the 'Treeknorm' is met. The outcome should describe for each specialty how much slots should be reserved for the accommodation of new patients.

4.3 Model input

This section discusses the model input, and the assumptions made to describe our specific situation. We gained data by performing interviews with various stakeholders, and by consulting the EZIS registration system. Data from the system was retrieved from the period of 01-01-2015 till 31-12-2015. The patient groups that were analysed were either of the IBD population or the general population. We constructed categories based on the medical priority where patients are assigned in a time-interval in which their consultation is advised (Demeulemeester & Van Riet, 2014). An overview is shown in Table 14.

Table 14 - Categorization of consultation types at the outpatient clinic of Gastroenterology in 2015

	Category	Interpretation	Interval
Non-elective	Emergency A	Today or tomorrow	[0, 1d]
	Emergency B	Within two weeks	[0, 2w]
Elective	New	Within four weeks	[0, 4w]
	Check-up	Requested by doctor	[2w, 7w]
	Periodic	Requested by doctor	[8w, 12m]

There are different norms formulated in consensus with the stakeholders. For emergency A and B consultations we find that the norm is that 100% of the consultations should be within the desired day or week. In practice however we see that emergency A is not used in the agenda procedure for the IBD and general population. This type of emergency is only used for the Rapid Diagnostics department, and sometimes for the hepatitis clinical session. Therefore we do not need to analyse this patient stream, neither need to calculate the required number of slots. For emergency B consultations we find that these are present at the outpatient clinic, but are not registered properly. As a result we advised the clinic secretary to change their registration procedures. However for the scope of this model, this consultation type is not included for the calculation of a number of dedicated slots. The check-up and periodic consultations are not applicable for this model, as these consultations have to take place at a certain predetermined week, instead of the earlier the better.

Eventually the arrival of new patients in 2015 was obtained for both specialties. Next to that a norm was formulated, which stated that 80% of the new patients require access within three weeks, and 100% within four weeks.

4.3.1 Assumptions

In the model we make the following assumption:

- We assume that both junior and senior doctors can perform all types of consultations. Therefore we can pool the demand amongst the doctors. This indicates that staff capacity is unified, and patients can be seen by all doctors of a certain speciality.

- New patients are scheduled as soon as possible.
- Service times are deterministic for the various consultation types. For new consultation this indicates a static duration of 30 minutes.
- Arrival rates are stochastic and cyclical. The arrival of a patient is the moment of request at the outpatient clinic secretary. The distribution of the arrival rate is determined by historical data, which is shown in Appendix J.
- A four week cycle lengths is assumed. Variations in demand over this cyclic period were calculated to be the least with this cycle length.

4.4 Technical model

The technical model describes the queuing theory model, as is proposed by Kortbeek (2012), to determine the slots needed to meet the norm for new patients.

4.4.1 Queuing theory

We use the method of Elkhuizen et al. (2007), in which they use an analytical queuing model, to determine the capacity needed to meet a certain norm. This required capacity is determined by the number of patients arrived per week, and the duration of the consultations (Elkhuizen, Das, Bakker, & Hontelez, 2007). In our case we consider the duration of consultations to be deterministic. Capacity for such consultation types are dedicated, which indicates that various patient streams do not interfere with each other. The percentage of new consultation requests in 2015 amounted to 8% of all IBD consultation requests and for the general clinic this amounted to 41% of all consultations.

The process is an example of a M/D/I model with a single queuing model, one waiting row and one service station (the outpatient clinic). We use the deterministic queuing theory model which is presented by Kortbeek (2012), to determine the number of slots per week that are required to accommodate new patients within their allowed access times. The norm we need to meet is seeing 80% of all new patients within three weeks, and 100% of all new patients within four weeks.

We used the historical arrival data of 2015 for both IBD and general population to determine the arrival distribution, as can be observed in Appendix J. For the arrival process of new IBD fitted a Poisson distribution ($p > 0.85$) with $\lambda_w = 3.06$ patients. For the new general patients a 3-parameter Weibull distribution ($p > 0.4$) was fitted with $\beta = 6.70$, $\gamma = -15.67$ and $\eta = 32.19$.

Although we fitted a distribution for both the arrival processes, there is still uncertainty about how much capacity should be reserved. If one reserves too little capacity, the access time will become higher than desired but staff utilization will increase. Then again if too much capacity is reserved access time will be reduced for new patients, but it would also result in underutilization and an increase of idle time.

4.4.2 Mathematical description

Now we discuss the mathematical notations and equations that describe the queuing model theory as based on the theory of Kortbeek (2012). Figure 17 shows a visualization of the model.

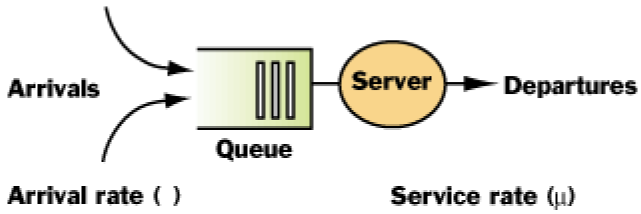

Figure 17 - Visualization of the queuing model. Arrivals represent the incoming new patients.

The notations used in the model are given in Table 15.

Table 15 - Notations used in the discrete time queuing model theory (Kortbeek N. , 2012)

Symbol	Definition
w	Current week
W	Cycle length in weeks
λw	Average arrival rate per week
B_w	Backlog at the beginning of week w
cw	Capacity at week w
A_w	Number of arrivals in week w
ESw	Number of empty patient slots in week w
AT_w	Access time of a patient arriving in week w

Patients arrive independently of each other, and join a single queue at the front of the system. To smoothen the system, patients cannot be scheduled in the same week as they arrive (Kortbeek N. , 2012). This should be no significant problem, due to the stationary nature of this model. The model we use has its focus on the backlog, B_w, at the start of each week. The backlog, representing the waiting list, is defined as the number of patients which requested an appointment, but the appointment making has not yet taken place. Consider week w, where a number of c_w patients are served, and a number of A_w patients arrive. The next Lindley-type equation can be formulated:

$$B_{w+1} = (B_w - c_w) + A_w$$

We say that x represents the number of patients that is removed from the backlog. Where $(x)^+$ = max (x, 0), which means that the number of patients removed from the backlog is at most the available capacity in week w. Now a probability of transitioning matrix from a backlog $B_w = i$ to state $B_w = i'$ is described by:

$$\mathrm{P}(B_{w+1} = i' | B_w = i) = \begin{cases} P\ (A_w = i') & if\ i - c_w \leq 0 \\ P(A_w = i' - i + c_w) & if\ i - c_w > 0 \end{cases}$$

Kortbeek (2012) states that the stationary probabilities of transitioning can be computed recursively, under the one condition that the capacity for patients is larger than the average demand, which is given by: $\sum_w E[A^w] < \sum_w c_w$. For a larger problem, Kortbeek (2012) approximates the stationary vector by determining the eigenvector of a large but finite stochastic matrix with backlog probabilities. With this method the stationary number of patients in the queue is known, and the expected access time can be calculated for new patients. This is our first and main performance indicator, as is discussed in Section 2.3.

The probability of an access time of larger than 0 weeks is 1, for every backlog size. The probability of an access time larger than y, where y > 0, is given by:

$$P\ (AT_w > y | B_w = b) = \begin{cases} 1 & if\ b\ \geq \sum_{i=0}^{y} c_{w+i} \\ \sum_{j=s+1}^{\infty} \frac{(j-s) * P(A_w = j)}{E(A_w)} & if\ else \end{cases}$$

In this formulation *s* represents the number of patients that arrived in week *w* and were planned within *y* weeks. The formula for *s* is as follows:

$$s = \min\left\{\sum_{i=1}^{y} c_{w+i}, \sum_{i=0}^{y} c_{w+i} - b\right\}$$

In words, the conditional probability of an access time of at least *y* weeks is 1 as the backlog *b* is larger than the available capacity up to week *y*. Now if this is not the case, all patients until *s* can be scheduled within *y* weeks and the remainder after *y* weeks. Using this information, the conditional expected access time in week *w* is given by:

$$E(AT_w | B_w = b) = \sum_{y=0}^{\infty} P(AT_w > y | B_w = b)$$

And thus

$$E(AT_w) = \sum_{b=0}^{\infty} (AT_w > y | B_w = b) * P(B_w = b)$$

And now

$$E(AT) = \frac{\sum_{w=1}^{W} E(AT_w) * E(A_w)}{\sum_{w=1}^{W} E(A_w)}$$

Using this last equation we can determine the number of weekly slots needed to meet the norms for new and emergency regarding to their access time.

We will run this model to determine how many slots are needed to accommodate 80% of new patients within three weeks, and 100% of the new patients within four weeks. As for emergency B, we determine the number of slots needed to accommodate 100% of the patients within one week.

4.5 Experiment design

The model is used to determine the number of slots needed to accommodate 80% of the new patients in three weeks, and 100% of the new patients in four weeks. The experiments we perform each describe a different number of dedicated slots per four weeks. In order to design experiments, we first determined the number of slots to be at least the average number of new patients per four weeks. This is necessary, as otherwise the system becomes unstable, and the probability of patients being seen within four weeks decreases to zero. For the IBD this indicated at least twelve slots, and for the general clinic at least 58 slots. An overview of the experiments is shown in Table 16 and 17.

Table 16 - Experiment number of dedicated slots for new IBD patients

Experiment	IBD1	IBD2	IBD3	IBD4	Total
1	4	3	3	3	13
2	4	3	4	3	14
3	4	4	4	3	15
4	4	4	4	4	16
5	5	4	4	4	17
6	5	4	5	4	18

Table 17 - Experiment number of dedicated slots for new general patients

Experiment	ALG1	ALG2	ALG3	ALG4	Total
1	15	14	15	14	58
2	15	15	15	14	59
3	15	15	15	15	60
4	16	15	15	15	61
5	16	15	16	15	62
6	16	16	16	15	63

As mentioned in Section 4.4.2 the model uses a backlog, for which we have to determine the maximum backlog. We performed the first experiment multiple times while increasing the maximum backlog. As the results were not affected by increasing the maximum backlog, we picked this value of the maximum backlog for all experiments per specialty. For the IBD this resulted in a maximum backlog of 40, and for the general clinic a maximum backlog of 120. The experiment results are discussed in Section 6.2.

In order to validate the analytical model, we test the outcomes with historical parameters in a simulation model, which is described in the next chapter.

4.6 Limitations to the analytical model

In order to determine the arrival distribution of the new patients, we used data of 2015. Analysing this data resulted in a Poisson distribution for new IBD patients per week with $\lambda_w = 3.06$. For the general population the arrival distribution was described by a 3-parameter Weibull distribution with $\beta = 6.70$, $\gamma = -15.67$ and $\eta = 32.19$. In order to validate this input, we analysed the data of 2013 and 2014. For the IBD both years showed that the arrival distribution can be described by a Poisson distribution. However for the general population we found that in 2013 a logistic distribution could describe new patient arrival, and in 2014 a normal distribution is identified. This indicates that various years have different arrival distributions, which make it hard to use their distributions in an attempt to predict the future arrival.

In our research we choose to use the arrival distribution of 2015, as this is period is most recent, to describe the arrival distribution in our model. We assume here that the most recent data has the highest probability to describe the new patient arrival.

5 Simulation Model: evaluation of access time

This chapter elaborates on the simulation model of the planning process of new patients. We use this model to evaluate the outcomes of the exact model, the number of dedicated slots for new patients. The experiment results of both models are shown in Section 6.2. We use the step approach as introduced by Law (2007). The steps of this methodology are visualized in Figure 18.

5.1 Goal & Scope

We would like to know how the outpatient clinic would have performed if they reserved the calculated number of slots, as shown in Section 6.2. Therefore the goal of this simulation study is to evaluate the outcomes of the analytical model. We do so by using the historical arrival data of the period January 2015 to December 2015. The population of IBD and general patients are within the scope.

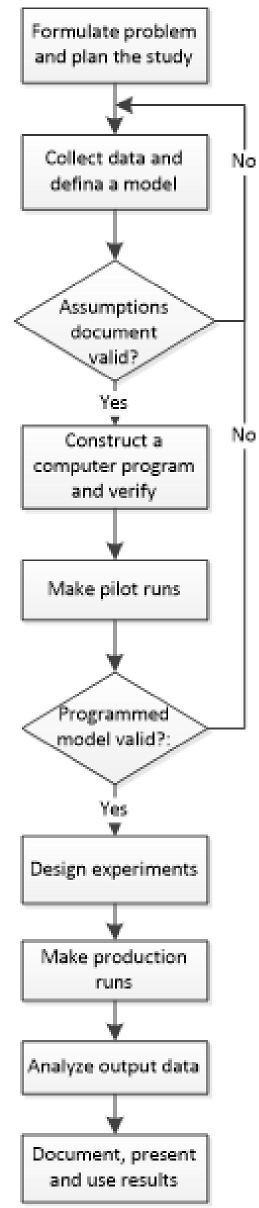

Figure 18 - Simulation study: stepwise approach (Law, 2007)

5.2 Conceptual model

The model concerns a simple queuing model with new patients. A *source* creates the new patients, and uses a table file with the historical arrival of new patients in 2015 per week per specialty. The *agenda* creates the scheme with the available slots for each specialty over the year. *Scheduling* involves planning new patients at an available slot. The *results* section describes the results per patient.

5.3 Assumptions

In de model the following assumptions are used:

- Patients arrive weekly, at Monday 8 AM.
- Junior and senior doctors can perform both types of consultations, therefore we can pool the demand amongst the doctors.
- Scheduling of new patients happens before the arrival of new patients.
- A planning horizon of 10 weeks is used.
- Online operational issues that can influence our solution, such as a late start, late show or no-shows are ignored.
- New patients are scheduled as soon as possible.
- Slots are dedicated to solely new patients.

5.4 Performance measures

To evaluate the performance of the experiments, we use access time of new patients. This is, as described in Section 2.3.3, the time between a request for a consultation and the actual consultation date. The performance indicators are used to validate the model.

5.5 Data collection

Using the model of Law (2003), we get to the collection of data section. We use the relevant factors of Cayirli & Veral (2003) to describe the system that is modelled.

5.5.1 Arrival process

The arrival process is described with the number of new patients arriving per week. Historical data is used in the first part, based on the period of January 2015 till December 2015.

5.5.2 Service times

Service times of the consultations are assumed to be deterministic, and are scheduled in a 15 minute block. This model translates this in one slot.

5.5.3 Capacity in number of slots

We assume 52 production weeks for the data of 2015, with a cyclic number of slots available for new patients. We assume no variations in available capacity in terms of available slots.

5.5.4 Online operation issues

To make sure that some online operational issues do not influence our solution, we briefly describe our assumptions:

- Punctuality: patients and doctors arrive, and start at the expected moment.
- No-shows: we consider a 0% probability of no show for both IBD and general population.
- Walk-ins: no walk-ins are considered during the clinical sessions.

5.5.5 Queue discipline

A first-come-first-serve discipline is used for the scheduling of patients per consultation type. Patients can only be scheduled in the slots that are available for their type of consultation.

5.6 Model description

The model is used to evaluate the results of the analytical model, to gain insight in the timeliness of new patients in 2015 if the calculated number of slots were reserved for new patients. Figure 19 shows the home screen of the simulation model. The upper left consist of methods and a generator to initialize the model, reset the model or to reset variables. The *methods for scheduling process* contain the process of new patient arrival and adding patient characteristics, schedule creation of available slots, and scheduling of new patients. The *settings* contain table files that are used to create the schedule and contain experiments. The *results* selection consists of table files where the results concerning patients and staff are registered. The *variables* selection consists of variables of the simulation.

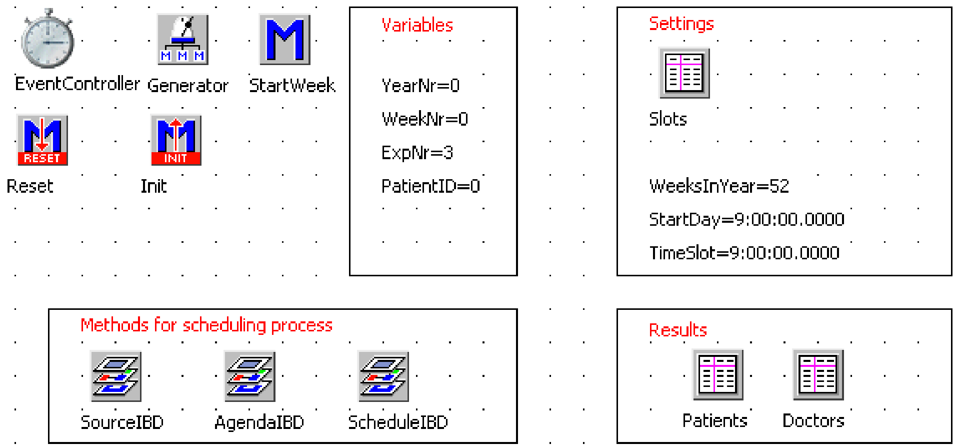

Figure 19 - Home screen simulation model

5.7 Verification

To verify the model we use methods as debugging, reviewing the model, and run the model under a variety of inputs and check if the outputs are reasonable. . Debugging has been performed first, as the model runs without troubles and runs well in small parts. This is done for each method. Reviewing of the model is also performed by interviews with the hospital staff and available process documents. Eventually we run the model with both small and large datasets, and both seem to give a reasonable output and correspond with the expected output.

5.8 Validation

In order to validate the simulation model, we would like to use the parameters as last year in the simulation model. Next we would like to compare the outcomes on the probability of access time within various weeks between the simulation and the realized situation in 2015. Unfortunately, there is no historical data available of the number of new dedicated slots per week for both the IBD and general population. We used *face validity*, which is the degree to which stakeholders view the content of a model and its characteristics relevant to the context (Weiner & Craighead, 2010), to validate the results. We explained the patient arrival, available capacity in terms of slots, assumptions and planning methods. The stakeholders, concerning mostly the secretary, discussed the model to be a realistic representation of the reality. Then again they argue that the simulation will yield somewhat more positive results than in reality, whereas different planning rules are applied. The simulation assumes slots to be dedicated to solely new patients, whereas in the secretary sometimes schedules check-up consultations at dedicated slots for new patients.

5.9 Experiment design

This section describes the characteristics and settings of the simulation experiments. Section 5.9.1 describes the experiment settings. Then Section 5.9.2 elaborates at the warm-up period.

5.9.1 Experiment settings

The experiments we perform are the same as described in Section 4.5. We are interested to know what the access time for new patients is, while reserving the calculated number of dedicated slots. Furthermore we find it interesting to see what happens to the access time in 2015, if we decrease of increase the number of dedicated slots.

5.9.2 Warm-up period

As we are interested to evaluate the access time of new patients, the system first has to be filled with consultations properly. Running the simulation with data of 2015, results in a maximum access time of five weeks. The warm-up period should rather be too high, than too low (Law, 2007). We therefore pick a larger period, thus an eight week warm-up period. To implement this, we add the last eight weeks of new patient arrival of 2014 to the sample. This added data will afterwards be subtracted.

5.10 Limitations to the simulation model

As the model is a simplistic queuing model, we are only able to evaluate the access time and compare this to the probability of access time calculated with the analytical model. No other insights can be retrieved from this simulation. Furthermore the arrival of new patients is based on the date of processing an application by the secretary. As this is not always equal to the actual date of request by a patient, this delay is not taken into account for the actual arrival of new patients.

5.11 Conclusions

The following conclusions follow from this chapter:

6.1 How can we model the process of the clinic?

A simulation model was used to describe the process, and was created in Siemens Plant Simulation 11. Scheduling of patients happens first in the week, and patients arrive weekly at 8 AM. Patients are scheduled first-come-first-serve. New patients gain patient characteristics, and are scheduled as soon as possible within the planning horizon of ten weeks.

6.2 Is the model validated and verified by stakeholders?

A *face validity* method is used to validate the model. The stakeholders agree with the functioning of the model, as it gives a realistic view of the scheduling process. Also the model inputs are checked upon and validated by the stakeholders.

6.3 What experiment settings do we use?

The same experiments as described in Section 4.5 are performed. This way the historical arrival data can be tested, and the outcomes of the analytical model can be validated with this simulation.

6 Simulation Model: use of a care pathway

This chapter elaborates on the simulation model of the planning process. We use this simulation to evaluate the effect of introducing a care pathway that describes the frequency and time-interval of check-up consultations. Again the step approach as introduced by Law (2007) is used, see Figure 17.

6.1 Goal & Scope

Our research problem lies at the tactical level of the resource capacity planning hierarchy. The goal of this simulation study is to test if we can solve the timeliness problem for check-up consultations, by introducing a care pathway that describes the time-interval. Within the scope we create a block planning for new patients, and the remainder for check-up consultations of the IBD and general population. An arrival distribution of new patients is used, based on historical data. At last, as Section 2.3.3 discusses, emergency patients are not taken into account in the simulation, as data was not available.

6.2 Conceptual model

The simulation model concerns a simple queuing model with new and check-up consultations. A *source* creates the new patients, and uses a table file in which the arrival distribution of new patients is given per specialty. The *agenda* creates the scheme with available slots, based on the tactical scheme as shown in Appendix D. *Scheduling* involves planning new and check-up consultations at an available slot. The *results* section describes the results per patient and staff. An addition to the model concerns check-up consultations, based on the follow-up for each patient.

6.3 Assumptions

In the model we use the following assumptions:

- Patients arrive weekly, at Monday 8 AM.
- Junior and senior doctors can perform both types of consultations, therefore we can pool the demand amongst the doctors.
- Slots are dedicated to either *new* or *check-up* consultations, this does not change over time.
- Scheduling of new patients happens before the arrival of new patients.
- A planning horizon of 10 weeks is used.
- Online operational issues that can influence our solution, such as a late start, late show or no-shows are ignored.
- New consultations are scheduled as soon as possible. Check-up consultations are scheduled in the requested time-interval, or later.

6.4 Performance measures

To determine the performance of the experiments in the model, we use access time, consultations within the desired time-interval and utilization of staff. These are measured the same as described in Section 2.3.3. The performance indicators are used to validate the model.

6.5 Data collection

Using the model of Law (2003), we get to the collection of data section. We use the relevant factors of Cayirli & Veral (2003) to describe the system that is modelled.

6.5.1 Arrival process

The arrival process is described with the number of new patients arriving per week. We use an arrival distribution, based on the historical data of the period of January 2015 to December 2015. For the IBD population this concerns a Poisson distribution with λ_w = 3.23, so approximately 3 new IBD patients per week. The arrival of new general patients can be described by a 3-Parameter Weibull distribution, with a mean of 14.14 per week. The method to determine the arrival distribution is shown in Appendix J.

Check-up consultations arise from new consultations. The frequency of the check-up consultations per patient and its desired time-interval is determined by the care pathway. This care pathway is the experimental factor in the simulation study. Section 5.9 elaborates further at this aspect.

6.5.2 Service times

For the IBD and general population the same service times are applied. For new patients two subsequent slots of 15 minutes are needed, and for check-up consultations one slot of 15 minutes is sufficient. These times are assumed to be deterministic, as 1 slot indicates 15 minutes.

6.5.3 Number of services and doctors

The model consists out of a waiting list and servers (doctors), which are used to schedule patients in the planning. The agenda with available slots is based on the number of doctors and clinical sessions per specialty as is shown in Appendix D.

6.5.4 Staff capacity in number of slots

This factor is described by the number of production weeks, clinical sessions per week and the number of slots per clinical sessions.

Production weeks

We use 52 production weeks per year, with a cyclic number of dedicated slots for new patients. The number of clinical sessions is based on the tactical scheme of 2016, see Appendix D. This results in 6 clinical sessions per week for the IBD population, and 4 sessions per week for the general population.

As Section 2.3.3 shows, both the IBD and general clinical sessions where blocked often. These blockages were moreover during the spring, summer vacation, autumn, and Christmas. We use these seasonal blockages to reduce the number of available clinical sessions, to gain a more realistic view of the expected available capacity. For the general population this resulted in approximately 14% blockages and approximately 13% for the IBD clinical sessions.

Number of slots per clinical session

Clinic sessions are either from 09:00 to 12:15 or 13:30 to 16:30. The number of slots per clinic session is therefore 13 in the morning and 12 in the afternoon. The slots are assumed to be dedicated to either new or check-up patients.

Online operational issues

To make sure that some online operational issues do not influence our solution, we briefly describe our assumptions:

- Punctuality: patients and doctors arrive, and start at the expected moment.
- No-shows: we consider a 0% probability of no show for both IBD and general population.
- Walk-ins: no walk-ins are considered during the clinical sessions.

Queue discipline

A first-come-first-serve discipline is used for the scheduling of patients per consultation type. Patients can only be scheduled in the slots that are available for their type of consultation.

6.6 Model description

The simulation model is used to evaluate the results of the analytical model, and experiment with various frequencies and desired time-intervals for check-up consultations, to gain insight in their usefulness concerning timeliness and staff utilization. Figure 20 shows the home screen of the simulation model. The upper left consist of methods and a generator to initialize the model, reset the model or to reset variables. The *methods for scheduling process* contain the process of new patient arrival and adding patient characteristics, schedule creation of staff availability, and scheduling of both new and check-up patients. The *settings* contain table files that are used to create the schedule and contain experiments. The *results* selection consists of table files where the results concerning patients and staff are registered. The *variables* selection consists of variables of the simulation.

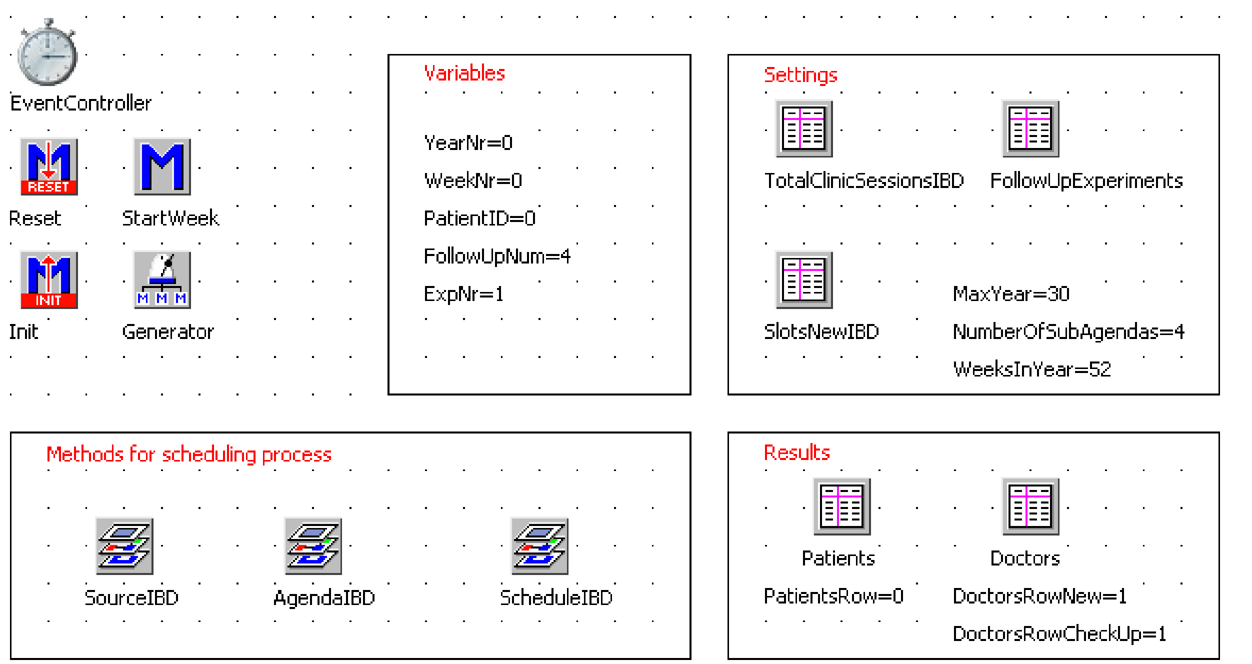

Figure 20 - Home screen simulation model

6.7 Verification

To verify the model we use methods as debugging, reviewing the model, and run the model under a variety of inputs and check if the outputs are reasonable. . Debugging has been performed first, as the model runs without troubles and runs well in small parts. This is done for each method. Reviewing of the model is also performed by interviews with the hospital staff and available process documents. Eventually we run the model with both small and large datasets, and both seem to give a reasonable output and correspond with the expected output.

6.8 Validation

In order to validate the simulation model, we would like to use the parameters as last year in the simulation model. Next we would like to compare the outcomes on the probability of access time within various weeks between the simulation and the realized situation in 2015. Unfortunately, there is no historical data available of the number of dedicated slots for either new or check-up consultations. Furthermore it is not possible to abstract the arrival of check-up consultation, in other words the desired follow-up after a consultation. Therefore the results cannot be compared.

Similar to the simulation discussed in Chapter 5, we used *face validity* to validate the model. We illustrated the patient arrival, which is either based on an arrival distribution or care pathway that describes the frequency and time-interval for check-up consultations. Furthermore the available capacity, planning horizon and queue discipline are discussed, together with our assumptions. Stakeholders confirmed that this model should be a realistic representation of the reality. However the inputs might not be realistic, as with the available data it is not possible to determine the desired moment and frequency per patient. This results into a difficult implementation, and makes it difficult to impossible to use the outcomes for decision making. The model can therefore only be interpreted as a small glimpse of the effect of using a care pathway that describes the time-interval.

6.9 Experiment design

This section describes the characteristics and settings of the simulation experiments. Section 6.9.1 describes the experiments settings. Then Section 6.9.2 briefly describes the use of common random number. Section 6.9.3 elaborates at the warm-up period, and eventually Section 6.9.4 gives the number of replications for each experiment.

6.9.1 Experiment settings

The simulation is used to experiment with the effect of a care pathway that described the desired time-interval of check-up consultations. The experiments for the IBD and general are slightly different in nature. For the IBD population we will experiment with various probabilities of a desired time-interval for the check-up consultations, where the probability of a patient exiting the system is the most important parameter. For the general population we will not experiment with the probability of a time-interval. Here we experiment with the probability of a certain frequency of check-up consultations after the new consultation. The desired time-interval is now fixed, indicating that the first check-up consultation has a desired time-interval of four weeks, and the other consultations are fixed at three at a three month desired time-interval.

We discussed the experiments with the stakeholders to construct the experiments. For the IBD the doctors were interested in the effect of increasing the probability of a patient exiting the system. This resulted in three experiments, as can be seen in table 18. For the general population the stakeholders were interested in the effect of increasing the probability of having one or two consultations versus three or even four consultations. The resulted in three experiments, which can be seen in table 19.

Table 18 –Experiments with the probability on a predetermined desired time-interval, or exit after a consultation.

Experiment	*P (12 months)*	*P (6 months)*	*P (2 months)*	*P (Exit)*
1	47%	30%	20%	3%
2	45%	30%	20%	5%
3	40%	30%	20%	10%

Table 19 - Experiments with the probability on a predetermined number of check-up consultations for the general population.

Experiment	*P (1 check-up)*	*P (2 check-up)*	*P (3 check-up)*	*P (4 check-up)*
1	65%	20%	10%	5%
2	80%	20%	0%	0%
3	100%	0%	0%	0%

6.9.2 Common random numbers

In order to reduce variation in our results between experiments, we introduce the use of common random numbers. By using common random numbers, the arrival pattern is the same for each experiment. This leads to more accurate results and a narrower confidence-interval.

6.9.3 Warm-up period

We introduce two different warm-up periods, as we run the simulation separate for the IBD and general. For IBD and general population we picked the experiment with the longest expected follow-up, and possibility for steady state utilization. The Welch method has been used, as can be seen in Appendix L. For the general clinic this resulted in 30 weeks, and for IBD 545 weeks.

6.9.4 Number of replications

The run length depends on the warm-up period. We would like to find a balance between accurate results, and not too long experiment time. As the run length should exceed the warm-up period, we pick a run length of five years for the general clinic an 30 years for the IBD clinic. The number of replications is chosen corresponding to a confidence interval of $\alpha = 0.05$ of the average staff utilization, and a relative error allowed of $\gamma = 0.10$.

It is our aim to find a sufficient number of replications per experiment. We deleted 82 weeks of warm-up of the general scheduling data, and 545 weeks of the IBD scheduling data. Next we calculated the mean of the staff utilization by taking the average of each replication. The number of replications is chosen if the relative error gets beneath 0.10. The next formula is used:

$$n^{*} = \min\{i \geq n; \frac{t_{i-1,1-\frac{\alpha}{2}}}{|\bar{X}_n|} \leq \frac{\gamma}{1+\gamma}\}$$

The corrected target value is at the right side of the function. Tables 20 and 21 show the calculation of the replications. We determine the number of replications to be i if the n* becomes smaller than γ' for the first time. For the IBD population this is the case when i = 4, so the number of replications is four. For the general population this is when i = 2, so the number of replications is two.

Table 20 - Calculation of the number of replications (Specialty = IBD)

Mean	Cum. mean	Variation	i	T-INV		n*	<y'
0,59	0.59	-	1	-	-	-	-
0,58	0,59	0,00	2	12,71	0,10	0,18	No
0,56	0,58	0,00	3	4,30	0,04	0,08	No
0,57	0,57	0,00	4	3,18	0,02	0,04	Yes

Table 21- Calculation of the number of replications (Specialty = general).

Mean	Cum. mean	Variation	i	T-INV		n*	<y'
0,99	0.99	-	1	-	-	-	-
0,99	0,99	0,00	2	12,71	0,04	0,04	Yes

Together our calculations result for the general clinic to perform two replications per experiment, with a run length of five years and a warm-up period of 30 weeks. For the IBD clinic we perform four replications per experiment, with a run length of thirty years and a warm-up period of 545 weeks. The experiment results are shown in Section 6.2.

6.10 Limitations to the simulation model

The assumptions and inputs in our simulation form the greatest limits. We discuss that consultations can be performed by all type of doctors, which lead to pooling the available staff time per specialty. In practice however, for the IBD, staff doctors are dedicated to annual consultations and junior doctors the remainder of consultations. Our assumptions therefore lead to better staff utilisation. Next we ignore a late start, late show or no-shows, which results in higher staff utilisation. Also emergency patients are not taken into account, as this data was not available. In practice this group requires consultation time, and therefore this could increase access time for other consultation types.

Furthermore, as mentioned in Section 6.8, the inputs of the model are based on the experiments that describe a certain care pathway. This care pathway describes the probability of a certain desired time-interval for a patient returning, or their frequency of return. As historical data was not sufficient to gain insight into a realistic follow-up, we cannot say that these experiments are in agreement with the reality. The experiments therefore can only be used to show a superficial view of the effect of steering on a patient exiting the system.

6.11 Conclusions

The following conclusions follow from this chapter:

6.1 How can we model the process of the clinic?

A simulation model was used to describe the process, and was created in Siemens Plant Simulation 11. Scheduling of patients happens first in the week, and patients arrive weekly at 8 AM. Patients are scheduled first-come-first-serve. New patients gain patient characteristics, and are scheduled as soon as possible within the planning horizon of ten weeks. After the new consultations, patients gain follow-up characteristics which describe the desired time-interval for a check-up consultation.

6.2 Is the model validated and verified by stakeholders?

A *face validity* method is used to validate the model. The stakeholders agree with the functioning of the model, as it gives a realistic view of the scheduling process. The inputs of the model are however not validated with historical data. Therefore we have to be cautious to draw conclusions by analysing the results per experiment.

6.3 What experiment settings do we use?

We use common random number to create even conditions for the arrival of new patients for each experiment. Additionally, we need a warm-up period of 30 weeks for the general population, and 545 weeks warm-up for the IBD population to get valid results. The experiment results are discussed in Section 7.2.

7 Results

In this chapter, we perform a quantitative analysis of the models we discussed in Chapter 4, 5 and 6. In Section 7.1 we describe the indicators that measure the performance. Section 7.2 presents the performance of our experiments of the models. Section 7.3 summarizes the results.

7.1 Performance indicators

We describe the performance measures and indicators to gain insight into our solution approach. The performance measures are:

- New patient access time
- Deviation of check-up consultations of desired moment
- Utilisation of staff.

Access time is measured as the probability of receiving care within a certain number of weeks for new patients. The analytical model uses this performance indicator to evaluate various numbers of cyclic dedicated slots for new patients, such that the 'Treeknorm' can be met. This performance indicator is used with the first simulation model, to check if this number of slots is sufficient to achieve the 'Treeknorm', while using historical arrival of new patients. The deviation of check-up consultations from the desired moment is given in a percentage. This percentage describes the deviation of the actual consultation week against the desired consultation week. Furthermore the utilization of staff is calculated as the available number of slots per week divided by the number of slots per week that are occupied by a consultation.

7.2 Experimental results

In this section we describe the performance indicator results for each model, with different experiments. The experiment settings can be found in Appendix J. We discuss each used model and its outcomes separate and eventual summarize the results in Section 7.3.

7.2.1 Analytical Model: Number of dedicated slots for new patient

We run the queuing model as described in Section 4.4 in MATLAB to determine the influence of the number of dedicated new patient slots on the probability on the access time.

IBD population

The weekly arrival of new IBD patients in 2015 is Poisson distributed, as is discussed in more detail in Appendix J, and can be described by $\lambda_w = 3.23$. As our system should be stable, the condition was added to the model that the cycle capacity is at least equal or larger than the average demand. With a cycle length of four weeks, this indicates that the minimum number of dedicated slots should be 13. The results are shown in Table 22.

Table 22 - Effect of varying number of dedicated slots for new IBD patients on probability of access time

Number of slots	< 1 week	< 2 weeks	< 3 weeks	< 4 weeks
13	28%	55%	72%	82%
14	50%	82%	94%	98%

15	65%	93%	99%	100%
16	76%	98%	100%	100%
17	83%	99%	100%	100%
18	88%	100%	100%	100%

Analyzing the data, we observe that the 'Treeknorm' of 80% within three weeks and 100% within four weeks is nearly met when reserving fourteen slots for new IBD patients. Adding one extra slot increases the probability of receiving a new patient within four weeks and less. Then again the marginal benefit of adding one extra slot is decreasing for receiving care within a certain number of weeks. So in terms of costs and in consultation with the stakeholders, we decided fifteen slots is a desired number of dedicated slots. This option is less expensive than reserving more dedicated slots, and nearly meets the norm.

General population

The weekly arrival of new general patients in 2015 is 3-parameter Weibull distributed and has a mean of 14.41. Again stability is required, so the minimum number of dedicated slots is at least 58. The results are shown below in table 23.

Table 23 - Effect of varying number of dedicated slots for new general patients on probability of access time

Number of slots	< 1 week	< 2 weeks	< 3 weeks	< 4 weeks
58	54%	89%	97%	99%
59	62%	94%	99%	100%
60	68%	96%	100%	100%
61	73%	98%	100%	100%
62	78%	99%	100%	100%
63	81%	99%	100%	100%

Analysing this data, we observe that the 'Treeknorm' is met when reserving 59 dedicated slots for new general patients. Adding more slots, slightly increase the probability of receiving a patient within one or two week. The marginal benefit of adding slots is low, and even zero for receiving patients within three or four weeks from 60 dedicated slots. We discussed the results with the stakeholders, while considering costs and access time. We concluded that 59 dedicated slots for new patients are most desirable, as it nearly meets the norm.

7.2.2 Simulation Model: Number of dedicated slots for new patient

We run the mode as described in Chapter 5. This model is used to validate the outcomes of the exact model, by using historical data. The arrival of new patients at the outpatient clinic of Gastroenterology is based on the period of January 2015 to December 2015. We run the model with a various number of cyclic dedicated slots, to gain insight into the actual access time for new patients. The results are shown in Table 24 and 25.

Table 24 – Effect of number of dedicated slots for new IBD patients on actual access time in 2015

Number of slots	< 1 week	< 2 weeks	< 3 weeks	< 4 weeks	< 5 weeks	< 6 weeks	< 7 weeks	More
13	36%	70%	78%	82%	89%	99%	100%	100%
14	43%	72%	77%	84%	99%	100%	100%	100%
15	49%	71%	79%	97%	100%	100%	100%	100%
16	56%	71%	88%	100%	100%	100%	100%	100%
17	58%	75%	98%	100%	100%	100%	100%	100%
18	62%	87%	100%	100%	100%	100%	100%	100%

Table 25 – Effect of number of dedicated slots for new general patients on actual access time in 2015

Number of slots	< 1 week	< 2 weeks	< 3 weeks	< 4 weeks	< 5 weeks	< 6 weeks	< 7 weeks	More
58	21%	75%	91%	99%	100%	100%	100%	100%
59	32%	84%	96%	100%	100%	100%	100%	100%
60	45%	88%	98%	100%	100%	100%	100%	100%
61	53%	90%	99%	100%	100%	100%	100%	100%
62	59%	91%	100%	100%	100%	100%	100%	100%
63	62%	93%	100%	100%	100%	100%	100%	100%

The results show for IBD that 16 slots should have been sufficient in 2015, to meet the 'Treeknorm'. This is one dedicated slots more than determined in the section before. For the general population we observe that 59 slots should have been nearly being enough in 2015. This number of dedicated slots is in line with the analytical calculated number of slots.

7.2.3 Simulation model: effect of introducing a care pathway

We run the model as described in Chapter 6. The model is used to evaluate the effect of using a care pathway, with follow-ups per patient. The performance indicators concern the deviation of check-up consultations of desired moment and the utilisation of staff.

IBD population

For the IBD population we are interested in a care pathway that steers towards an exit for patients. Per experiment we increased the probability of a patient exiting the system per experiment, as can be seen in Section 7.9.1. Table 26 shows an overview of the percentage of the consultations in time, and the average utilization for each experiment.

Table 26 - Overview of the IBD experiment performance

Experiment	Main characteristic	Realisation		Avg. deviation	Avg. Utilisation
1	P(Exit) = 3%	73% on time	27% too late	40%	92%
2	P(Exit) = 5%	92% on time	8% too late	1%	82%
3	P(Exit) = 10%	99% on time	1% too late	0%	53%

Analysing the data, we observe that the percentage of check-up consultations that are in time increases as the probability of a patient exiting the system increases. The third experiment, which introduces a 10% probability of a patient exiting the system after a consultation, even realizes a 99% probability that check-up consultations are in time. However the average utilization is decreasing for an increasing experiment number.

In consultation with the stakeholders, we expect the first experiment to be in line with the actual probability of an IBD patient exiting the clinic. Therefore we plotted the average deviation from the desired moment versus the average utilization for the first experiment. The outcome is shown in figure 21. We observe that as the utilization reaches a steady-state moment, the deviation from the desired moment increases drastically. This is not the case in the second and third experiment.

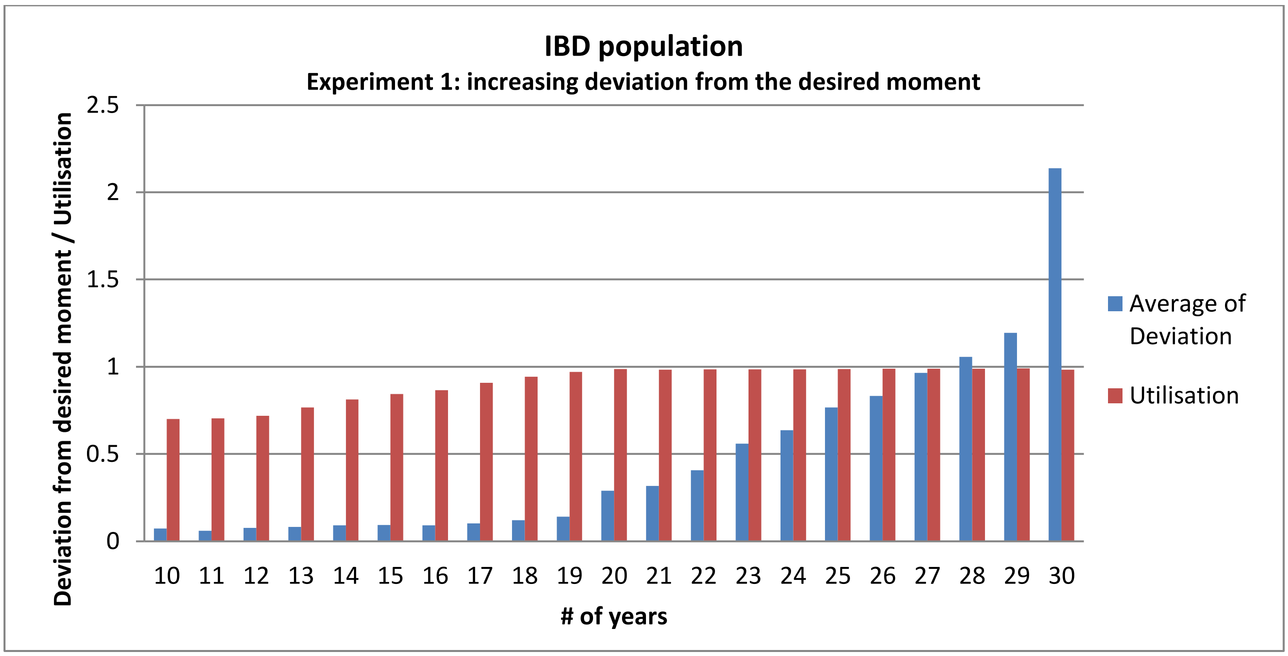

Figure 21 – Steady-state utilization in the first experiment shows an increase of deviation from the desired moment

General population

For the general population we would like to gain insight into the effect of using a care pathway that describes the frequency and desired time-interval of check-up consultations. This care pathway can either include one, two, three or four check-up consultations, with a fixed time-interval. Table 27 shows the percentage of consultations in time, and average utilisation per experiment.

Table 27 - Overview of the general experiment results

Experiment	Desired moment	Realisation		Avg. Deviation	Avg. Utilisation
1	Either 1 or 3 months	23% on time	77% too late	270%	99%
2	Either 1 or 3 months	23% on time	77% too late	63%	98%
3	Either 1 or 3 months	64% on time	36% too late	11%	93%

We obtain several insights when we inspect the results. A high deviation from the desired moment is observed in the experiments, and only seem to decrease when only one check-up consultation is introduced. For all experiments a high average utilisation is observed, indicating that the system is nearly completely filled with consultations. As a result, it seems that reserving enough slots for the new patients shows that the current staff capacity is not sufficient for the check-up consultations.

7.3 Summary

In this chapter we performed the experiments described in Chapter 4, 5 and 6, and presented the performance of the models for the various experiments.

We ran the analytical model to determine the number of slots needed to meet the 'Treeknorm' for the IBD and general population. We find that in a cycle of four weeks, the norm was met for the IBD population with 15 dedicated slots. For the general population this resulted in 59 slots. To evaluate this outcome, we simulated the process as discussed in Chapter 5. Here we checked if the calculated number of slots should have been sufficient in 2015 to meet the norm, as the historical arrival per week in 2015 was used. The performance indicator was the probability of access time within a certain number of weeks. The simulation showed that if we wanted to meet the norm in 2015 for IBD, we needed 16 slots per four weeks. For the general clinic 59 slots should have been sufficient to meet the norm.

The results show that the analytical model is validated with the simulation, which introduces fluctuations in demand. The arrival distribution of the analytical model is therefore a good estimator for the arrival of new patients, and the calculated number of slots should therefore be sufficient to meet the norm.

In the simulation model, as described in Chapter 6, we were interested in the use of a care pathway that describes the frequency and desired time-interval for check-up consultations. As no historical data was available to make an estimation of a realistic care pathway, we cannot validate the results. Still, in order to carefully take a look in the use of a care pathway, we experiment with various care pathways. The available capacity is determined as the number of slots per week per specialty, reduced by blockages. The arrival of new patients is described by a distribution based on historical data of 2015. As the 'Treeknorm' should be met, the earlier calculated number of slots is reserved for new patients. The remainder is available for check-up consultations. The experiments with the general population showed that, as the new patients are seen in time, the check-up consultations will often be too late with the current available capacity. Even with only one check-up consultation, still 36% of the check-up consultations will deviate from the desired moment. A balance between the handling of new patients and the deviation of the desired moment is therefore to be made by the management.

8 Conclusion

In this chapter we will present the conclusions (8.1), discussion (8.2) and recommendations (8.3) based on our research and experiment results, and future researches (8.4).

8.1 Conclusions

The aim of our research is to identify how the planning of the outpatient clinic of Gastroenterology can be organized effective. We formulated the next research objective:

"Develop a method on a tactical level that helps to deliver care within the desired time-interval for various consultation types within the outpatient clinic of Gastroenterology."

We will repeat each sub-question and our findings, and the corresponding conclusions are described at the remainder of this section.

What are the current structures and processes of the outpatient clinic of Gastroenterology concerning planning and what is their current performance?

We analysed the IBD and general patient group of the outpatient clinic. Our findings showed that the current planning method only distinguished *new* and *check-up*, whereas in reality *emergency* and *periodic* are also present. As the schedule has no time reservations for these various consultation types, and an infinite planning horizon is used, the schedule is fully booked with long term periodic consultations. The data shows that the access time norm, the 'Treeknorm', is not being met for new patients of both the IBD and general population. Also recurring patients are often not received at the desired moment. The staff utilization is almost at its maximum, but fluctuations in available capacity are observed frequent due to blockages.

What concepts are mentioned in the literature to organize effective planning for the outpatient clinic at a tactical level?

The literature mentions various methods to solve the access time problem, but Kortbeek (2012) introduces an interesting method. They used an approach that involved an analytical queuing model, which determines the capacity needed to receive patients within a certain number of weeks. As we find this method appropriate to solve our problem, we use this type of model to determine the number of slots needed to meet the 'Treeknorm' for new patients. In order to evaluate the outcomes with fluctuating demand, we find in the literature that queuing simulation is appropriate (Elkhuizen, et al., 2007). In order to solve the timeliness problem for recurring patients, we find a study in the literature that uses a care pathway for the reservation of slots (Zonderland et al., 2012). This care pathway describes the time-interval for recurring patients. We introduce a similar approach, a model which can experiment with various care pathways, such that an insight can be obtained in the use of such a care pathway and with steering patients towards exiting the system.

How can the process be modelled and what intervention can be used to increase the probability of receiving new patients in time?

The arrival of new patients can be modelled with a simple analytical queuing model. We are interested to know how many slots are required to meet the ‘Treeknorm’. In order to do so, new patients should have an 80% probability to receive care within three weeks, and an 100% probability to receive care within four weeks. The model shows that, on a four week cyclic basis, the norm is achieved when reserving 15 slots for the IBD population and 59 slots for the general population.

How can the process be modelled and how does the solution perform with historical data?

In order to validate the results of the analytical model, we construct a simple queue simulation model to deal with fluctuations in demand. The use of a historical arrival distribution shows that in reality the ‘Treeknorm’ would have been met for IBD when reserving 16 slots, and for general 59 slots.

How can the process be modelled and what interventions can be used to increase the performance of the outpatient clinic of Gastroenterology?

In order to improve the timeliness of returning patients, we model a queuing simulation. Although no data of the desired moment for recurring patients is available, we are interested to gain insight into the effect of using a care pathway. The model shows that increasing the probability of an IBD patient to exit the system, results in more timely care and lower staff utilization. For the general population we observed that introducing only one check-up consultation after the first consultation, results in 64% of the check-up patients to be in time, with an average utilization of 93%.

What is the impact of the interventions on the performance at the outpatient clinic of Gastroenterology?

We conclude that in order to deliver care within the desired time-interval for consultation types, a block planning can support this goal. By using the method of Kortbeek (2012) the access time for new patients can be reduced, such that the ‘Treeknorm’ can be achieved.

For the recurring patients we introduced a method that experiments with various care pathways, which describes the frequency and time-interval. The results showed that using a care pathway to steer towards an exit increases the probability of receiving patients in time.

In this research a substantial part of the required data was not available. In order to organize the planning process effective, such that all consultation types receive care in time, the registration has to be sufficient. The consultation types *emergency*, *check-up* and *periodic* need to be distinguished and their time-interval needs to be registered. As this is performed correct, the performance measures can be monitored and steered upon. Norms for all consultation types can be formulated and introduced. Reserving time-blocks for the various consultation types can then be an effective method to organize care such that patients can be received in time. For the new patients this indicates 15 dedicated slots for the IBD clinic and 59 dedicated slots for the general clinic. As reserving too much capacity for a certain type of consultation results in too low staff utilization, a balance between timeliness and staff utilization has to be made.

8.2 Discussion

The objective of our research is to "*Develop a method on a tactical level that helps to deliver care within the desired time-interval for various consultation types within the outpatient clinic of Gastroenterology*". Based on our context analysis in Chapter 2, we identified the next core causes of poor performance:

- Lack of registration of desired time-interval for check-up consultations
- Lack of registration of emergency consultations
- Too little time reserved for new patients
- No care pathway is developed
- No reservation of consultation type dedicated time-blocks
- Too long planning horizon
- Lack of capacity balancing

This research has showed that good registration is essential in order to improve timeliness of care delivery. By performing a context analysis, we observed that the desired time-interval for check-up consultations was not proper registered. As a result, we discovered that check-up consultations should be divided into check-up consultations and periodic consultations. A periodic consultation is desired at a later moment, and therefore has a lower medical urgency. By good registration, this bisection can be made, and by prioritizing more short-term consultations can prevail.

Another observation was the lack of emergency consultations registrations. As the clinic would like to increase the access time for this group, it is first necessary to register the desired access time and the realization. Not only the size of the problem, but also the arrival process of emergency patients can then be used to determine the number of slots needed to meet the norm for this type of patients.

For both the IBD and general population we observed that the number of slots for new consultations was not sufficient to meet the 'Treeknorm'. By using an arrival distribution, based on historical data, the number of needed slots for this group was calculated. The result is that the remainder of capacity is used for check-up consultations. As the simulation shows, adding only one check-up consultation with a desired time-interval of three months, results in only 63% of the check-up consultations to be in time and a high utilization. In order to deal with more check-up consultations per new patient, while still reaching the 'Treeknorm' for access time, more capacity is needed.

As in the current situation no care pathway is used, the simulation showed the effect of a care pathway with various probabilities on return. The first experiment illustrates the current situation, a low probability of a patient exiting the system, and shows that the system becomes fully utilized and check-up consultations are deviating much from the desired moment. In order to prevent this from happing, the simulation showed that a small increase of the probability of a patient exiting the system, can increase timeliness and still maintain an 82% utilization of the staff. Suggestions are a more effective supervision and developing a patient specific care pathway, such that changes in the plan are visible and acted upon.

Furthermore a discussion point is the long planning horizon, whereby the schedule gets filled with long-term or periodic consultations. A part of the solution is to use dedicated time-blocks, such as the dedicated capacity for new patients. But a shorter planning horizon has as advantage that more short-term check-up consultations can be planned before the schedule is filled with long-term consultations.

The context analysis also showed that blockages are frequently present in the IBD and general clinic planning. As doctors are simultaneously not available, appointments get cancelled or rescheduled. As a result consultations are performed later than the desired moment, or doctors will perform overwork activities such that more urgent consultations can still take place.

A last remark is intended to our model assumptions. As discussed in Section 4.6, the arrival distribution for the general clinic cannot be determined unambiguously. The effect is that the used arrival distribution might not be valid to describe that future arrival of new general patients. The clinic therefore should investigate what determines the patient arrival, and determine how to make this more predictable.

8.3 Recommendations

In this section we describe general recommendations, implement recommendations and suggestions for future research.

8.3.1 Data registration

Currently it is barely or not possible to determine the performance, as there is a lack of measurement of various data types. Performance indicators such as utilization, start time, end time, overtime, consultation duration, access time and deviation from desired moment are insufficiently measured. We recommend management to decide on a set of performance indicators that are essential to the clinic performance. Additionally, poor data registration makes it difficult to measure the indicators. An example is the availability of a desired period and end date, but this option is in practice not used. We recommend that using such options is more mandatory in the scheduling process.

8.3.2 Staff capacity

A few recommendations come to mind as utilization of staff capacity is important. In the current situation, the staff capacity is sufficient to meet the formulated access time norm for new patients. For the general clinic reserving the number of dedicated slots for new patients, creates a bottleneck for the follow-up as the remainder of minutes is not sufficient for check-up consultations. The management needs to decide whether to increase capacity, minimize the number of check-up consultations or decrease the inflow of new patients. The latter can be performed by becoming more flexible in the norm for access time, so accepting a lower probability of receiving care within four weeks.

Furthermore we observed in the context analysis that simultaneous blockages of staff availabilities lead to cancellations, and overwork at a later moment. This results in overbooking and a decrease of timeliness. A method to solve a part of this problem is to divide the absence of doctors over the year. This way bulking of consultations can be prevented.

8.3.3 Care pathway

A care pathway can help to steer on an exit. Thereby if a patient is interfered with the construction of their continuation, it is most likely that only meaningful consultations will take place. As a new patient enters, the doctor can create a care pathway with the first consult. Here the expected number of consultations, their urgency and desired time-interval can be registered. As a result the secretary and clinic will get a better insight of what consultations to expect, and what staff capacity to reserve for upcoming consultations. Eventually a patient can exit the system as expected. As more consultations are requested, induced by the doctor or patient, this deviation from the care pathway can be registered and acted upon. This way a better flow of consultations can take place at the outpatient clinic of Gastroenterology.

8.3.4 New patient arrival

The new patient arrival is not the same each year. Although the new patient IBD arrival can be described by a Poisson distribution, the average arrival per week (λ) still varies. In order to use a block planning, the clinic should correct the number of dedicated slots on the predicted λ. It might be possible to assume that the λ increases each year with a certain percentage, but the clinic should investigate such a trend. For the general this is even more important, as not only the average differs between the years, but so does the arrival distributions themselves. The clinic should investigate by what factors their general new patient arrival is influenced, and how they can predict their new patient arrival in the distribution.

8.3.5 Implement recommendations

To implement the outcomes of our research, the outpatient clinic of Gastroenterology has to start at the beginning. In order to improve their processes, the clinic has to determine what describes their performance, and how this can be measured in terms of performance indicators. Registration and its processes should therefore be adapted, such that the performance indicators can be measured and monitored accurately. Done effective, the current performance can be described by analysing the data. Then the performance can be compared with a desired performance, and might shows which processes do not perform as desired. Norms can be constructed for the PI's, and then method to achieve these.

In context of this research, we determined the performance indicators to be the access time, deviation from the desired moment and staff utilization. We showed that access time is not at a desired level and staff utilization almost at its maximum. It was not possible to gain a complete insight into the recurring patient's appointment deviation from the desired moment. We advise that for an effective registration, the scheduling process should expand the consultation types with *emergency* and *periodic*, next to *new* and *check-up*. Together with the individual consultation desired moment, the secretary can prioritize and registration is becomes complete. However as this was not the case, the current performance could not be compared with the performance of some intervention.

For the new patients we discusses that the 'Treeknorm' should be met. We showed that on a four week cycle, we expect the norm to be met while reserving 15 dedicated new IBD slots and 59 new general slots. Such a blocking strategy can also be implemented for other consultation types, if their arrival pattern and desired moment are well registered. Using such a strategy, the clinic should take into account in what extent the dedicated time blocks cause under-utilization of the staff. Planning rules can therefore be investigated, such as how soon a dedicated time-block is released for other consultation types. Furthermore, in advance on how to increase timeliness of recurring patients, a care pathway that describes the frequency and time-interval of check-up and periodic consultations can be used. Such a care pathway can steer towards an exit, and therefore help to decrease the number of consultations. This results in a remainder of capacity, which can be used to improve timeliness of the follow-up.

Implementation difficulties

A few aspects are expected to be difficult in the implementation of such a plan:

- Available data: as performance indicators concern historical data, which was back then not measured, it is not possible to retrieve such information. The clinic can than choose other PI's, or adapt their processes and obtain the desired data over time.
- Change of processes for the secretary and/or doctors: employees of the clinic often perform their work for many years. It might not be easy to change their processes, in order to obtain the needed data. These stakeholders should therefore be included in the process.
- Availability of using a care pathway: although the IBD will use a care pathway in the future, it remains a question if this approach is even possible for the general population. The differences cannot be too large, as too many sub-groups result in a great number of care pathways. This variation between patients makes it more difficult to standardize.

8.4 Future research

In this section we present our research scientific value and suggestions for future research as an extension of this research.

8.4.1 Scientific value

In this research we showed that the analytical queuing model as introduced by Kortbeek (2012) is applicable to determine the required capacity such that new patients receive care within a certain number of weeks. However, we should be cautious in the use of an arrival distribution, as it is important that such a distribution is valid for the expected new patient arrival. The simulation as proposed by Elkhuizen et al. (2007) seemed to be a good approach to validate the analytical model and use of such an arrival distribution. We were able to show that the variations in demand were closely to the distribution.

In the literature a method of reservation of blocks in advance was introduced, which used a care pathway to describe the frequency and desired moment (Zonderland, Boucherie, Boer, & Litvak, 2012). Using this approach showed the shortcomings in our data. As no care pathway was constructed, and no data about the desired time-interval of recurring patients was known, it proved to be difficult in the use of such a time-block reservation method. Our method showed however that the concept can be turned around. Instead of using the desired moment, as a fixed given input, one can experiment with a care pathway which describes this desired moment. Using such a method, might support in decreasing the length of the follow-up.

8.4.2 Planning rules

Reservation of time slots is not the only solution to the timeliness problem. As we reserve a fixed number of dedicated slots per cycle, we find that the arrival process is not always constant. The arrival of new patients knows peaks and troughs, as can be observed in Appendix J. For example, if multiple troughs take place one after each other, we find that dedicated capacity remains unused. This underutilization of staff is undesirable and costly. The use of planning rules might be a solution, which incorporates among other things the release of dedicated capacity for other consultation types. The clinic should investigate at what moment they can release dedicated capacity, and what amount. For example if the clinic finds a way to predict multiple troughs, they can decide to release some dedicated capacity for new consultations for emergency consultations or other types. They should not only experiment if they should do this one, two, three or more weeks in advance, but also the number of slots. Then again this should be performed cautiously, as the 'Treeknorm' should not be compromised. A solution might therefore be to perform a simulation, as that way multiple planning rules scenarios can be tested, while no harm in reality is done by these experiments.

8.4.3 Panel sizing effect

The effect of seeing new patients in time results in a larger aftermath of check-up consultations. This puts pressure on the planning and ultimately asks for more capacity. As a balance between these new patients and their follow-up has to be found, it would be interesting to get a better understanding of this. It is interesting to determine the norm, which describes the probability of patients seen in time and their desired moment, for both new and check-up consultations. The clinic might find out that, with the current arrival pattern of new patients, this will not fit in the current capacity. Instead of increasing the capacity, the clinic might think of ways to influence factors that describe the patient mix. An example is to investigate if they can steer on accepting less new patients, by referring them to other care providers. This grip on the new patient arrival might result in not overloading the system, while receiving patients within the desired moment.

8.4.4 Patient compliance

The topic is not often mentioned in this research, but patient compliance is also a problem at the clinic. No-shows, cancellations and reschedules lead to lower staff utilization and decreased patient satisfaction. Introducing a short planning horizon can result in lowering no-shows (McMullen, 2015). A 10 week planning horizon is introduced, which is shorter than the current horizon. However in order to determine the optimal planning horizon length, the clinic should experiment with the effect of this length and patient compliance.

Improving the quality of communication with patient might increase patient compliance, so lower no-shows and cancellations. Willis et al. (2011) state that telephone contact with patients can increase patient attendance. This includes choice of day and time. The clinic might also experiment with more patient induced consultations, where patients call in case of the need for a consultation, instead of a doctor who induces a follow-up consultation.

8.4.5 Other specialties within the clinic

In this research we have proposed multiple methods to organize the planning process of the outpatient clinic more effectively. This contained awareness of the problem, good registration and a method towards block planning. It would be interesting to see if this problem is identified the same at other clinics, and if also their timeliness can be improved by introducing block planning and a care pathway. At these clinics the data of emergency patients and desired time-interval for check-up consultations might even be complete, such that a more valid method can be constructed.

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Appendix A – Diseases at the outpatient clinic of Gastroenterology

A list is shown with diseases that are treated at the outpatient clinic of Gastroenterology.

Bowel diseases	Haemorrhoids
	Celiac disease
	Diarrhea
	Colon cancer
	Diverticula and diverticulitis
	Faecal incontinence
	Polyps in the large intestine
	Irritable Bowel Syndrome
	Digestion (prevention of digestive diseases)
	Constipation
	Crohn's disease and ulcerative colitis
Oesophagus and stomach diseases	Heartburn
	Functional dyspepsia
	Stomach Cancer
	Ulcer
	Oesophageal cancer
	Pancreas and gall bladder
	Acute pancreatitis
	Pancreatic cancer
	Chronic inflammation of the pancreas
	Gallstones
Liver diseases	Hepatitis
	Cirrhosis

Other aspects of the functioning of the outpatient clinic include researches (Colonoscopy, ERCP, gastroscopy and sigmoidoscopy), nutrition and information for children.

Appendix B – Oncologic Rapid Diagnostics Department

Nationally we observe that the Dutch population is ageing as a whole. Together with the fact that cancer is more frequently present at elder people, the incidence of cancer is increasing. The UMC Utrecht has therefore created the Rapid Diagnostics department, which is established for patients that are suspected with cancer. This department is a special side way in the care pathway within the outpatient clinic of Gastroenterology. This department influences the planning of the outpatient clinic, since doctors are scheduled weekly for performing endoscopy, and the outflow of the rapid diagnostic department influences the pressure on the planning. In medical terms, the rapid diagnostics concerns endoscopy of patients. This concerns diagnostics by performing endoscopy, gastroscopy, colposcopy, sigmoidoscopy, and even 'Endoscopic retrograde cholangio-pancreaticography' (ERCP). These patients have pressing questions as: 'Do I have cancer?' or 'Should I worry?'. The Rapid Diagnostics Department offers the possibility for these anxious patients to reduce the sleepless nights, since the presence of cancer can be determined at a very short notice. The Rapid Diagnostics department is designed with the following goals:

- In case of a cancer suspicion, the patient should be able to visit the Rapid Diagnostics department the next day for diagnosis;
- 80% of this patient group should retrieve the outcome the same day;
- 95% of this patient group should retrieve the outcome within four days after diagnosis.

As cancer is diagnosed, the patient is placed at the Cancer Center. In case of the presence of a polyp, frequently the polyp is removed during the endoscopy. The patient then returns to the general outpatient clinic of Gastroenterology for a check-up consultation.

Appendix C – Senior doctors

The table contains an overview of the senior doctors that are present at the outpatient clinic of Gastroenterology.

Name of senior doctor:	***Specialty within Gastroenterology:***
Akol	Inflammatory Bowel Disease / general
Bogte	Benign oesophageal and stomach problems
van Erpecum	Liver
Fidder	Inflammatory Bowel Disease
Monkelbaan	Liver, Percutaneous endoscopic gastrostomy (feeding tube)
Moons	Polyps
Oldenburg	Inflammatory Bowel Disease
Vleggaar	Pancreas, Benign oesophageal and stomach problems

Appendix D – Tactical scheme of clinical sessions in 2016.

The table shows the division of clinical sessions at the clinic in 2016.

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Appendix E – Duration overview in minutes

The table shows a time overview of the clinical sessions.

Clinical sessions

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Appendix F – Literature research for performance measures

The table shows an overview of the articles that were found in the literature research for performance measures.

Author (year)	Performance measure(s)
(Balasubramanian, Banerjee, Denton, Naessens, & Stahl, 2010)	• Patient waiting time • Patient/Clinical continuity: 'Continuity is defined as the inverse of the proportion of times patients are redirected to see a provider other than their primary care physician (PCP).'
(Berg & Denton, 2012)	• Patient waiting time • Staff and resource utilization • Patient throughput • Overtime costs • Number of reschedules
(Cayirli & Veral, 2003)	• Waiting time of patients • Flow time of patients • Idle time of doctors • Overtime of doctors • Resource utilization • Delay between request and appointment • Percentage of urgent patients served
(Choi, et al., 2013)	• Waiting time • Overwork for the staff • Resource utilization • Congestion (queue length)
(Elkhuizen, Das, Bakker, & Hontelez, 2007)	• Access time • % of patients within norm
(Glowacka, Henry, & May, 2009)	• Number of no-shows • Doctor/Nurse idle/OT costs • Patient waiting costs • Revenue per patient
(Huang, 2008)	• Patient waiting time • Physician idle time
(Hulshof, Kortbeek, Boucherie, Hans, & Bakker, 2012)	• Total visit time • Waiting time • Queue length • No-shows

	• Resource utilization • Resource overtime
(Joustra, De Wit, Struben, Overbeek, Fockens, & Elkhuizen, 2010)	• Access time (target)
(Liu, Ziya, & Kulkarni, 2010)	• Number of no-shows • Number of cancellations
(Kortbeek & Zonderland, Designing Cyclic Appointment Schedules for Systems with Scheduled and Unscheduled Arrivals, 2011)	• Waiting time for unscheduled patients • Access time for scheduled arrivals
(Muthuraman & Lawley, 2008)	• Patient waiting time • Staff overtime • Patient revenue
(Qu X. , Rardin, Williams, & Willis, 2007)	• Access time
(Qu, Rardin, & Williams, 2011)	• Appointment lead time, also mentioned as access time • Average number of patients consulted • Variance of number of patients consulted in a session
(Zhao, Zhu, & Xueping, 2013)	• Effective use of resources • Timely access • No-shows • Cancellations • Waiting time • Overtime

Appendix G – Consultations at desired moment

Detailed approach of the performance of both check-up and periodic consultations at the period of January 2015 to December 2015.

IBD check-up consultations

Table 28 shows the descriptive statistics of the data of check-up consultations. The first quartile to the third quartile of the data, which indicates the bulk of the data, seems to be spread from 0% to 25%. This indicates that the larger part of the data was either in time or too late.

Table 28 - Descriptive statistics of the desired moment of check-up consultations in the IBD population

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IBD periodic consultations

Table 29 shows the descriptive statistics of the data of periodic consultations. The first quartile to the third quartile of the data, which indicates the bulk of the data, seems to be spread from -1 to 7%.This indicates that the larger part of the data was in time.

Table 29 - Descriptive statistics of the desired moment of periodic consultations in the IBD population

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General check-up consultations

Table 30 shows the descriptive statistics of the data of check-up consultations. The first quartile to the third quartile of the data, which indicates the bulk of the data, seems to be spread from -0 to 33%.This indicates that the larger part of the data was either in time or too late.

Table 30 - Descriptive statistics of the desired moment of check-up consultations in the general population

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General periodic consultations

Table 31 shows the descriptive statistics of the data of periodic consultations. The first quartile to the third quartile of the data, which indicates the bulk of the data, seems to be spread from -0 to 25%.This indicates that the larger part of the data was either in time or too late.

Table 31- Descriptive statistics of the desired moment of periodic consultations in the general population

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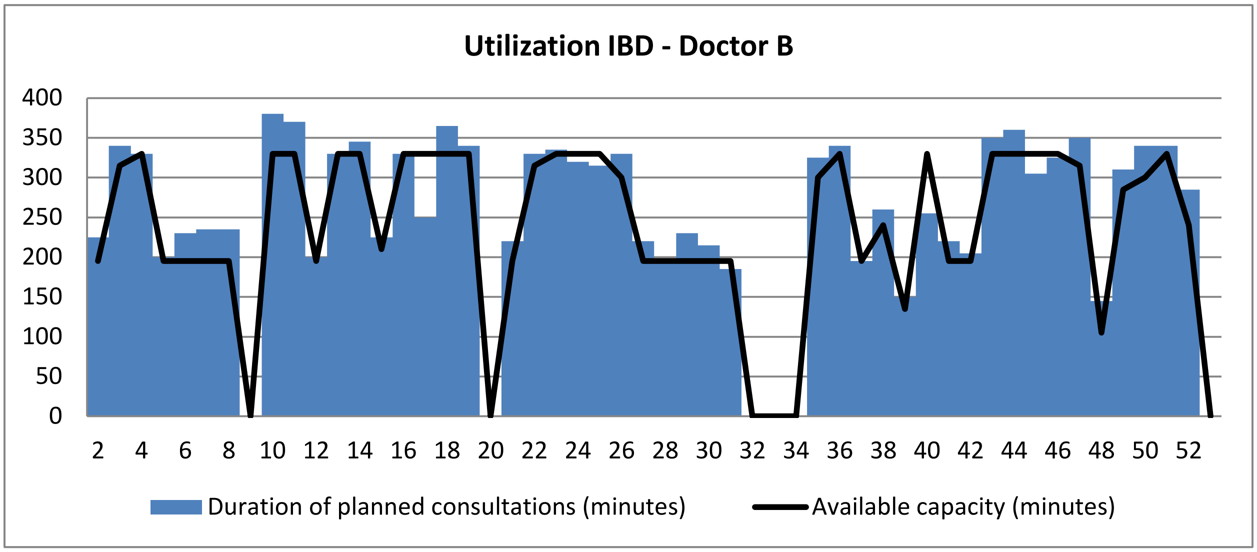
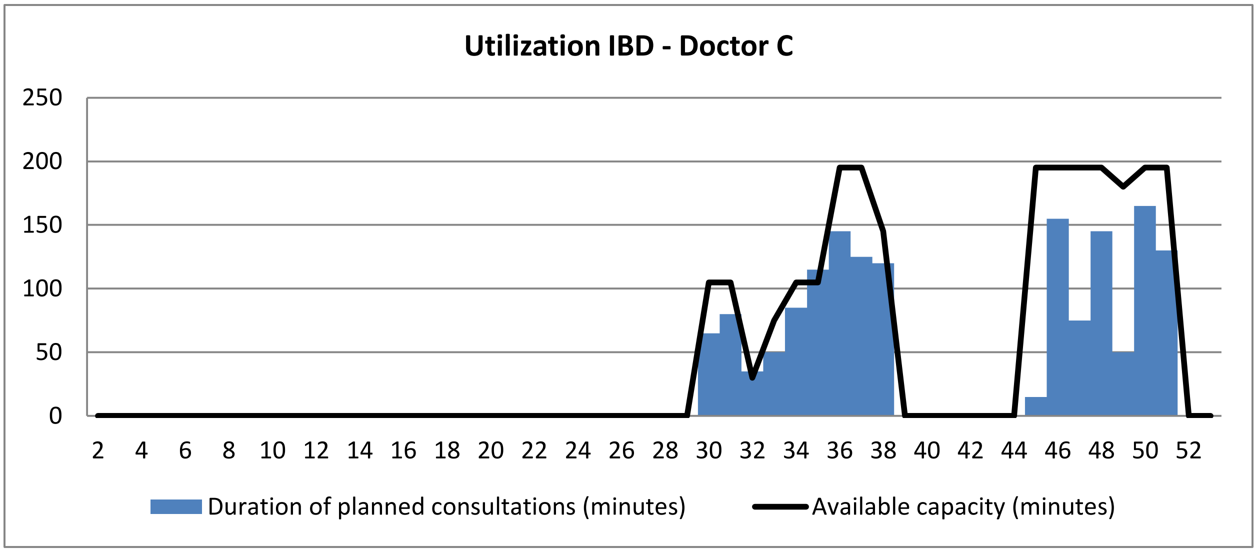
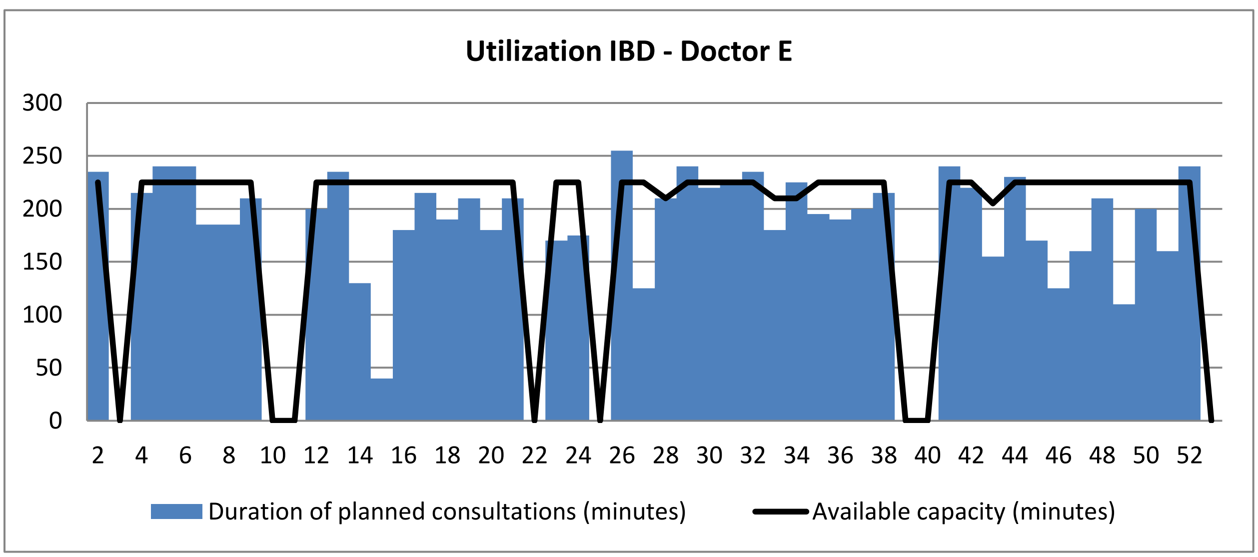
Appendix H – Staff utilization

This section gives a more detailed insight into the utilization of doctors at the IBD clinical sessions. The figures describe the actual planned usage of available minutes of the doctors.







Appendix I – Sample of consultation types

This appendix shows a sample of random days in the historical data of 2015. We found it interesting to determine the distribution of consultations types, and possible differences between a senior and junior doctor.

Sample of distribution of consultation types during two high occupied months for an IBD senior doctor in 2015

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Sample of distribution of consultation types during two high occupied months for an IBD junior doctor in 2015

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Appendix J – Arrival distributions

This section will elaborate on the methods used to identify distributions using elective patient group data.

What patient groups and data?

We identified the two clinical sessions of IBD and general population to analyse in our study. In order to increase timeliness, we identified four types of consultation types for each clinical session. These types are new, emergency, check-up and periodic. This section focuses on the new and emergency consultations, as we want to know how much time to reserve to meet the norm. Therefore we collected data of January 2015 till December 2015 at the outpatient clinic of Gastroenterology for new patients. As a result of lack of registration, no data of emergency patients was available. Therefore we cannot elaborate on this type of patients. The data we obtained gave us information about the number of patients that arrived in a certain week.

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Using the data and fitting a distribution.
We removed outliers outside a two sided confidence interval of 95%. To identify the distribution of the new and emergency patients we used Minitab.

New IBD patient
For the weekly arrival of new IBD patients we used a Goodness-of-Fit Test for Poisson. This method gave us the following data:

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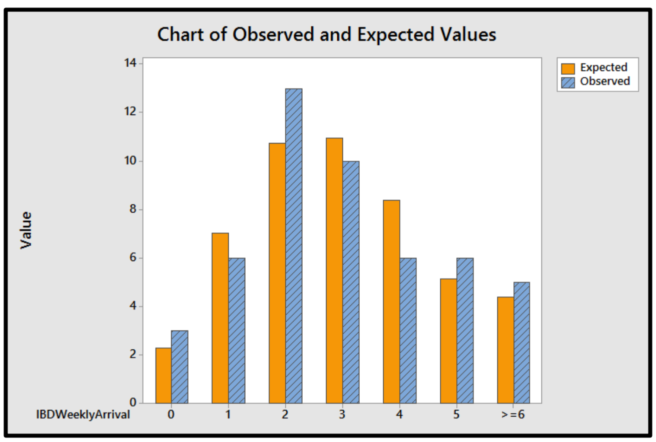

We observe that the p-value is 0.873, which is greater than the common alpha level of 0.05. Therefore we can assume that the data follows the Poisson distributio *CONFIDENTIAL INFORMATION* e seen in the graph, where the observed data closely follows the expected data.

New general patients
For the weekly arrival of new general patients we performed a Goodness-of-Fit- Test for Poisson. The p-value was however 0.00, which is lower than the common alpha level of 0.05. We therefore approximated the data with a continuous distribution, with a so called Individual Distribution Identification test. This gave the next results:

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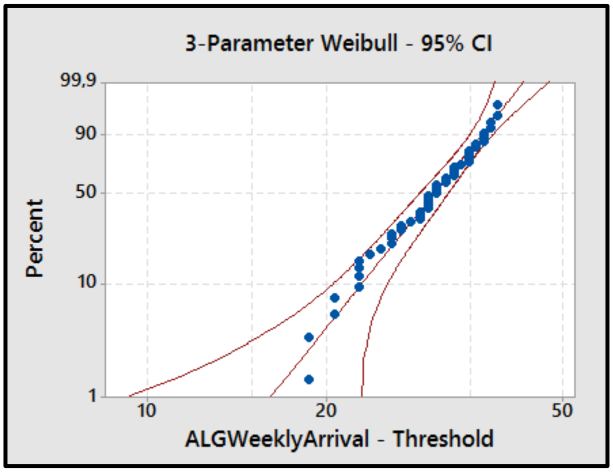

This Goodness of Fit Test showed us that the data is most likely to follow a 3-parameter Weibull distribution, as the p-value is highest for this distribution ($p > 0.4$). The parameters were identified as β = 6.70, γ = -15.67 and η = 32.19. We can convert the 3-paramter Weibull variables to a 2-parameter Weibull distribution, by correcting for the location. We therefore propose a method to drop for the threshold parameter. Now X is a random variable with a 3-parameter distribution with β, γ and η, then:

$$Y = X - \gamma$$

This data can be used to estimate the probabilities on a certain interval. However, since we would like to estimate the probability on discrete events, we perform a continuity correction. This indicates that we calculate the probability of value between *a* - ½ and *b* + ½. So, *P*(*a*-½ <= *Y* <= *b*+½).

Appendix K – Experiment Settings

The analytical model uses various numbers of slots to experiment with, such that the probability of meeting a certain access time can be determined. Tables 32 and 33 show the experiment settings for the analytical model as described in Section 4.4. The same experiments are performed in the simulation model, Chapter 5. Here the outcome of the analytical model is evaluated with the historical arrival data of 2015.

Table 32 - Experiment number of dedicated slots for new IBD patients (Maximum Backlog = 40)

Experiment	IBD1	IBD2	IBD3	IBD4	Total
1	4	3	3	3	13
2	4	3	4	3	14
3	4	4	4	3	15
4	4	4	4	4	16
5	5	4	4	4	17
6	5	4	5	4	18

Table 33 - Experiment number of dedicated slots for new general patients (Maximum Backlog = 120)

Experiment	ALG1	ALG2	ALG3	ALG4	total
1	15	14	15	14	58
2	15	15	15	14	59
3	15	15	15	15	60
4	16	15	15	15	61
5	16	15	16	15	62
6	16	16	16	15	63

The simulation study as described in Chapter 6 experiments with various probabilities of check-up consultations, such that the use of a care pathway can be evaluated. Table 34 and 35 show the probabilities on either a certain desired time-interval or number of check-up consultations.

Table 34 –Experiments with the probability on a predetermined desired time-interval, or exit for IBD check-up consultations.

Experiment	*P (12 months)*	*P (6 months)*	*P (2 months)*	*P (Exit)*
1	*47%*	*30%*	*20%*	*3%*
2	45%	30%	20%	5%
3	40%	30%	20%	10%

Table 35 - Experiments with the probability on a predetermined number of check-up consultations for the general population.

Experiment	*P (1 check-up)*	*P (2 check-up)*	*P (3 check-up)*	*P (4 check-up)*
1	65%	20%	10%	5%
2	80%	20%	0%	0%
3	100%	0%	0%	0%

Appendix L – Warm-up period

The warm-up period for the second part of the simulation is determined for both clinics.

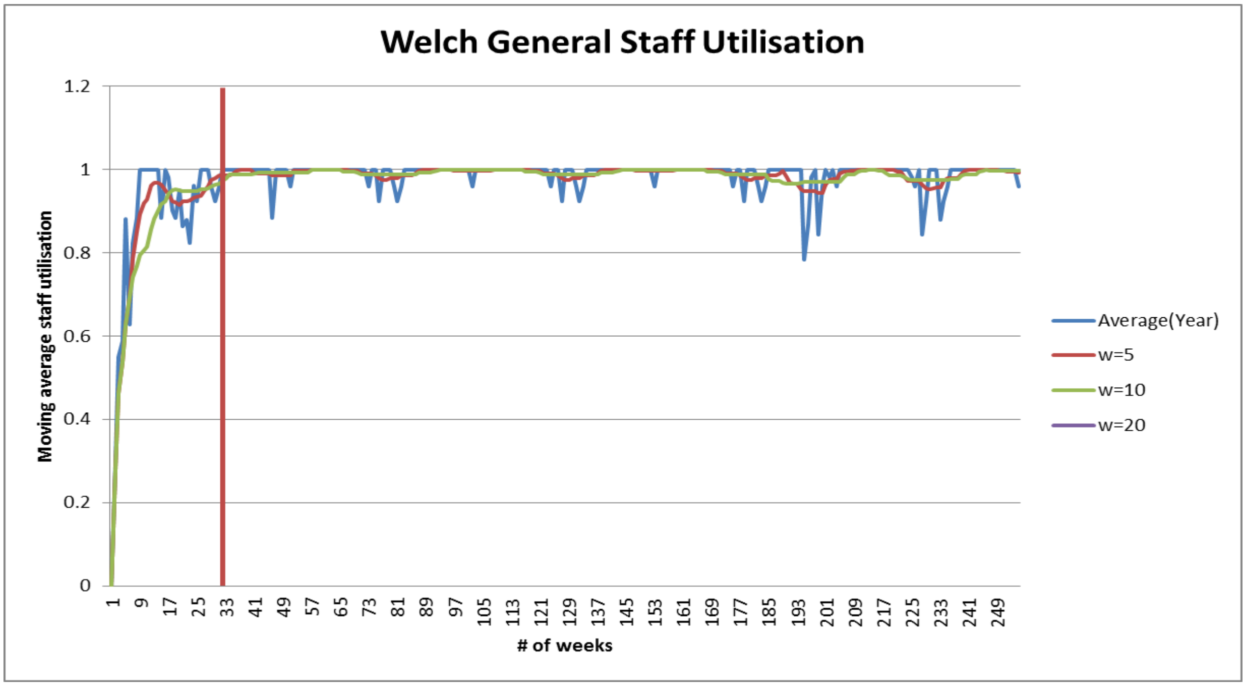

Figure 22 - Staff utilization of general clinic according to the simulation model and by using Welch. The red line shows the end of the warm-up period.

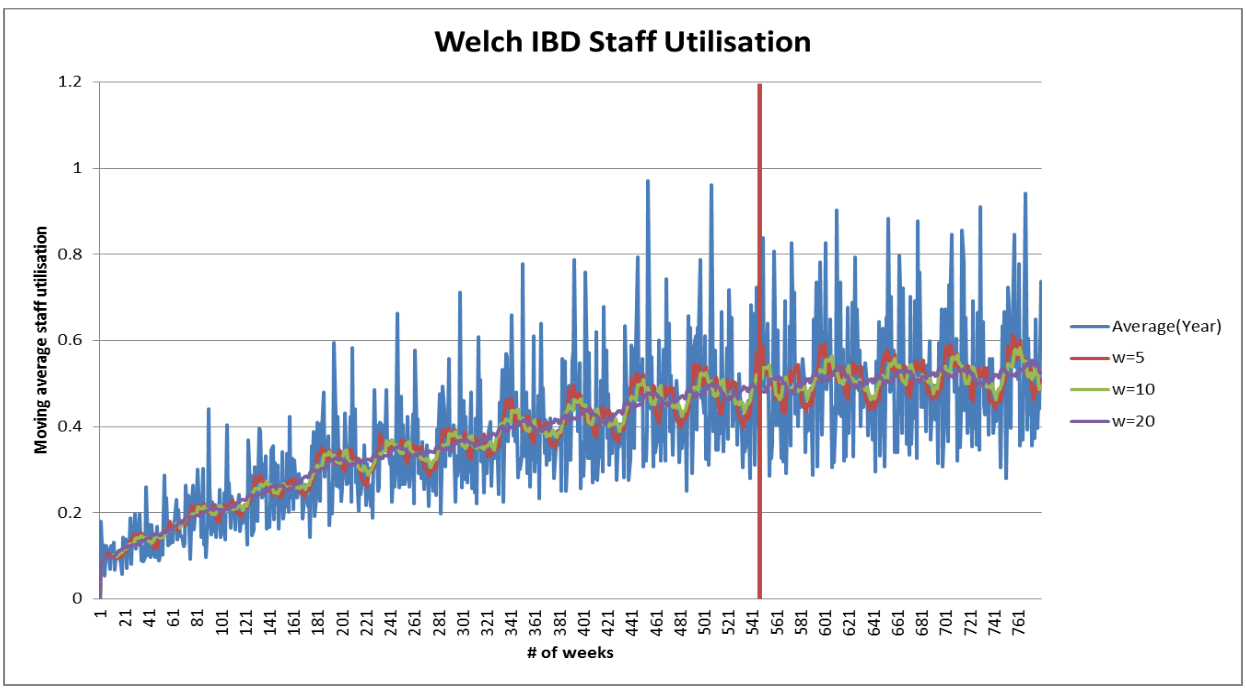

Figure 23 - Staff utilization of IBD clinic according to the simulation model and by using Welch. The red line shows the end of the warm-up period.