Pro Juventus

Center for youth and adult psychiatry

DECREASING THE WORKLOAD AT A MENTAL HEALTHCARE INSTITUTION

A SIMULATION STUDY

Sven Stienissen, S1853147

Bachelor Thesis Industrial Engineering & Management

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Author
Sven Stienissen
s1853147
s.stienissen@student.utwente.nl

University of Twente
Drienerlolaan 5
7522 NB, Enschede
The Netherlands

Pro Juventus Wijhe
Oranjelaan 10
8131 DB, Wijhe
The Netherlands

Supervisors University of Twente
Dr. Ir. M.E. Zonderland
Prof. Dr. Ir. E.W. Hans

Supervisors Pro Juventus
Drs. E.H. (Dineke) Smit
N.R. (Irene) Homan CMC

Preface

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Dear reader,

In front of you lies my report “Decreasing the workload at a mental healthcare institution”, which is the result of an enjoyable and interesting time I had at Pro Juventus, the host company where I conducted this research. This thesis is written to conclude my bachelor study, Industrial Engineering and Management, at the University of Twente.

Hereby I want to thank all people who have supported me in the past few months while I was conducting this research. First of all I want to thank Dineke Smit and Irene Homan (my supervisors at Pro Juventus) for giving me the opportunity to apply my knowledge at Pro Juventus. In addition, I want to thank them for giving me a warm welcome and for the feedback that I have received. In addition, I want to thank the department advice and support for the nice working atmosphere and for helping me to obtain useful information and data.

Furthermore, I want to thank my first supervisor of the University of Twente, Maartje Zonderland, for her valuable feedback on concept versions of this report and her involvement in this research. Next to my first supervisor, I want to thank Erwin Hans in assisting me to start this research. Finally, I would like to thank my fellow student Thom Rikken for his great feedback on earlier versions of this report.

I hope you will enjoy reading this thesis as much as I have enjoyed my time at Pro Juventus!

Kind regards,

Sven Stienissen

Management Samenvatting

Achtergrond
Gedurende de afgelopen Jaren heeft Pro Juventus verschillende problemen ondervonden met betrekking tot de planning van hun cliënten. Op dit moment is Pro Juventus erg trots dat hun cliënten hen waarderen met hoge scores. Een belangrijk aspect van deze hoge scores is hun zorg op maat. Desalniettemin loopt de behandelplanning van Pro Juventus vast vanwege meer aanvragen, steeds moeilijker wordende behandelingen en beperkingen in aanvullende thuiszorg. Dit heeft vervolgens geresulteerd in langere wachttijden voor cliënten en een hogere ervaren werkdruk van behandelaren. Dit onderzoek zal zich richten op het tweede aspect: de hoge ervaren werkdruk van behandelaren.

Doel en Methode
Momenteel plant Pro Juventus hun afspraken in zonder rekening te houden met de variabiliteit van de afspraaktijden. Daarnaast worden de directe en indirecte afspraaktijden achter elkaar gepland en soms zijn er te veel lege plekken te vinden in de dagelijkse planning van een behandelaar. Dit is soms opzettelijk gepland vanwege het feit dat een aantal afspraken veel van behandelaren vergen. Echter gebeurt dit ook vanwege de cliëntgerichtheid die centraal staat binnen Pro Juventus. Als een bepaalde afspraak niet precies uitkomt voor een cliënt, wordt deze 15 minuten later gepland. Dit is niet in lijn met een optimale planning.

Dit rapport heeft als doel om Pro Juventus inzichten te geven in de effecten van variabiliteit en cliëntgerichtheid, met betrekking tot hun behandelplanning, op de ervaren werkdruk van de behandelaren. Dit dient zo gedaan te worden dat verbeterpunten uit deze inzichten zullen worden verkregen. Om dit doel te behalen, is een simulatieonderzoek uitgevoerd waarin meerdere planningsmethoden worden geanalyseerd.

Allereerst is er een overzicht gemaakt van de huidige processen die gerelateerd zijn aan de behandelplanning binnen Pro Juventus. Om de algehele prestatie van de behandelplanning te evalueren, worden drie zogenoemde key performance indicators (KPI's) geformuleerd: de wachttijd van cliënten in de kliniek, de overuren die door behandelaren worden gemaakt en de productiviteit van de behandelaren.

Nadien is de huidige situatie vergeleken met drie planningsmethoden. De eerste planningsmethode die wordt gebruikt is de afspraakinterval methode. Bij deze methode wordt de lengte tussen twee opeenvolgende afspraken verkleind. Dit gebeurt voor zowel directe als indirecte afspraaktijden. De tweede planningsmethode die wordt geëvalueerd, is het gebruik van afspraaksloten van 4 uur. Als deze methode wordt gebruikt, worden cliënten eerst gepland in een tijdslot van 4 uur. Nadien, wanneer alle afspraken in dat tijdslot bekend zijn, zal de cliënt de exacte tijd voor de afspraak krijgen. De derde methode is een wachtrijdiscipline waarbij taken die moeten worden uitgevoerd niet worden gekozen op basis van een first-come, first-served principe. Daarnaast zullen de drie theorieën worden gecombineerd om te kijken of dit zal resulteren in een betere afsprakenplanning.

Resultaten
De resultaten zijn verdeeld in vier delen aangezien er vier experimenten zijn uitgevoerd met het simulatiemodel. Allereerst worden de resultaten van de afspraakinterval methode gepresenteerd. Bij deze methode kan het afspraakinterval van de indirecte afspraaktijd het beste worden verlaagd tot 0%, terwijl het afspraakinterval van de directe afspraaktijd het beste behouden kan blijven op 100%. Dit zal resulteren in een verhoging van de productiviteit van 6,75%, terwijl de wachttijden gemiddeld

met slechts 25 seconden toenemen. Daarnaast zullen de gemiddelde overuren worden gereduceerd van 1,11% naar 0,75%.

Op het moment dat afspraaksloten van 4 uur worden gebruikt en er rekening wordt gehouden met de variabiliteit, neemt de productiviteit toe van 64,03% (huidige situatie) naar 77,17%. Ook zullen de gemiddelde overuren afnemen van 1,11% naar 0,39%. Echter zal de gemiddelde wachttijd in de kliniek aanzienlijk toenemen van 2 minuten en 12 seconden naar 5 minuten en 9 seconden.

Momenteel wordt er al een wachtrijdiscipline gebruikt binnen Pro Juventus. In het derde experiment worden inzichten gegeven wat er gebeurt als Pro Juventus geen wachtrijdiscipline zou gebruiken. Dit verschil zit vooral in de gemiddelde wachttijd van de cliënten, die zal toenemen van 2 minuten en 12 seconden naar 6 minuten en 35 seconden. De andere twee KPI's blijven vrijwel hetzelfde.

Op het moment dat de beste opties van de drie planningsmethoden die hierboven zijn beschreven worden gebruikt, is de gemiddelde wachttijd van een cliënt in de kliniek gelijk aan 5 minuten en 11 seconden, de productiviteit gelijk aan 76,43% en de totaal gemaakte overuren gelijk aan 0,26%.

Conclusie en Aanbevelingen

Als Pro Juventus besluit om afspraaksloten te gaan gebruiken, zullen de klanten hun exacte afspraaktijd pas in een veel later stadium weten dan in het huidige planningsproces. Hierdoor wordt, vanwege dit grote nadeel, de volgende aanbeveling gedaan: Pro Juventus moet alleen de directe afspraaktijden in gaan plannen. Echter dient Pro Juventus wel rekening te houden met de indirecte afspraaktijden, aangezien deze alsnog op diezelfde dag uitgevoerd moeten worden. Dit betekent dat het bijvoorbeeld niet mogelijk is om vier uur directe afspraaktijd in de middag in te plannen, aangezien er dan geen tijd meer over is om alle indirecte afspraaktijd uit te voeren. Voor het overgrote deel worden indirecte afspraaktijden namelijk uitgevoerd na de directe afspraaktijden.

Management Summary

Background

During the past few years, Pro Juventus has faced several problems concerning the planning of their clients. Currently, Pro Juventus is very proud that their clients rate them with high ratings. An important aspect of these high ratings is their customized care. Nonetheless, due to more applications, increasingly difficult treatments, and limitations in additional home care their treatment planning got stuck. Hence, waiting times for clients and the experienced workload of practitioners have increased. This research will focus on the second aspect: the high experienced workload of practitioners.

Goal and Method

Currently, Pro Juventus is scheduling their appointments without taking into account the variability of appointment times. In addition, the direct and indirect appointment times are scheduled one after another, and sometimes there are too much empty spaces within the daily planning of a practitioner. This is sometimes done deliberately after a severe appointment. Though, this happens also due to the client focus that is central within Pro Juventus. If a certain appointment time is not convenient for a client, he or she will be scheduled 15 minutes later, which is not preferable for an optimal planning.

In this report, the goal is to give Pro Juventus insights in the effects of variability and their client focus concerning their treatment planning on the experienced workload by practitioners, such that points of improvements will be gained from these insights. In order to do this, a simulation study is performed to analyze multiple scheduling methods.

First of all, an overview is made about the current processes that are related to the treatment planning at Pro Juventus. In order to evaluate the overall performance of the treatment planning, three key performance indicators (KPIs) are created: the waiting time of clients at the clinic, the overtime hours that are made by practitioners, and the productivity of the practitioners.

Afterwards, the current situation has been compared with three scheduling methods. The first scheduling method that is used is the appointment interval method. In this method, the length between two consecutive appointments will be decreased. This is done for both direct and indirect appointment times. The second scheduling method that is evaluated is the use of appointment slots of four hours. If this method is used, clients will first be scheduled in a timeslot of four hours. Afterwards, when all appointments in that timeslot are known, the client will obtain the exact appointment time. The third method is a queue discipline, in which tasks that need to be performed are not chosen on a first-come, first-served basis. In addition, the three theories will be combined in order to look if this will result in a better appointment schedule.

Results

Since there are four experiments that have been executed with the simulation model, the results are divided into four parts. First of all, the results of the appointment interval method are presented. Using this method, it is best to decrease the appointment interval of the indirect appointment times to 0%, and to keep the appointment interval of the direct appointment times to 100%. This will result in an increase of the productivity of 6,75%, while the waiting times only increase 25 seconds on average. In addition, the overtime hours will decrease from 1,11% to 0,75%.

When appointment slots of 4 hours are used and variability is taken into account, productivity will even increase from 64,03% (current situation) to 77,17%, and overtime hours will decrease from 1,11% to

0,39%. Though, the average waiting time at the clinic will increase significantly from 2 minutes and 12 seconds to 5 minutes and 9 seconds.

Currently, a queue discipline is already used. However, in the third experiment, insights are given what happens if Pro Juventus does not use a queue discipline. The difference can mainly be found in the average waiting time of the clients which will increase from 2 minutes and 12 seconds to 6 minutes and 35 seconds. The other two KPIs remain almost the same.

If the best options of the three scheduling methods that are described above will be used, the average waiting time of a client is 5 minutes and 11 seconds at the clinic, the productivity is 76,43%, and the overtime hours are 0,26%.

Conclusion and Recommendation

If Pro Juventus is going to use appointment slots, clients will know their exact appointment time substantially later than currently. Therefore, due to this major disadvantage, the following recommendation is given: Pro Juventus needs to schedule only direct appointment times in their planning. However, they need to take into account that the indirect appointment times still need to be executed on the same day. Therefore it is for example not possible to schedule four hours direct appointment time in the afternoon, since indirect appointment times need to be executed after the direct appointment times for the major part.

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Reader's Guide

This reader's guide is created to give the reader a better understanding of the structure of this bachelor thesis. Below, a short overview is given of the different chapters in this bachelor thesis.

Chapter 1 Introduction
This chapter covers the introduction to this bachelor thesis. First, an introduction will be given about the company followed by the motivation for this research. Afterwards, the core problem, a problem solving approach and a research design will be presented amongst others.

Chapter 2 Current Situation
In this chapter, the current situation with regard to the planning process of Pro Juventus is described. Amongst others, the situations that could occur on the appointment day, information about the clients and practitioners, and key performance indicators for the planning process are presented.

Chapter 3 Literature Review
This chapter consists of a literature review that is conducted in order to improve the daily planning process of Pro Juventus. Therefore, several methods are discussed in order to improve a daily planning process.

Chapter 4 Conceptual Model
This chapter contains a conceptual model of the current planning process that is created in order to create a simulation model current planning process. Therefore, assumptions, input data and output data of the simulation model will be discussed.

Chapter 5 Implementation, Verification and Validation of the Simulation Model
This chapter comprises of theory on simulation model designs and the implementation of the conceptual model into a simulation model. Furthermore, it elaborates on the verification and validation of the simulation model.

Chapter 6 Experiments
This chapter covers theory on the preparations that need to be carried out in order to obtain accurate simulation results. Besides that, it covers all experiments that are performed in order to improve the planning process of Pro Juventus. These experiments are in line with the theory that is found during the literature review.

Chapter 7 Conclusions, Recommendations and Discussion
In this final chapter, conclusions will be drawn from the experiments that have been executed in chapter 6. After these conclusions are drawn, recommendations concerning the current planning process will be presented. Finally, a discussion about the research and suggestions for further research will be shown.

Each chapter in this bachelor thesis is structured in the same manner. First of all, a short introduction to the chapter is given. Afterwards, the structure of the chapter is presented. Eventually, the different sections in the chapter will be discussed in line with the structure presented in the introduction of the chapter.

Definitions

In this bachelor thesis, several terms are used multiple times. Some of the terms seam natural, but it is good to define them to avoid misunderstandings while reading this bachelor thesis. Therefore, the list below with definitions has been made.

Practitioners	All employees who provide mental support to clients. This includes, amongst others, psychiatrists, clinical psychologists and (youth) mental healthcare doctors.
Clients	All people who had an appointment in the past or who are going to have an appointment in the future with a practitioner.
Medicore	Medicore is an electronic patients file. In Medicore all information about clients, appointments and the practitioners can be found. Medicore is very useful since multiple data about appointments is automatically administrated in advance.
Daily planning	The planning of one specific day.
Client focus	The orientation of an organization towards serving its clients' needs.
Direct time of an appointment	The time that is used for an appointment together with a client.
Indirect time of an appointment	The time that is spent for an appointment without a client. This is for example time spent on preparing for an appointment, processing an intake or making a report about the appointment.
KPI	Key Performance Indicator

1. Introduction

In this chapter an introduction to Pro Juventus, the focus of this research, the problems that are faced and the problem solving approach with research design will be presented. This chapter is structured as follows:

- 1.1 Introduction to Pro Juventus
- 1.2 Motivation for the research
- 1.3 Theoretical framework
- 1.4 The problem identification
- 1.5 Research objective
- 1.6 The formulation of the problem solving approach
- 1.7 The scope of this research

1.1 Introduction to Pro Juventus

Pro Juventus is a medium-sized mental healthcare institution which practices in numerous mental healthcare disciplines. To name a few: psychiatrists, clinical psychologists, psychomotor therapists and nurses. Pro Juventus started their business in 2009 and currently has five locations: Wezep, Wijhe, Ommen and two in Kampen. At these five locations multidisciplinary teams work together on the diagnosis and treatment of children, adolescents, and adult clients.

Pro Juventus is performing their business in line with three core values: client focus, knowledge driven, and flexibility. Their client focus can be found in multiple aspects of their organization. First of all, practitioners do not focus on the disorder of clients but on the request for help. Besides that, management is there to facilitate the primary process (diagnostics and treatments) and to guarantee the continuity of care. Lastly, the secretaries do their utmost to put the clients at ease and schedule their appointments as desired. The knowledge driven attitude of Pro Juventus can be seen in their drive to learn from the experiences of clients and partners. In addition, all employees have a fixed annual training budget, and the teams also have a training budget to organize joint training. Flexibility encourages Pro Juventus to keep thinking critically about the growing stream of bureaucracy in healthcare and to have the guts to swim against the stream sometimes.

1.2 Motivation for the Research

During the last few years, Pro Juventus has faced several problems concerning the planning of their clients. Currently, Pro Juventus is very proud that their clients rate them with high ratings. An important aspect of these high ratings is their customized care. Nonetheless, due to more applications, increasingly difficult treatments, and limitations in additional home care their treatment planning got stuck. Hence, waiting times for clients and the experienced workload of practitioners have increased. Since another student is already working on an assignment about the long waiting times, this research will focus on the high workload that is experienced by the practitioners. In order to decrease the high workload, this thesis will provide insights on how to improve Pro Juventus' treatment planning. In section 1.4, a more in-depth analysis of the overall problems that Pro Juventus is facing can be found.

1.3 Theoretical Framework

In order to solve business problems, several methodologies are available. Within the study Industrial Engineering and Management, one of the most commonly used methodologies is the Managerial Problem Solving Method (Heerkens & Van Winden, 2012).

The Managerial Problem Solving Approach is an approach to solve business problems in a systematic manner. This methodology is very general and can therefore be applied to many different problems. The managerial Problem Solving Method consists of the following 7 phases:

1. The problem identification
2. The solution planning
3. The problem analysis
4. The solution generation
5. The solution choice
6. The solution implementation
7. The solution evaluation

In this research project the Managerial Problem Solving Approach will be used as a theoretical framework.

1.4 The Problem Identification

According to Heerkens & Van Winden (2012), an action problem is a discrepancy between the norm and reality perceived by the problem owner. As already mentioned above, the action problem regarding this project is that the practitioners at Pro Juventus experience a high workload. In this action problem, the norm is that the workload of practitioners in terms of overtime hours needs to be decreased, since the reality is that the number of overtime hours is too high at the moment. However, according to the director of Pro Juventus, currently the total number of overtime hours is not known, since not everyone is reporting the made overtime hours. In order to create structure in the problem context and to identify the so called "core problem", a problem cluster is designed. According to Heerkens & Van Winden (2012), the core problem is the problem that has no known cause and that can be influenced by the researcher. In addition, the problem cluster also supports to determine cause and effect relationships between problems. The problem cluster is shown in figure 1.

Figure 1 shows that the problem of the high experienced workload by practitioners can be divided into two causes. The first cause is that the treatments at Pro Juventus are heavier than before. This does not only apply to Pro Juventus, but also to other mental healthcare institutions. A few years ago, rules of government instances have changed which resulted in general practitioners solving the "easier" mental healthcare problems. Therefore, only heavier problems remain at Pro Juventus, which results in a higher experienced workload by practitioners. Concluding, this first cause of the high experienced workload cannot be the core problem, since the researcher cannot influence the problem.

The second cause of the high experienced workload is that practitioners make a lot of overtime hours. This is mainly a result of a bad daily planning at Pro Juventus. First of all, this planning does not take into account the variability of the length of time of the appointments. At almost every appointment that is scheduled, a distinction is made between the direct and indirect time that is used to help a client. At this moment it occurs often that the direct time of an appointment is longer than scheduled. Therefore the practitioner needs to do the same amount of work in a shorter time period, or he/she does not finish the work in the scheduled time, which means that the practitioner needs to do it at another time. If the whole day is already scheduled with appointments, the practitioner needs to do his or her unfinished work at the end of the day. However, if another appointment at that day was shorter than expected, the practitioner could finish the unfinished work of the first appointment at that moment. Besides this, Pro Juventus is trying to fulfill almost all wishes of the clients with regard to the planning. At this moment Pro Juventus has no insights in the effects of their client focus concerning the planning. Besides that, Pro Juventus has no insights in the effects of not considering the variability of appointment times. Since this is not the case, an optimal daily planning is very hard to achieve.

As can be seen in figure 1 the productivity of practitioners is low, while they make a lot of overtime hours. This may contradict each other, but due to a sub-optimal daily planning, there are a lot of empty spots in the daily planning of the practitioners. An example of this is that a client is scheduled at 09:00, while the practitioners starts working at 08:30 according to their contract.

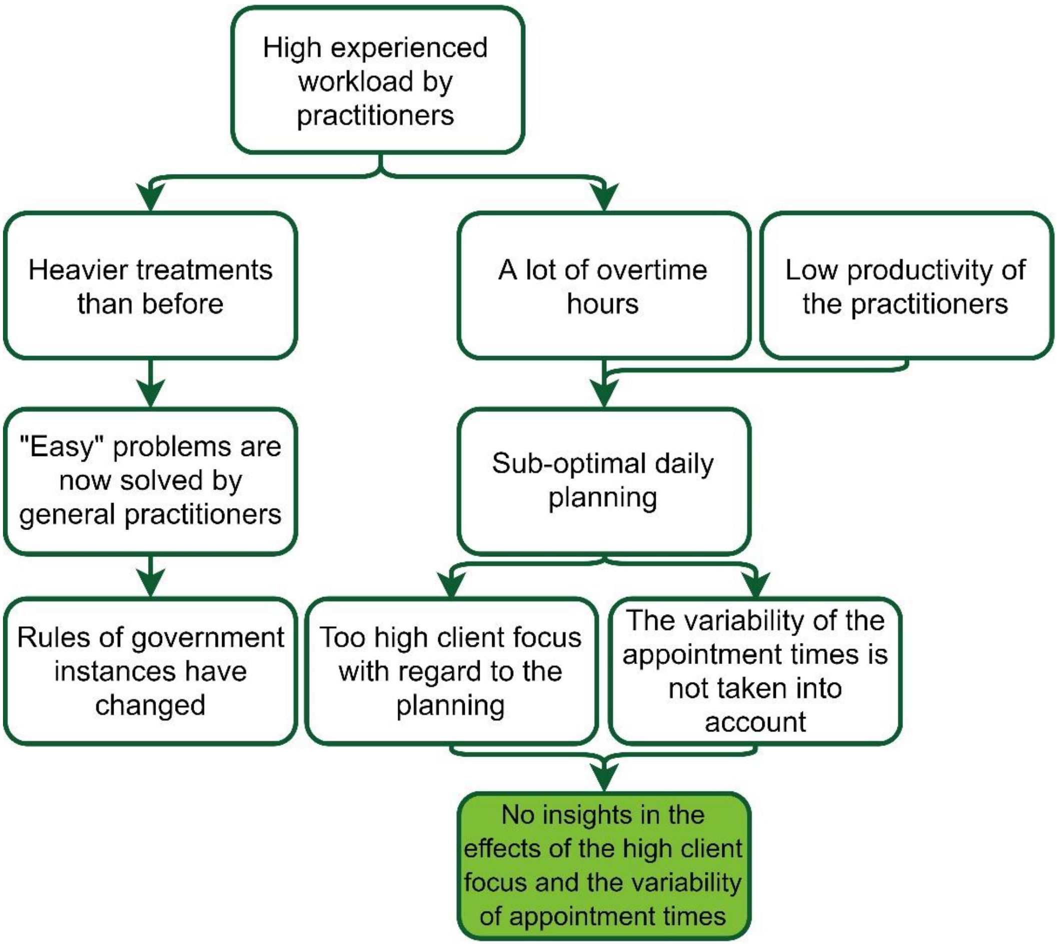

Figure 1 - The Problem Cluster

Together with the director of Pro Juventus the following core problem has been chosen: Pro Juventus has no insights in the effects of their client focus and the variability of appointment times with regard to their daily planning. Within this core problem there is a clear gap between the norm and the reality. The norm is that Pro Juventus wants to have insights in the effects of the variability of appointment times and their client focus, while this is not the case in reality. This core problem has been chosen for several reasons. First of all, this problem is appropriate for an Industrial Engineering & Management bachelor thesis since it will require the knowledge that is obtained during the study, such as planning methods, mathematical models and a simulation study. Secondly, it is possible to solve this problem within the given time period of ten weeks, and lastly, from the potential core problems, the solution to this problem is probably going to have the most effect on the high experienced workload.

In order to measure the high experienced workload by practitioners, the following two indicators have been chosen:

1. The percentage of the total number of overtime hours at the end of the day in proportion to the total hours worked on a day
2. The percentage of the contractual working hours that a practitioner is actually working. Also known as the productivity of a practitioner.

Preferably, in line with an optimal planning, the first indicator should be as low as possible and the second indicator should be as high as possible.

1.5 Research Objective

The main goal of this research is to give Pro Juventus insights in the effects of their client focus concerning the daily planning and the effects of variability on the experienced workload by practitioners. In addition to obtaining these insights, the goal of this research project is to deliver a list with substantiated points of improvement and recommendations regarding the planning process.

Furthermore, the recommendations of this research can serve as starting points for possible follow-up studies. Due to the complexity of the planning process not all problems found can be investigated and improved in this research. Therefore, these problems can serve as possible core problems in future research.

1.6 The Formulation of the Problem Solving Approach

The second phase of the Managerial Problem Solving Method (Heerkens & Van Winden, 2012, p.60) is the formulation of the problem approach. In this section, a design will be made in order to solve the problem, in this case, the high experienced workload by practitioners. First of all, a short definition of a simulation will be presented. Afterwards, a motivation will be given why a simulation study is chosen for this research. Eventually, an overview of the problem solving approach will be presented.

According to Shannon (1975), a simulation can be defined as: "The process of designing a model of a system and conducting experiments with this model for the purpose either of understanding the behaviour of the system or of evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operation of the system." In the following section, the motivation to carry out a simulation study will be presented.

1.6.1 Motivation Simulation Study

In this research project, a simulation study will be executed. This has been chosen for several reasons. First of all, by doing a simulation study it is possible to execute multiple different what-if scenarios. Since a lot of experiments need to be executed in order to get insights in the effects of the client focus on the daily planning and the effects of variability, a simulation study will be appropriate. Secondly, a simulation study enables the organization to study the behavior of a system without building it into their business. Therefore, it is cheaper to get insights into new planning methods than to implement it directly into the real world. Thirdly, assumptions can more easily be made in a simulation model than when using queueing theory (Robinson, 2014, p.15). This will be useful since assumptions can be made on the distributions of the appointment times and the arrival process of clients. Fourthly, a simulation study is appropriate if a lot of stochastic relations exist within a model, which is the case for Pro Juventus. Lastly, a simulation model is much easier to understand and to convince people than a queueing model.

1.6.2 Problem Solving Approach

In this section the problem solving approach will be discussed. This problem solving approach is composed together with the research design in section 1.7 in order to arrive at the intended deliverable of this research project: to give Pro Juventus insights in the effects of their client focus concerning the daily planning and the effects of variability on the experienced workload by practitioners. The problem solving approach consists of 6 phases. Below, the 6 phases of the problem solving approach are presented.

Phase 1: Collect information about the planning process of Pro Juventus

In this phase, information will be collected in order to understand the current planning process of Pro Juventus. Insights will be gained about how appointments are made within the planning of practitioners, how many and which appointments have been made, and if there are restrictions within the planning process that need to be taken into account in the simulation model.

Phase 2: Collect information about planning improvement techniques

In order to improve the planning process of Pro Juventus, several planning improvement techniques need to be investigated. In this section no planning optimization techniques can be used, since it is not feasible to find an optimal solution for Pro Juventus. This is the case, due to the fact that there are too many tasks that need to be performed within a day. Sometimes more than 20 tasks are performed by one practitioner. This will already result in more than 2 trillion different day schedules for every practitioner.

Phase 3: Create a conceptual model

In this phase, a conceptual model of the planning process of Pro Juventus will be built. In order to create a simulation model, a conceptual model is a very useful tool. In performing a simulation study the developer needs to make decisions about what to include in the simulation model and what to exclude. The modeler is faced with the very difficult choice of determining what is the best model to develop. The process of determining what to model is known as conceptual modeling (Robinson, 2011). In this phase, assumptions, input data and output data of the simulation model will be determined.

Phase 4: Implementation, verification and validation of the simulation model

In this phase, first the conceptual model will be implemented into a simulation model. This simulation model will look like the current planning process of Pro Juventus. Afterwards, the simulation model will be verified and validated.

Phase 5: Conduct experiments

In this phase, several experiments will be conducted using the chosen planning improvement techniques. First, the experiments that are needed to get insights into the effects of the client focus will be determined. Subsequently, the outcomes of the experiments will be elaborated.

Phase 6: Present the recommendations on the planning process

In the last phase, conclusions will be drawn from the experiments and recommendations to Pro Juventus about their planning process will be given. Eventually, the limitations of the simulation model and suggestions for further research will be discussed.

1.7 Research Design

In this section the research design is presented. For every phase discussed in section 1.6.2, research questions and corresponding sub-questions have been formulated. These sub-questions are needed in order to answer the research questions.

Phase 1: Collect information about the planning process of Pro Juventus
For this phase, one main research question has been formulated, supported by four sub-questions, which can both be seen below.

1) How does the current planning process of Pro Juventus look like and what are the degrees of freedom concerning the planning process?

a) How are appointments scheduled? Is it done via an application on the internet, phone call, mail or in person at the secretary desk?
b) How many and which appointments have been scheduled in the past?
c) Which restrictions are applicable to the planning process?
d) What are variables that need to be taken into account while reducing the experienced workload at Pro Juventus?

To answer the first and third sub-question, an interview will be conducted with the secretary and the registration office, since they know a lot about the scheduling processes and the restrictions that they need to take into account while planning a client. Besides that, for the third sub-question an interview will be conducted with the director of Pro Juventus to specify the restrictions with regard to the new planning method even further. In order to answer the second sub-question, a quantitative data analysis will be conducted on the obtained data. Eventually, the variables that need to be taken into account will be discussed. These variables will be chosen by conducting a literature review.

Phase 2: Collect information about planning improvement techniques
For this phase, one main research question has been formulated, supported by one sub-questions, which can both be seen below.

2) How can the daily planning process of Pro Juventus be improved?

a) Which mathematical planning model can be used to improve the daily planning?

For the sub-question above, a literature review will be conducted. This will be done in order to find multiple mathematical planning and scheduling methods. After the review has been conducted, the methods will be used within the simulation model.

Phase 3: Create a conceptual model
For this phase, one main research question has been formulated, supported by four sub-questions, which can both be seen below.

3) How does the conceptual model of the daily planning of Pro Juventus look like?

a) What needs to be included into a clear conceptual model?
b) Which assumptions can be made in the simulation model?
c) What is the input data for the simulation model?
d) What are the output variables of the simulation model?

In order to get more insights into the requirements of a conceptual model, a literature review will be conducted. By doing this, the first sub-question will be answered. To answer the second sub-question, interviews will be conducted at Pro Juventus, in which the possible assumptions of the simulation model will be shown. To determine the input data for the simulation model, data found in phase 1 will be used. Besides that, a quantitative data analysis method will be used in order to determine the values of the input data, such as probability distributions of appointment times and interarrival times. Afterwards, the fourth sub-question will be answered by conducting a literature review about output variables that are generally used in a planning process.

Phase 4: Implementation, verification and validation of the simulation model
For this phase, one main research question has been formulated, supported by two sub-questions, which can both be seen below.

4) How can the simulation model be implemented, verified and validated?

a) How can the conceptual model be implemented into a simulation model?
b) How can the simulation model be verified and validated?

To answer the first sub-question, the conceptual model that has been designed in phase 3 will be used. During the implementation of the simulation model probably several problems will occur. Therefore, knowledge will be gained about the implementation of a conceptual model into a simulation model. Since it is currently not known which information will be needed exactly, an unsystematic literature review will be executed. Once the simulation model is created, the simulation model will be verified and validated. In order to do this, a systematic literature review will be conducted to find several verification and validation techniques.

Phase 5: Conduct experiments
For this phase, one main research question has been formulated, supported by three sub-questions, which can both be seen below.

5) Which experiments will be conducted in the simulation study and what is needed to execute the experiments?

a) How can the mathematical models be implemented into the simulation model?
b) Which experiments are needed to get insights into the effects of variability and the client focus?
c) What are the results of the experiments?

Before the experiments can be executed, the mathematical models that have been found in phase 2 need to be implemented into the simulation model. Since probably several problems will occur during the implementation of the mathematical models, an unsystematic literature review will be conducted. To decide which experiments will be conducted, the information obtained in phase 1 will be used. In phase 1 restrictions on the planning process have been established. These restrictions need to be taken into account when deciding which experiments can be conducted. Besides this, possible experiments will be discussed with the management team to confirm if these experiments are applicable. Eventually, the results of the experiments will be presented after they have been executed.

Phase 6: Present the recommendations on the planning process
For this phase, one main research question has been formulated, supported by three sub-questions, which can both be seen below.

6) Which planning method should be used by Pro Juventus?

a) What can be concluded from the experiments?
b) Which are the recommendations regarding the planning process?
c) Which limitations does the simulation model have concerning the accuracy of the output?

The first two sub-questions will be answered using the data and knowledge obtained in phase 5 will be used. After that, the limitations of the simulation model will be discussed concerning the accuracy of the output. This will follow from logical reasoning of the obtained knowledge during the research project.

1.8 The Scope of this Research

The scope of a research project is used to demarcate the project. At Pro Juventus two action problems have been discovered: long waiting times and high experienced workload. This research will only focus on the high experienced workload by practitioners. In addition, this research will only give Pro Juventus insights into improvements of their planning process with regard to the effects of their client focus and the variability. So, the new planning method will not directly be implemented into the planning process of Pro Juventus during this research project.

2. Current Situation

In this chapter, the current situation of Pro Juventus is described. This is done to get more insights in the current performance of Pro Juventus and to analyze several problems within the current situation. Therefore, the following research question will be answered: "How does the current planning process of Pro Juventus look like and what are the degrees of freedom concerning the planning process?". This chapter contains the following subjects:

- 2.1 The growth of Pro Juventus
- 2.2 The practitioners
- 2.3 The clients
- 2.4 Application process
- 2.5 Planning process
- 2.6 Situations on the appointment day
- 2.7 KPIs that determine the performance of the planning process

2.1 The Growth of Pro Juventus

In order to get more insights in the current situation of Pro Juventus, first an analysis is made about the growth that Pro Juventus has experienced during the past years.

As can be seen in figure 2, Pro Juventus has faced an immense growth since the start of their business in May 2009. The number of activities and number of practitioners increased on average around 27% and 23% per year from 2010 till 2018, respectively.

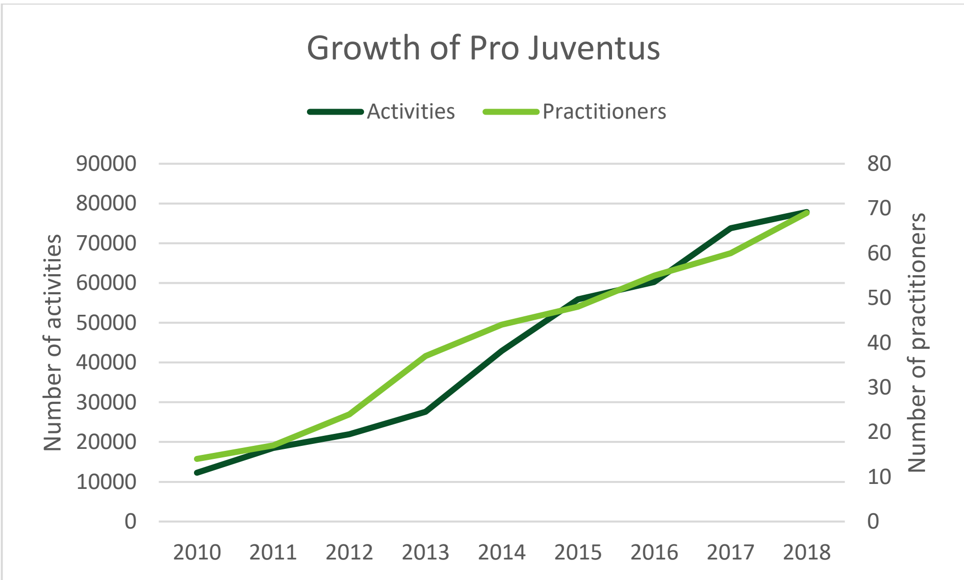

Figure 2 - Growth of Pro Juventus

The growth of Pro Juventus can also be seen in the number of locations that are owned by Pro Juventus. In 2009 Pro Juventus started in a small building in Hattem, which they rented at that time. Only a short period after starting the business it became clear that the building was too small. At this moment Pro Juventus has five locations. The newest building was opened in March 2019.

2.2 The Practitioners

Currently, there are 74 practitioners working at Pro Juventus spread over the five locations. These 74 practitioners occupy in total twelve different specializations within the organization. In appendix A, the distribution of these specializations can be seen for the total organization and for the five locations separately. Besides that, in appendix B the total contract hours per week can be found per specialization.

All twelve specializations perform different tasks in the organization. In total there are 102 distinct tasks that have been executed in 2018 and the first four months of 2019. These tasks include intelligence tests for youth, initial interviews, pharmacotherapy, psychiatric examination, email or telephone contact with the client and a lot of other tasks. Among these tasks there are a lot of tasks that are rarely performed. In appendix C an overview is given about the number of activities per appointment type. Out of the 102 tasks, there are 57 tasks that are only performed less than 100 times. In the simulation model all these tasks will be seen as remaining, since they only occupy 1,1% of the total activities.

In appendix D an overview can be found about the appointment types that each specialization can perform according to the data of 2018 and the first four months of 2019. As can be seen, a lot of tasks overlap the different specializations.

2.3 The Clients

At Pro Juventus there are a lot of different clients with different backgrounds and different ages. The practitioners treat children, young adults and adults. To give an impression, Pro Juventus had treated 2.384 unique clients in 2018. Most of the practitioners can treat both children and (young) adults.

2.4 Application Process

In this section the application process of Pro Juventus will be presented. The application process includes the whole process between the first contact with a client and the first appointment of a client. In figure 3, a business process model can be seen of the application process. As can be seen, the initial interview is not seen as the first appointment and is therefore included into the application process.

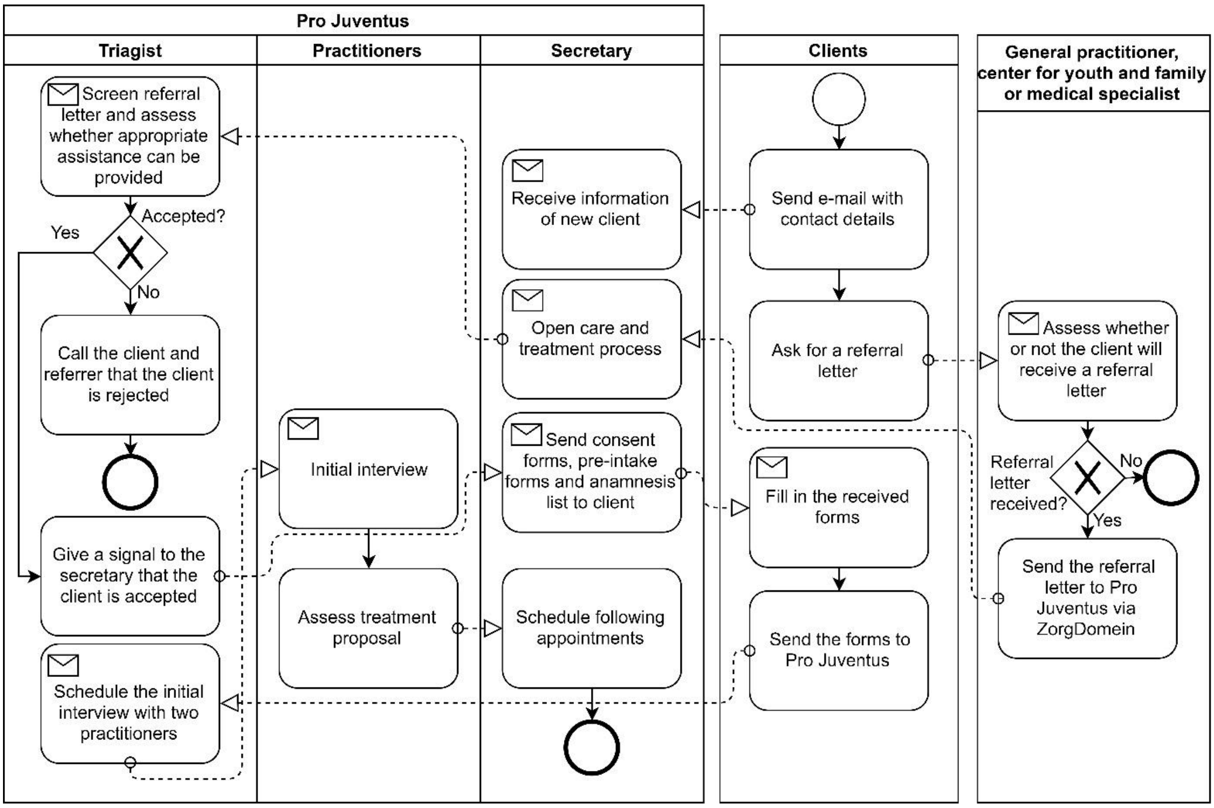

Figure 3 - The Application Process

As can be seen at the general practitioner, center for youth and family or medical specialist, ZorgDomein is mentioned. ZorgDomein is a digital platform where care providers request care, offer care and where they can exchange patient information quickly and securely. ZorgDomein is linked to the electronic patients file Medicore. If referral letters of new clients are sent via ZorgDomein, the client is automatically added to Medicore.

During the initial interview, the expectations and wishes from the client or the client's parents are discussed. Besides this, the pre-intake forms and anamnesis lists are discussed together with the client. After this, the two practitioners will deliberate which treatment will be appropriate for the client. Most of the times, the treatment proposal consists of a diagnostic proposal, for children this is often an intelligence test. During the consultation, a more extensive treatment proposal is made about the required treatment. Afterwards, the following appointments will be scheduled together with the secretary.

Currently, there is no prioritization while choosing the next client to help. So, the longest waiting client will be chosen first to plan an initial interview or other appointments. This is also known as the principle of first-come, first-served (FCFS).

2.5 The Planning Process

Once the application process is finished, the client is going to have his or her first treatment. Most of the times a treatment consists of multiple appointments. Sometimes these appointments are scheduled all at once and sometimes these are scheduled one after another. If the appointments are all scheduled at once, the program Medicore tries to find a regularity in the planning. So, if clients need to make an appointment every week, Medicore tries to schedule the appointment at the same day at the same time every week. If at a certain moment it is not possible to schedule someone at the same time, Medicore skips that week and schedules the appointment the next week. In appendix E an example can be found of planning multiple appointments in Medicore.

The problem here is that Medicore is only trying to find an appointment on the exact same time on the exact same day, without taking into account the other appointment times on that day. This could result in a schedule that is far from optimal, since appointments could be scheduled with too much time in between.

Most of the times the secretaries try to avoid this by rescheduling the appointments made by Medicore. Though, it happens too often that there is too much time in between the appointments. This is also partly due to the fact that some of the appointments are scheduled by practitioners themselves. Generally, this is less efficient than when the secretaries schedule the appointment. In addition, sometimes time is deliberately scheduled between two appointments. This is done, since some appointment types are very demanding for practitioners. Therefore, to give them some rest, a little bit of resting time between two consecutive appointments is scheduled.

For every distinct appointment type there is a standard time that is scheduled. This standard time consists of direct time, indirect time and travel time. Most of the times, this standard time is maintained. However, it happens too often that there is a deviation from this time. Therefore this is not negligible.

2.6 Situations on the Appointment Day

Once the appointment is scheduled, several situations could occur on the day of the appointment. In this section these situations are presented.

2.6.1 Normal Situation

In a normal situation the client shows up and the appointment will be executed. In this normal situation three things can happen. The first thing is that the appointment could be shorter than was initially scheduled. At this moment the practitioner can start earlier with the indirect time of that appointment. Since the appointment is shorter, the practitioner will be able to do other tasks that he or she still has to do. However, if there are no other tasks, he or she will have nothing to do until the next appointment. This will result in a lower productivity. The second thing that could happen is that the appointment will be longer than was initially scheduled. If this happens the practitioner has less indirect time. As a result, the practitioner cannot finish their tasks before the next appointment. Therefore, the practitioner will need to do these tasks at a later time that day. If the whole day is already fully scheduled with appointments, he or she needs to do it at the end of the day and thus make overtime hours. The third and most preferable thing that could happen is that the appointment is exactly as long as scheduled. At this moment the practitioner has exactly enough indirect time after the appointment to finish their tasks before the next client arrives.

2.6.2 Cancellation > 24 hours

Appointments that are scheduled can also be cancelled by clients or by practitioners. If an appointment is cancelled more than 24 hours before the appointment, it will be seen as a cancellation. From the 1^{st} of January 2015 till the 11^{th} of February 2019, 11,196% of the scheduled appointments had been cancelled. It is not known how long in advance these appointments had been cancelled. If it possible to plan a new appointment in that timeslot, this will be done. Most of the times this will be possible. Nonetheless, most of the times the planning is less efficient if another appointment is scheduled during that time. Though it will be the better than no appointments during that time. If there are no new appointments that can be scheduled at the cancellation time, the practitioners try to do other tasks. If this is not possible, the productivity will decrease.

2.6.3 No-shows < 24 hours

Besides cancellations, the so called no-shows could occur. An appointment is seen as a no-show if the appointment is cancelled within 24 hours of the appointment time or if the client does not show up for the appointment. From the 1ste of January 2015 till the 11^{th} of February 2019, 1,275% of the client-related appointments were no-shows. If there is a no-show, practitioners still try to write time for that appointment. They do this by contacting the client. Most of the times they try to call the client and to make a report out of this phone conversation. Generally this is much less time than the appointment, therefore the productivity will decrease. During the no-show time, most of the times the practitioners try to take on other tasks.

2.6.4 Emergency clients

In addition to the scheduled appointments, emergency clients could arrive at Pro Juventus. Most of the times, family, acquaintances of the client or the client self calls to Pro Juventus to say that things are going really bad. At that moment, support is offered to the client wherever this is possible. It is not known how much emergency arrivals happen per unit of time. Though, this does not happen very often relative to the total number of appointments according to some employees.

2.7 KPIs that Determine the Performance of the Planning Process

To evaluate the performance of the current planning process, three key performance indicators (KPIs) will be presented in this section. Currently Pro Juventus is only using the productivity of their practitioners to measure the performance of their planning process. This number is not a real-time number, but is calculated once in a while. In this section the following three KPIs will be discussed: the overtime hours, the productivity and the waiting time of a client at the clinic.

2.7.1 Overtime Hours
The overtime hours are all hours that a practitioner has worked after their contractual hours. For most of the practitioners this will be hours made after five o'clock in the afternoon. However, this will not always hold since some of the practitioners stop working around 3 o'clock in the afternoon sometimes. If they work after 3 o'clock this will count as overtime. The following KPI is drawn from the overtime hours: the average percentage of overtime hours on one day divided by the total hours worked on one day.

2.7.2 Productivity
The second KPI of the planning process is the productivity. The productivity is measured in terms of written time per working hour. The written time consists of direct time, indirect time and travel time. Once a practitioner has executed a task, he can write down the direct, indirect and travel time that he has spent on that task in Medicore.

2.7.3 Waiting Time
The third KPI of the planning process is the average waiting time of the clients. The waiting time is measured in terms of the time between the arrival of a client at the clinic and the start time of an appointment. So, the waiting time at home for an appointment is not taken into account.

2.8 The Actual Problem
As already mentioned in section 1.4, Pro Juventus has no insights in the effects of variability of appointment times, and the effects of their client focus with regard to the planning. As a recap, with client focus concerning the planning, it is meant that almost all wishes of clients will be fulfilled. After a thorough analysis of the current situation, several problems can be derived from the situations that could occur on the appointment day as described in section 2.6. The main problem can be found within the daily planning process of Pro Juventus. Due to the fact that Pro Juventus is scheduling both direct and indirect times of an appointment one after another, productivity will decrease if an appointment has ended earlier than scheduled. Due to this productivity loss, less clients can be treated on an appointment day. Therefore, schedules of practitioners are already fully booked for a long time. Besides that, if a day is fully scheduled and an appointment takes longer than scheduled, overtime hours are easily made. Therefore it is important to look at the effects of planning direct and indirect times together or separate. Besides that, it is significant to look at other planning methods that can be used to improve the planning process with regard to the KPIs mentioned above.

Now that more insights have been gained from the analysis of the current situation of Pro Juventus, a literature review can be performed in order to find improvement methods for the problems faced.

3. Literature Review

In this chapter a literature review will be carried out. The goal of this literature review is to answer the following research question: “How can the daily planning process of Pro Juventus be improved?”. This chapter is divided in two sections:

- 3.1 Theory on planning and scheduling
- 3.2 Planning and scheduling in the healthcare industry

3.1 Theory on Planning and Scheduling

In this section the basic concepts of planning and scheduling are introduced. First of all, a definition is given for both planning and scheduling to see the difference between the two. Second, the purpose of planning and scheduling in a company are described and an introduction is made to planning and scheduling in service industries.

According to Slack (1999), planning is defined as the process of reconciling supply and demand (i.e., dealing with capacity decisions). Scheduling is described as defining the sequence and time allocated to the activities of an operation. It is the construction of a detailed timetable that shows at what time or date jobs should start and when they should end (Slack, 1999). An important thing to mention is that the problem of scheduling consist of two steps: sequencing and scheduling (Baker & Trietsch, 2009). In the first step, a sequence is planned or a decision is made on how to select the next task. In the second step, the start time and completion time of each task will be determined. In short, planning concerns the matter of effectively defining what is to be done and how, while scheduling is the decision of when the tasks need to be done.

According to Pinedo (2009), the planning and scheduling functions in a company rely on mathematical techniques and heuristic methods that allocate limited resources to the activities to be done. This allocation of resources has to be done in such a way that the company optimizes its objectives and achieves its goals. In order to improve the planning and scheduling functions, several methods will be discussed in section 3.2.

Describing a generic service organization and its planning and scheduling systems is not as straightforward as describing a generic manufacturing system (Pinedo, 2009). In service industries resources need to be reserved (e.g., meeting rooms or time slots), equipment needs to be allocated (e.g., specialized equipment), and the workforce need to be allocated and scheduled (e.g., shifts in a call center). In this simulation study, the allocation of equipment will not be taken into account, since this is not a core business in the mental healthcare industry, i.e. special equipment is barely needed. Since planning and scheduling systems in service organizations are different from manufacturing systems, only theory on planning and scheduling in service industries will be analyzed. In the section below, a focus is made on planning and scheduling in the healthcare industry.

3.2 Planning and Scheduling in the Healthcare Industry

In this section theory on planning and scheduling in the healthcare industry is discussed. First of all general theory with regard to this subject is presented and afterwards three appointment scheduling methods will be discussed in order to improve the daily planning process of Pro Juventus.

The complete spectrum of health care delivery is a composition of many different services provided by many different organizations (Hulshof, Kortbeek, Boucherie, & Hans, 2012). However, from a resource capacity planning and control, different services may face similar questions. Therefore, Hulshof, Kortbeek, Boucherie & Hans (2012) have identified a clustering of six care services. The cluster that is applicable for Pro Juventus is the ambulatory care service, which is defined as a care provider to patients without offering a room, a bed and board. In addition, an ambulatory care service may be free-standing or part of a hospital. In the literature review, the focus will therefore be on theory that is focused on the planning, specifically appointment scheduling, within ambulatory care services.

Appointment scheduling comprises the design of blue prints that can be used to provide a specific date and time for patient consultation. The objectives of this design are generally to reduce the waiting of a patient or client, to maximize resource utilization (in this case the productivity of the practitioners) or to minimize resource overtime (in this case the overtime hours made by practitioners) (Hulshof et al., 2012). According to Ho and Lau (1992), there is a key trade-off between patient waiting time and resource waiting time. If someone wants to decrease the patient waiting time, the resource waiting time will increase, which results in a lower productivity. According to Hulshof, Kortbeek, Boucherie & Hans (2012) there are six frequently modeled aspects that influence the performance of an appointment schedule: patient punctuality, patients not showing up, walk-in patient or urgent patients, doctor lateness at the start of a consultation session, doctor interruptions, and the variance of consultation duration. In this simulation study, the focus is on the variance of consultation duration.

As already mentioned, there is a trade-off between patient waiting time and resource waiting time. This is also depicted in figure 4 below from Welch & Bailey (1952), where an example is shown of clinics where 25 patients are scheduled on one day with an average appointment time of five minutes, and an appointment interval with exactly five minutes. The appointment interval is the interval between two successive appointment times (Cayirli & Veral, 2003). The trade-off between patient waiting time and resource waiting time would look like figure 4. In this figure Welch & Bailey assume that the appointment times are independent identically distributed following a Gamma-distribution.

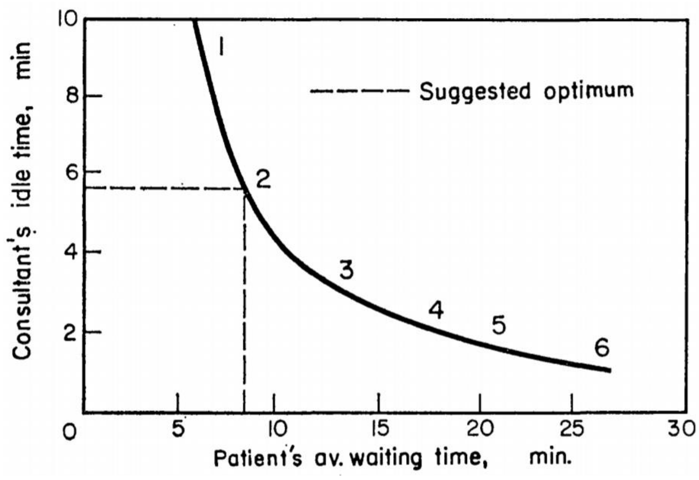

Figure 4 - Trade-off between Consultant's idle time and Patient's waiting time (Welch & Bailey, 1952)

In addition to the above mentioned key performance indicators of appointment scheduling (patients' waiting time and practitioner's idle time), Cayirli and Veral (2003) discuss another frequently used key performance indicator in the healthcare industry: the overtime hours made by practitioners. According to Cayirli and Veral (2003), a "reasonable" trade-off level between those key performance indicators is to be decided subjectively by the decision-maker.

Below, the following three key decisions are discussed in order to improve the process of appointment scheduling: the length of the appointment interval, the sequence of appointments, and queue discipline in the waiting room. In chapter 6 these key decisions are used as experiments of the simulation model.

The Length of the Appointment Interval

As already mentioned, the appointment interval is the interval between two successive appointment times. To clarify, if a patient is scheduled at 9:00 and the next patient is scheduled at 9:10, the appointment interval is 10 minutes. Generally, according to Fetter and Thompson (1966), the length of the appointment interval and the resource idle time are positively correlated, so if the length of the appointment interval decreases, the resource idle time will also decrease. The patients' waiting time is however negatively correlated with the length of the appointment interval. If the length of the appointment interval decreases, the patients' waiting time will increase. The length of appointment intervals can be constant or variable. According to Cayirli and Veral (2003), there are seven appointment rules that can be used to schedule patients. In this simulation study only the second appointment rule that is mentioned by Cayirli and Veral (2003) is used, which is the individual-block/fixed-interval rule. As the name of the rule already says, clients are scheduled individually during an appointment slot and the length of the appointment interval is fixed.

The Sequence of Appointments

In this section the importance of the sequence of appointments will be discussed. According to Hulshof, Kortbeek, Boucherie & Hans (2012), when different patient groups are involved, the sequence of appointment influences waiting times and resource utilization. In a lot of sequencing methods, scheduling of multiple clients during one timeslot is involved. Due to the sometimes long appointment times, this is not possible for Pro Juventus. Therefore, these methods are not taken into account. From a paper of Klassen and Rohleder (1996), patients can be classified based on their expected service time variability. According to their simulation, it is better to plan patients with a relatively low expected service time variability at the beginning of a session and the patients with a relatively high expected service time variability at the end of a session.

The Queue Discipline in the Waiting Room

In this section the importance of the queue discipline in the waiting room will be discussed. According to Hulshof, Kortbeek, Boucherie & Hans (2012), the queue discipline in the waiting room affects patient waiting time. In most cases, the queue discipline in the waiting room is first-come, first-served (FCFS). This is however, not always an optimal discipline. In most cases, a queue discipline is used when emergency patients or walk-in patients are included into the planning process.

Now that theory is found on appointment scheduling techniques to improve the daily planning, a conceptual model of the simulation model can be constructed. The conceptual model of the planning process of Pro Juventus can be found in chapter 4.

4. Conceptual Model

In this chapter the conceptual model of the simulation model will be presented and therefore the following research question will be answered: "How does the conceptual model of the daily planning of Pro Juventus look like?" This chapter consists of the following parts:

- 4.1 Assumptions
- 4.2 Input variables
- 4.3 Output variables

4.1 Assumptions

This section answers the question: "Which assumptions can be made in the simulation model?". Below, all assumptions that are made in the simulation model are listed. In total there are 13 assumptions listed.

Remaining appointments

In the available data there are a lot of appointment types that have only occurred for a few times from the 1st of January 2018 till the 24th of April 2019, which can be seen in C. Therefore, these appointments will be grouped into "remaining appointments" in the simulation model.

The same specializations can perform the same tasks

From the obtained data it can be seen that two practitioners with the same specialization perform slightly different tasks. An example can be seen below where two coaches perform different tasks (the purple filled cells). For the simulation model the assumption is made that the same specializations can perform the same tasks.

Coach 1		Coach 2	
1	**3.1.2.1**	1	3.1.4.4
04	**3.1.3.8.2**	04	3.1.4.6
06	3.1.4.1	06	**4.2.1**
08	3.1.4.4	08	7.1
10	3.1.4.6	10	7.3
2.1	7.1	2.1	**7.4**
2.12	7.3	2.12	7.5
2.13	7.5	2.13	A02
3.1.1.1	A02	3.1.1.1	**A13**
3.1.1.2	A15	3.1.1.2	A15
3.1.1.4	A19	**3.1.2.4**	A19
3.1.1.6	A22	3.1.4.1	A22

Table 1 - Same specializations can perform the same tasks

There is no seasonal demand

In reality it could occur that there is seasonal demand for mental healthcare. Though, this will not be very significant and is therefore not taken into account into the simulation model.

Data from 2018 and 2019

Data of the appointments is available since Pro Juventus started their business in 2009. Though, for the analysis of the interarrival times and length of the appointments, only the data from the 1st of January 2018 till the 24th of April 2019 is used. This is done, since Pro Juventus has experienced an immense growth over the past years as can be seen in figure 2. If the data from earlier years is used, the interarrival times will be higher than they actually are. Therefore, this data will not present the current situation of arrivals. Besides that, the data will not present the length of the appointments since several appointments have changed over the past years.

Each practitioner has the same processing speed

In reality, it could be the case that there is a distinction between the processing speed of different practitioners for the same appointment. With processing speed the speed of processing an appointment, both direct and indirect time, is meant. In the simulation this distinction is not taken into account.

No appointments with multiple practitioners

In the simulation model, there are no appointments with multiple practitioners. In reality there are appointments in which multiple practitioners are involved. Most of the times this is a multidisciplinary consultation, which is a conversation between practitioners to discuss the status and treatment of a client. Appointments with multiple practitioners are not taken into account, since it will make the simulation model a lot more complex. Though, if for example there was an appointment with three practitioners, this appointment will arrive three times in the simulation model. Therefore, the workload will still be the same.

No emergency clients

In reality sometimes emergency clients could show up. It is not known exactly how many clients are emergency clients, but according to some employees an emergency client arrives less than once a week. This is less than 0,07% of the total appointments and is therefore not taken into account.

There are no No-Shows < 24 hours

As already mentioned in section 2.6.3 the number of no-shows (< 24 hours) over the period of 1 January 2015 till 11 February 2019 is 1,275%. This amount is a lot, but due to the fact that according to the data the number of no-shows decreased over the past years, and due to an increase in costs for the clients as a result of a new no-show policy, it is assumed that the number of no-shows will be negligible.

The are no cancellations > 24 hours

In the simulation model, the cancellations that occur more than 24 hours before the appointment will not be taken into account. This is not taken into account due to two reasons. First of all, looking at Medicore, it is most of the times possible to reschedule a client during that time, and second, the input data for the simulation model will be the appointments that have been executed. Therefore, the cancellations > 24 hours are not included in the number of client arrivals.

Maximum scheduled hours

The maximum scheduled hours per practitioner on a day are equal to the hours that a practitioner is working on a day. So, as an example to clarify, if a practitioner is working six hours on a Monday, the maximum scheduled sum of the appointment times should be equal or smaller than six hours.

Clients arrive on time

In the simulation model all clients arrive exactly at the clinic on their appointment time and can therefore be treated from that time if the practitioner is available.

Processing times are variable

In the data that is received, all processing times are rounded to five minutes. In reality this is not the case. Therefore, it is assumed that the actual processing time is a variable number between two and a half minutes before the registered processing time, and two and a half minutes after the registered processing time.

The chances of accepting an appointment day

In the simulation model it is assumed that a client is accepting a random appointment day with a probability of 50%. To clarify, for example the client will accept an appointment on a Monday with a probability of 50%.

4.2 Input Data

In this section the following research question will be answered: "What is the input data for the simulation model?". The input data will be divided into three main parts: arrival data, practitioner data and appointment length data.

4.2.1 Arrival Data

The following arrival data are input for the simulation model: the interarrival times between consecutive appointments and the appointment type distribution. Below the data of these two are presented.

Interarrival Times

Before the data of the interarrival times will be shown, first a definition about interarrival times is given to clarify this input variable. The interarrival time is defined as the time between the "start" of two events. In this case, the start of an event will be the arrival of a client. So, the interarrival time is the difference between the arrival of two consecutive clients. In order to be as accurate as possible in analyzing the interarrival times of the clients, only the data from 2018 and 2019 is used. This is done, since Pro Juventus has faced an immense growth in activities over the past years as discussed in section 2.1. If the interarrival times from a longer time ago will be used, the simulation will not represent reality.

Below in figure 5 the interarrival times are shown in a graph. However it seems that the interarrival times are following an exponential distribution, according to calculations in Minitab this is not the case, as can be seen in Appendix F. Therefore, a histogram of the interarrival times will be used in the simulation model. In order to create a histogram that will represent reality it is significant to choose the bin-width that is appropriate for the data. In order to choose the correct bin-width two formulas are used. Scott's rule (1979) is the first:

$$h_n = 3{,}49 s n^{-1/3}$$

Where h_n is the bin-width if there are n observation with an estimated standard deviation s. The second rule that is used is devised by Freedman & Diaconis (1981) and is formulated as follows:

$$Bin\ width = \frac{2 * IQR(x)}{\sqrt[3]{n}}$$

Where $IQR(x)$ is the interquartile range of the data of sample x with n observations.

Eventually to calculate the bin-width of the histogram, the mean of these two formulas is taken. In this case the bin-width is 139,8 seconds. The input data that is used in the simulation model for the interarrival times is an empirical distribution, which represents ranges of data values. According to Robinson (2014), these should be treated as a continuous distribution so values can be sampled anywhere in the range. This theory is therefore applied with regard to the interarrival times. In the simulation model, a random number will therefore be drawn between the start of a bin and the end of a bin (e.g. between 0 and 139,8 seconds or between 139,8 and 279,6 seconds). The histogram that is used in the simulation model can be found in Appendix G.

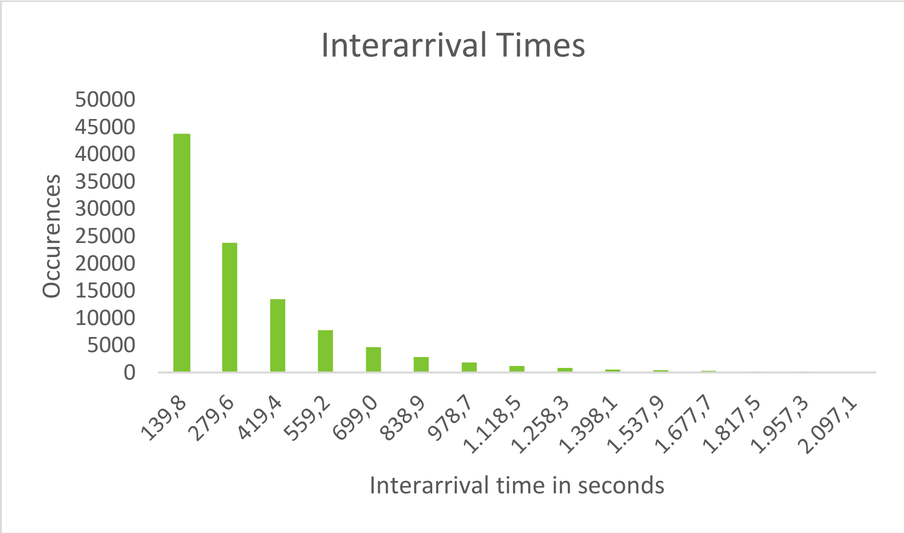

Figure 5 - Interarrival times of Clients

Appointment Type Distribution

In order to determine the appointment type of an arrival, an appointment type distribution is made. In this distribution, the probabilities of having a specific appointment are calculated. This is done by analyzing how many times a specific appointment type occurred in 2018 and 2019. In Appendix H the appointment types with corresponding probabilities of occurrence can be found.

4.2.2 Practitioner Data

The following practitioner data are input for the simulation model: the working hours per week per practitioner, the probabilities of assigning an appointment to a certain specialization and the probabilities of assigning an appointment to a certain practitioner. In this section, these three input data are presented. As already mentioned in chapter 2, there are currently 74 practitioners working at Pro Juventus. Since the focus of this research is to improve the daily planning per practitioner, all practitioners will be included in this simulation.

Working Hours per Week

Since all practitioners will be included into this simulation, as mentioned above, the working hours per week per practitioner serve as input of the simulation. To clarify the term working hours per week, this means the actual working hours per week, so not the contractual hours. Thus, the working hours are the contractual hours excluding holidays and sick days. According to Intermediair (2013), the average person in the Netherlands has 30 days off if he or she is employed full time. This will be calculated pro rata. Besides this, according to the Central Bureau of Statistics (CBS, 2019), the sickness absence rate in the Netherlands was 4,3% in 2018. In addition, the CBS says that the sickness absence rate in healthcare is higher, but for smaller enterprises the sickness absence rate is lower. Therefore, the average sickness absence rate of 4,3% will be used in the simulation model. Below the actual working hours per contractual hour will be calculated:

$$Working\ hours\ per\ contractual\ hour = 1 - \frac{(Days\ off + sickness\ absence\ rate * working\ days) * 8}{Contractual\ hours\ per\ year}$$

$$Working\ hours\ per\ contractual\ hour\ =\ 1 - \frac{\big(30 + 0{,}043 * (52 * 4{,}5 - 30)\big) * 8}{36 * 52} \approx 0{,}8343$$

In Appendix I all contract hours and actual working hours per week can be found. As can be seen, for the input of the simulation model, the actual working hours are round on half hours. This is done for convenience, since it will not influence the output of the simulation significantly.

Appointments Assigned to a Specialization

As already mentioned in section 4.1.3, if a practitioner has the same specialization as another practitioner, they can both perform the same appointment types. If the appointment type of a client is established, he or she will first get assigned to a specialization in the simulation model. In order to do this, first the appointment types that a certain specialization can perform are determined. The appointment types per specialization can be found in Appendix D. Afterwards, the probabilities of assigning an appointment type to a specialization have been determined. This is calculated by dividing the total contractual hours for a specialization divided by the total contractual hours of all specializations that can perform a certain appointment types. The contractual hours per specialization can be found in Appendix B. For this calculation it does not matter whether the contractual working hours or the actual working hours are used, since the probabilities will be relative to the total contractual or actual working hours respectively. To clarify the description above, the following example is given: a client arrives at the clinic and needs an appointment type 04. The probability that he or she will get assigned to a psychomotor therapist is $\frac{Contractual\ hours\ psychomotor\ therapist}{Total\ contractual\ hours - contractual\ hours(parent\ mentor + trainee)} = \frac{152}{1879} \approx 0{,}0809$. The cumulative probabilities of the assignment of appointment types per specialization can be found in Appendix J.

Appointments Assigned to a Practitioner

Once the client is assigned to a particular specialization, he or she needs to be assigned to one of the practitioners within that specialization. This is done by evaluating the probabilities of assigning a client to a practitioner taking into account the contractual hours per practitioner. The contractual hours per practitioner can be found in Appendix I and the cumulative probabilities of assigning a client with a certain specialization to a practitioner can be found in Appendix K.

4.2.3 Appointment Length Data

The following two appointment length data are input for the simulation model: the appointment length distributions per appointment type and the distributions of the processing times per appointment length per appointment type.

Appointment Length Distributions

Generally, every appointment type has its own standard appointment length in Medicore. Once a practitioner or the secretary is planning a certain appointment there will always be a standard length that is scheduled. Though, it is possible to change this standard time and to make the appointment longer or shorter. According to the data this happens too often to neglect this. Therefore, the appointment length distributions are determined for every appointment type. Once the appointment type for a client is determined, the scheduled direct and indirect time of an appointment will be determined.

Processing Time Distributions

With the input variable above, the scheduled appointment length has been determined. However, the actual appointment or processing time could variate from the initially scheduled time for that appointment. Therefore, the processing times per appointment length per appointment type have been determined. To clarify, if for example an appointment type 04 is scheduled for 30 minutes indirect time, it could actually take 25 minutes or 35 minutes.

4.2.4 Conceptual Model of the Simulation Model

In figure 6, the conceptual model of the simulation model can be seen. There is one thing that is significant to mention that is not included in the conceptual model below. If a client arrives at the clinic while a practitioner is handling indirect tasks, the practitioner will directly quit doing indirect tasks and he or she will start treating the arrived client. Once the client is treated and no other clients are in the waiting room, the practitioner will continue working on the indirect tasks where he left.

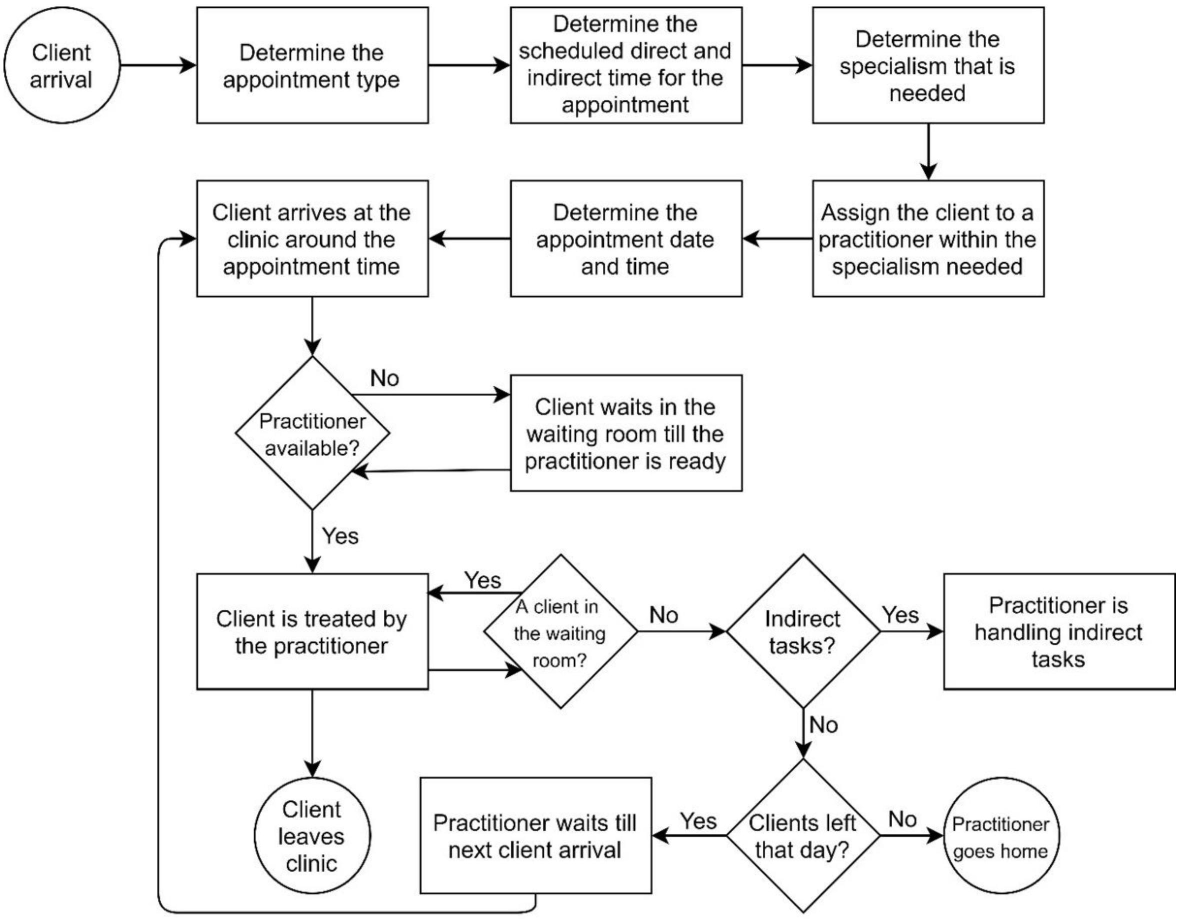

Figure 6 - Conceptual Model of the Simulation Model

4.3 Output Data

In this section the following research question will be answered: “What is the output data for the simulation model?”. The output variables in this section are already mentioned in section 2.7: The overtime, productivity and waiting time.

4.3.1 Overtime Hours

The overtime hours are all hours that a practitioner has worked after their contractual hours. For most of the practitioners this will be hours made after five o’clock in the afternoon. However, this will not always hold since some of the practitioners stop working around three o’clock in the afternoon sometimes. If they work after three o’clock this will count as overtime. In addition, if a practitioner is working during break hours, this will be seen as overtime hours. In the simulation model every practitioner has a break from 12:30 till 13:00. The following KPI is drawn from the overtime hours: the average percentage of overtime hours on one day divided by the total hours worked on one day. This KPI is calculated for every day and at the end of the simulation the average of all days is calculated.

The number that is calculated at the end of the simulation will be the main KPI for the overtime hours of the practitioners.

4.3.2 Productivity

This variable will measure the productivity of the practitioners. The productivity is measured in terms of written time per working hour. The written time consists of direct time, indirect time and travel time. Once a practitioner has executed a task, he can write down the direct, indirect and travel time that he has spent on that task in Medicore. From the simulation, first of all the average productivity per day will be calculated for all practitioners. Eventually, at the end of the simulation an average number of the productivity of all days will be calculated, excluding the days that nobody is working (Saturdays and Sundays). This number is the main KPI for the productivity of the practitioners.

4.3.3 Waiting Time

The waiting time is the time that a client is waiting at the clinic between the scheduled start of the appointment and the actual start of the appointment. In the simulation model this is first of all calculated per day, so the average waiting time of all clients on one day is taken and calculated for all days. At the end of the simulation an average of all these days is taken. This number will be the main KPI for the waiting time of clients.

Now that the conceptual model of the planning process of Pro Juventus, the input data and the output variables are determined, the conceptual model needs to be implemented into a simulation model. This will be done in the next chapter.

5. Implementation, Verification and Validation of the Simulation Model

In this chapter, the simulation model will be implemented, verified and validated in line with some common used techniques. In this chapter the following research question will be answered: “How can the simulation model be implemented, verified and validated?”. Before the simulation model will be implemented, theory about simulation model designs is discussed to determine which simulation model design will be most appropriate for this simulation study. This chapter is structured as follows:

- 5.1 Theory on simulation model designs
- 5.2 Implementation of the simulation model
- 5.3 Verification and validation of the simulation model

5.1 Theory on Simulation Model Designs

There are a lot of different model designs for a simulation. Therefore it is first of all important to determine which type of simulation model is appropriate for the simulation study. According to Banks and Carson (1984), there are three dimensions which distinguish different types of simulation models. These three dimensions are listed below.

- Static vs. dynamic simulation models: a static model is a representation of a system at a particular time, whereas a dynamic model represents a system as it evolves over time.
- Deterministic vs. stochastic simulation models: a deterministic model has a known set of inputs which will result in a unique set of outputs. A stochastic model has one or more random variables as input. Due to these random input, the output will also be random and can therefore be considered only as an estimate of the true characteristics of a model.
- Continuous vs. discrete simulation models: in a discrete model the state variables only change at a discrete point in time, whereas a continuous model is one in which the state variables change over time. Where the state of a system is the collection of variables necessary to describe the status of the system at any given time (Winston, 2004).

In this research, a Dynamic Stochastic Discrete Event Simulation (DSDES) is chosen as the type of simulation model design. First of all, the simulation model is dynamic, since the simulation model will represent a system as it evolves over time. Secondly, it is stochastic since it will contain multiple random input variables, such as the length of the appointment times and the interarrival times. Lastly, the simulation model will be discrete since the state variables change at a discrete point in time, e.g. if a new client arrives or if an appointment is finished. Now that the type of simulation model design is determined, the conceptual model can be implemented into a simulation model, which is discussed in the following section.

5.2 Implementation of the Simulation Model

This section answers the question: “How can the conceptual model be implemented into a simulation model?”. In this section the simulation model that is created will be shown and a description about the working of the simulation model can be found.

In figure 7, a simplified version of the simulation model of Pro Juventus can be seen. A simplified version is shown, since the actual model was too big to present in this chapter. The actual simulation model can however be found in Appendix L. The difference between the actual simulation model and the model below is the process at the clinic in the green box. In the actual model there are 74 practitioners, 74 queues with appointment types and 74 schedules for each practitioner. Below, a description is given per colored box.

The Red Box

In the red box various information about the simulation can be found. As can be seen, the number of clients, the day number and the day of the week can be seen. The variables “BreakNr” and “EndBreakNr” are used together with the methods “GenerateBreakMUs” and “DeleteMUsEndBreak” to generate the break from 12:00 till 12:30 and to calculate the overtime hours during the break. In the table “Clients”, the clients that are currently active in the system can be found and information about those clients, such as appointment time and their waiting time can be found. The table “DayInTheWeek” is used as input for code in several methods. It contains the day number and the day of the week. In the table “WorkingDaysPractitioner”, the days plus the hours that a practitioner is working at a certain day can be found. So, for example it can be seen that psychiatrist2 is working four hours on Tuesday. The days at which a practitioner is working is randomly generated at the beginning of the simulation. Normally, a practitioner works 8 hours a day if his or her contractual hours allow this (e.g. a practitioner with 20 contractual hours works two days of eight hours and one day for four hours).

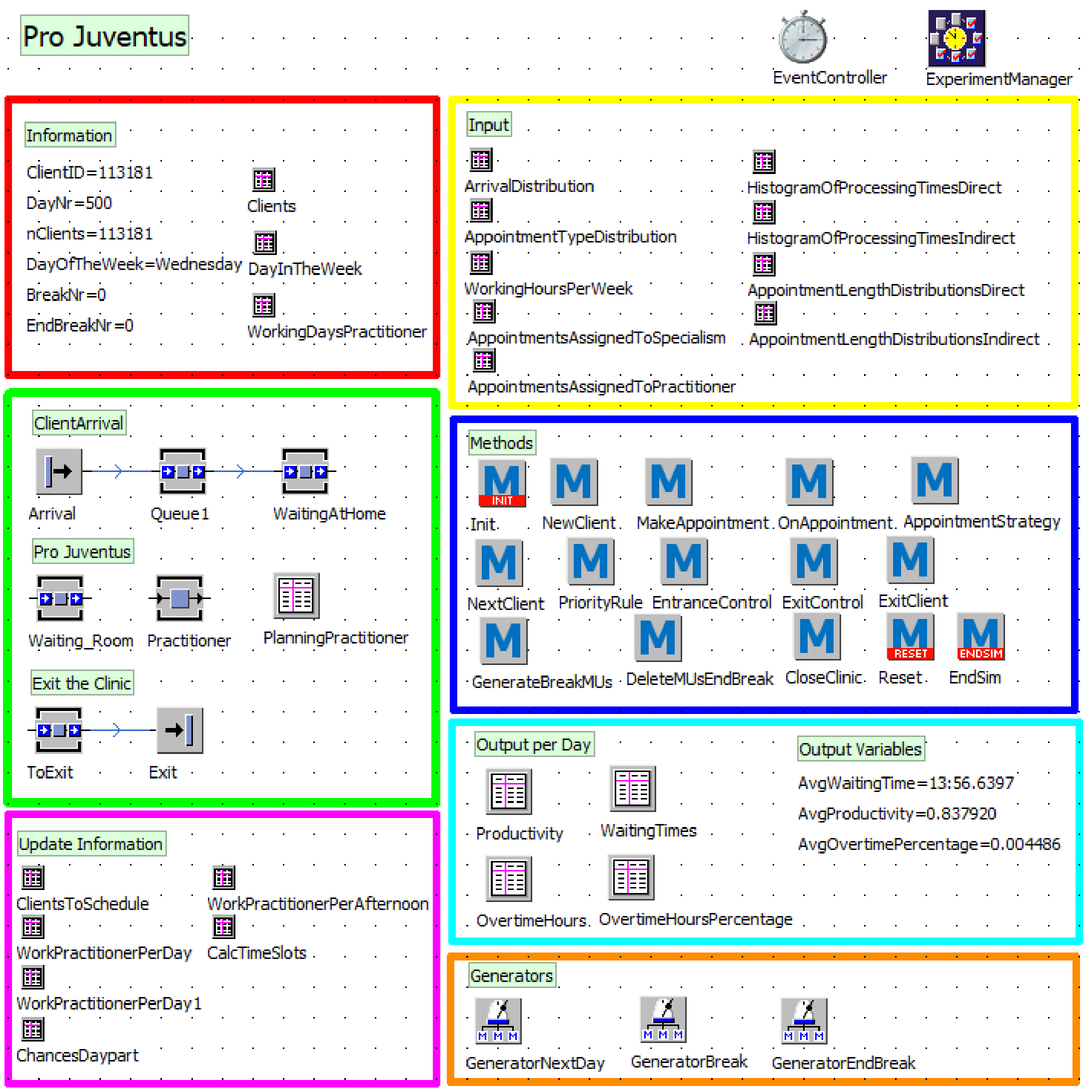

Figure 7 - The Simplified Simulation Model of Pro Juventus

The Yellow Box

In the yellow box all the input variables of the simulation can be found. An explanation about these input variables can be found in section 4.2.

The Green Box

In the green box the core of the simulation model can be seen. First of all clients arrive according to the distribution that can be found in the input variable "ArrivalDistribution". Afterwards, the appointment type, the specialization that is needed, the assigned practitioner, the scheduled appointment length and the appointment time will be determined. Once the time of the simulation is equal to the appointment time, the client will move to the waiting room and if the practitioner is ready, the client will have his or her appointment. Subsequently, the processing time of the appointment will be determined with the distributions from the tables "HistogramOfProcessingTimesDirect" and "HistogramOfProcessingTimesIndirect". If a client arrives at Pro Juventus and the practitioner is busy with indirect time tasks, the indirect times will be set back to the waiting room and the practitioner will help the client. Eventually when the practitioner has finished both direct and indirect time of a client, he or she will move to "ToExit", which stores information of the client about waiting times. Afterwards the client will leave the system.

The Dark Blue Box

In the dark blue box all methods are presented. In these methods, all code that has been programmed in order to run the simulation in line with reality are shown. These methods are amongst others used to calculate the output variables, to schedule clients and to move clients in the correct way through the model.

The Purple Box

In the purple box information is stored and updated during the simulation. In the table "ClientsToSchedule" all new clients that arrive on a day will be stored. All the other tables are used to calculate the appointment times of all clients in the table "ClientsToSchedule" at the end of the day.

The Light Blue Box

In the light blue box the output variables that are mentioned in section 4.3 are presented. As can be seen both the output per day and the average output over all these days can be found.

The Orange Box

In the orange box three generators can be found. These generators are used to generate the start and the end of the break, to store stats of the past day and to schedule new clients.

5.3 Verification and Validation of the Simulation Model

In this section the following question will be answered: "How can the simulation model be verified and validated?". In order to understand the difference between the two main concepts in this section, a definition is given for both verification and validation. According to Schlesinger et al. (1979), model verification is defined as: "ensuring that the computer program of the computerized model and its implementation are correct". Model validation is defined as: "substantiation that a computerized model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model" (Schlesinger et al., 1979). In this section, several verification and validation techniques that have been used in this simulation study will be presented.

5.3.1 Validation

In this section first of all four basic validation approaches will be discussed. Secondly, two validation processes will be described. Afterwards, the validation techniques that have been used in this simulation study will be presented and eventually a description will be given about how the simulation model is validated.

Basic Validation Approaches

According to Sargent (2005), there are four basic approaches for deciding whether a simulation model is valid. The first is for the model development team itself to make the decision as to whether a simulation model is valid. However, if the size of the simulation team developing is not large, this is not a good approach. Therefore, this technique is not used in this simulation study. The second validation technique mentioned by Sargent (2005) is to have the user(s) of the model heavily involved with the model development team in determining the validity of the simulation model. The third approach is called "independent verification and validation" (IV&V). This technique uses a third party to decide whether the simulation model is valid. The fourth and last approach for determining whether a model is valid is to use a scoring model. In this scoring model weights or scores are determined subjectively when conducting various aspects of the validation process. Once this is done the total score will be calculated. If the score passes a certain threshold, the simulation model is seen as a valid model. In practice this approach is seldom used.

Validation Processes

Within the above mentioned approaches there are two validation processes that always need to be considered. According to Sargent (2005), these two are conceptual model validation, which is the connection between the real world and the conceptual model, and operational validation, which is the connection between the computerized model and the real world. Conceptual model validation consists of determining whether or not the content, assumptions and simplifications of the proposed model are sufficiently accurate for the purpose at hand (Robinson, 2014). Operational validation is defined as determining that the model's output behavior has sufficient accuracy for the model's intended purpose over the domain of the model's intended applicability (Sargent, 2005).

Validation Techniques

According to Robinson (2014) operational validation consists of two techniques. The first being white-box validation, which is a technique that determines if the constituent parts of the computer model represent the real world with sufficient accuracy. The second technique is black-box validation, which is a macro check of the model's operation. These two validation techniques are both used in this simulation study. Besides the above mentioned, Sargent (2005) addresses a few other validation techniques that also have been used to validate the simulation model. The first technique is the extreme condition test. Within this test the model structure and outputs should be plausible for any extreme and unlikely combination of levels of factors in the system. The second technique that is used is internal validity, where several replication runs of a stochastic model are made to determine the amount of (internal) stochastic variability in the model. In chapter 6, methods are described to cope with internal validity, such as the number of replications. The third and last validation technique that is used is sensitivity analysis. This technique consists of changing the values of the input of a model to determine the effect upon the model's output.

Validation of the Simulation Model

In this simulation study the second and third validation approach, as discussed under the heading "Basic Validation Approaches", have been used to validate the simulation model. First of all, the director of Pro Juventus was involved in the validation of the simulation model. This was done by stepping through the logic behind the conceptual model and the programmed code, which is white-box validation. Additionally, the logic behind the simulation input and output have been discussed, which is black-box validation. Secondly, a few fellow industrial engineering & management students were involved in the validation process of the simulation model, particularly in the white-box validation of the simulation model.

5.3.2 Verification

In this section theory about verification methods and one verification technique that is used are presented.

Sargent (2005) describes one major verification process that should be taken into account while verifying the simulation model. The process mentioned is computerized model verification, which is the connection between the conceptual model and the computerized model. When a simulation language is used, according to Sargent (2005), verification is primarily concerned with ensuring that an error free simulation language has been used, that the simulation language has been properly implemented on the computer, that a tested pseudo random number generator has been properly implemented, and the model has been programmed correctly in the simulation language. In order to test simulation software two basic approaches have been distinguished by Fairley (1976): static testing and dynamic testing.

In this simulation model a static testing method is used called structured walk-throughs. In structured walk-throughs, the programmer explains the logic of the algorithm, while members of the programming team step through the program logic. Since nobody at Pro Juventus can understand the programming language that is used in this simulation study, fellow industrial engineering & management students were asked to play the role of the programming team. The major objective of a structured walk-through is to find errors and to improve the quality of the simulation.

Now that the base model of the simulation model is created, experiments need to be executed in line with the theory that has been obtained in chapter 3. In the next chapter, these experiments will be executed and the results of these experiments will be shown.

6. Experiments

In this chapter the following research question will be answered: "Which experiments will be conducted in the simulation study and what is needed to execute the experiments?". In order to answer this question, first of all, theory is presented about simulation experimentation. Afterwards, the experiments that will be executed are presented and eventually the results of the experiments will be presented. Therefore, this chapter is structured as follows:

- 6.1 Theory on Simulation Experimentation
- 6.2 Simulation Experiments
- 6.3 Experimentation Results

6.1 Theory on Simulation Experimentation

During the experimentation phase of the simulation model the aim is to obtain a better understanding of the real world system and to improve that system. In the experimentation phase of the simulation, there is one major issue, which is to ensure that accurate results on model performance will be obtained from the simulation model. In this section, methods will be discussed to obtain accurate data on the performance of the model. According to Robinson (2014), this does not say anything about the accuracy of the model with regard to the real system. This is the concern of model validation which is already discussed in chapter 5.

The main aim of simulation output analysis is to obtain an accurate estimate of average (normally the mean) performance, although measures of variability are also important (Robinson, 2014). In order to do this, there are two issues that need to be taken into account: the removal of initialization bias, and ensuring that enough output data have been obtained in order to get accurate estimates of the performance. Below, methods are discussed to cope with these issues.

The Removal of Initialization Bias

In order to solve the first issue, the removal of initialization bias, there are two ways: run the model for a warm-up period, or set initial conditions in the model. For this research the warm-up period of a simulation model will be used. According to Law and Kelton (2000), Goldsman and Tokol (2000) and Alexopoulos and Seila (2000), Welch's method is a good way to determine the warm-up period of a simulation model. Therefore, this method is used. Welch's method (1983) is a method based on the calculation and plotting of moving averages. Where the moving averages are calculated using the following formula:

$$\bar{Y}_i(w) = \frac{\sum_{s=-(i-1)}^{i-1} \bar{Y}_{i+s}}{2i-1} \qquad if\ i = 1, \dots, w$$

$$\bar{Y}_i(w) = \frac{\sum_{s=-w}^{w} \bar{Y}_{i+s}}{2w-1} \qquad if\ i = w+1, \dots, m-w$$

Where:

$\bar{Y}_i(w)$ = moving average of window size w
$\bar{Y}_i$ = time-series of output data (mean of the replications)
i = period number
m = number of periods in the simulation run

Once the moving averages are calculated and plotted in a graph, the warm-up period can be determined. The warm-up period is selected by identifying the point where the line becomes flat (Robinson, 2014). To calculate the warm-up period, the moving averages for all three output variables that are described in section 4.3 are created. In order to ensure that the moving averages for all three output variables are reliable, 10 replications are performed. Subsequently the mean of the moving averages is taken to plot the three graphs. As can be seen in the graphs in Appendix M, the warm-up periods for the three output variables: waiting time, productivity and overtime hours are respectively 32 days, 32 days and 35 days. In order to provide accurate simulation outputs, the longest warm-up period is chosen, otherwise this output variable could not be reliable. In addition, in order to deal with uncertainty in other experiments, it is favorable to overestimate the warm-up period. Therefore, the warm-up period that is used in the simulation is 40 working days, excluding Saturdays and Sundays. Therefore, the real warm-up period will be 56 days.

Obtaining Accurate Output Data

Once the warm-up period is determined, the second issue that is described above needs to be solved: ensuring that enough output data have been obtained. In order to solve this issue, there are two solutions. The first is to execute multiple replications of the simulation model. The second solution is to perform a single long run. According to Robinson (2014), it is not easy to calculate the confidence intervals from a single time-series, since the data are likely to be correlated. Since the confidence intervals of the output will be significant in this simulation study, only the calculation of the number of replications will be discussed. For this calculation two methods can be used: the graphical method (Robinson, 2014) and the confidence interval method (Robinson, 2014). In this study only the graphical method is used. Below, the graphical method is explained.

The graphical method is an approach to plot the cumulative mean of the output data from a series of replications. According to Robinson (2014), it is recommended to perform at least 10 replications initially. If the cumulative mean is still variating a lot after 10 replications, more replications are needed to flatten the plot of the cumulative mean. The required number of replications is defined by the point at which the line becomes flat. Before the replications can be executed, the run-length of the simulation model need to be determined. According to Banks et al. (2001), the run-length should be at least 10 times the length of the warm-up period. As can be seen in the graphs in Appendix N, the number of replications are analyzed for all three output variables that are discussed in section 4.3. To determine the number of replications, the highest number of the three output variables is used. This is done, so that all plotted graphs of the output variables become flat. According to Robinson (2014), theoretically, the number of replications should however be calculated for all experiments. In practice, the number of replications is determined from the base model and could then be applied to all other experiments. To give a margin of safety, it is worth to overestimate the number of replications that are needed. Following the output variables of the base model, the number of replications that are needed are 10 replications. However, in order to give a margin of safety, the number of replications that will be used per experiment are 15 replications.

6.2 Simulation Experiments

Now that the initialization bias is removed and the number of replications are determined, the experiments that are performed in line with the planning techniques discussed in chapter 3 will be described in this section.

6.2.1 The Length of the Appointment Interval

As discussed in chapter 3, the length of the appointment interval influences the idle time of practitioners, and therefore the productivity, and the patients' waiting time. In chapter 3 theory is discussed with regard to the second rule of Cayirli and Veral (2003), which is the individual-block/fixed-interval rule. In this rule, clients are scheduled according to a fixed appointment interval. In this theory, Cayirli and Veral only take one distribution of the processing time into account. Since at Pro Juventus there are multiple appointment types with different processing time distributions, the appointment intervals will be fixed per appointment type. So, for example, for every appointment type A02 that is scheduled, the appointment interval is the same. However, the appointment intervals between the appointment types A02 and A03 may differ.

In addition to the different appointment types that Pro Juventus is facing, the planning with regard to direct and indirect planning is different than is used in most theory about the length of the appointment intervals. To cope with this, experiments will be executed where both the length of the appointment intervals of the direct time and the indirect time of an appointment will be changed. Since appointment times will differ per appointment type, a percentage change of the appointment interval is made per experiment.

First of all, experiments will be executed with the change in the length of the direct appointment intervals. Afterwards this will be done for the length of the indirect appointment intervals. If it will be valuable, experiments will be executed that combine the length of the direct and the indirect appointment intervals. The following experiments will be executed:

Experiment	Length of direct appointment interval	Length of indirect appointment interval
1	0%	100%
2	20%	100%
3	40%	100%
4	60%	100%
5	80%	100%
6	100%	100%
7	100%	0%
8	100%	20%
9	100%	40%
10	100%	60%
11	100%	80%

Table 2 - Experiments with the Length of the Appointment Interval

In table 2, the numbers represent the amount of percentage that the appointment interval will be during the experiment relative to the initial scheduled appointment interval. So, if for a certain appointment the indirect appointment interval was initially 60 minutes, in experiment 10, the indirect appointment interval will be 36 minutes.

6.2.2 The Sequence of Appointments

As already mentioned in section 3.2, it is better to plan patients with a relatively low expected service time variability at the beginning of a session and the patients with a relatively high expected service time variability at the end of a session. Therefore, the variability of all appointment lengths per appointment type are analyzed. For this method it is however important to know the clients that need to be scheduled before an appointment time is given. The idea is that clients can choose between certain timeframes in which their appointment will take place. If the timeframe is completely filled with clients, the optimal sequence will be determined. Since the clients that need to be scheduled on a day are generally known long before the appointment day, this is possible. If the timeframe is however not yet filled a long time beforehand, the first clients in that timeframe can already be given an appointment time. If a client arrives after the appointment times are determined in a certain timeframe, it will still be possible to schedule that client in that timeframe if there is room for an extra client. This could however result in a non-optimal sequence. This experiment will be conducted with two timeframes: one in the morning from 08:30 till 12:30 and one in the afternoon from 13:00 till

17:00. First of all, an experiment will be performed without taking into account the variability of the appointment times and afterwards an experiment will be conducted where the variability will be taken into account to see the effects of the variability. The disadvantage of this scheduling method is that the clients will experience some inconveniency, since appointment times will be known shorter before the appointment is taking place.

6.2.3 The Queue Discipline in the Waiting Room

As discussed in section 3.2, a queue discipline is most of the times used when emergency clients or walk-in clients are involved. At Pro Juventus this is not the case. Though, there is a clear queue discipline, which involves the tasks that need to be performed. If both direct and indirect appointment tasks remain in the waiting room, the direct tasks that involve client interaction, are carried out first. If multiple tasks are in the waiting room, a first-come first-served principle is used, since no priority is given to certain clients. In this experiment, the effects of this queue discipline will be analyzed, so an experiment is performed where no queue discipline is used, and an experiment where the above mentioned queue discipline is performed. Further, the queue discipline mentioned above is used in all of the experiments above and below.

6.2.4 Combination of the Three theories

The last experiment that will be carried out is a combination between the three theories that are mentioned above. The best settings of the experiments per theory are used as the combination of the three.

6.3 Experimentation Results

In this section, the experiments discussed in section 6.2 are executed and the results of these experiments will be shown. This section is structured according to the sequence of the experiments mentioned in section 6.2. For all these experiments, the warm-up period and the number of replications determined in section 6.1 are used. These are 56 and 15 respectively. The run-length of the simulation is 556 days. In all tables that will be shown in this section, the left interval and right interval represent the left and right intervals of a 95% confidence interval of the mean of the KPIs.

6.3.1 Results Length of the Appointment Interval

In this section, the result of the experiments that are performed in line with the theory on the length of the appointment interval are shown. In table 3, the output of the experiments for all three KPIs described in section 2.7 can be seen. In this table, the red cells represent the worst outcomes and the green values represent the best outcomes per KPI. To give an indication of the overtime hours, if the worst outcome of 2,3% of overtime is used, the overtime made is equal to about 11 minutes on average per day per practitioner on an 8 hour working day.

As can be seen in table 3, the first experiment, where 100% of the indirect time and 0% of the direct time is scheduled, ranks worst on two KPIs: Waiting time and overtime. Besides that, this experiments scores relatively on productivity and is therefore chosen as the experiment with the worst settings. The best experiment is where 0% indirect time and 100% direct time is scheduled, since it ranks best on productivity and overtime. In addition, this experiment scores relatively high on the waiting time.

Indirect	Direct	Waiting Time	StDev	Minimum	Maximum	Left interval	Right interval
100%	0%	7:49.6423	12,53	7:29.4991	8:18.5331	7:42.6983	7:56.5862
100%	20%	5:37.9399	9,22	5:22.1063	5:53.6920	5:32.8300	5:43.0499
100%	40%	3:39.8575	7,30	3:26.9890	3:50.2990	3:35.8148	3:43.9002
100%	60%	2:23.9949	5,78	2:15.8664	2:34.1229	2:20.7954	2:27.1945
100%	80%	1:59.6815	6,68	1:48.0150	2:11.3202	1:55.9810	2:03.3821
100%	100%	2:12.0780	6,13	2:01.5945	2:23.1865	2:08.6800	2:15.4761
0%	100%	2:37.5225	7,29	2:18.1790	2:49.1651	2:33.4853	2:41.5597
20%	100%	2:31.4413	4,88	2:21.4751	2:43.7480	2:28.7396	2:34.1430
40%	100%	1:49.5867	4,24	1:41.5832	1:56.0943	1:47.2396	1:51.9338
60%	100%	1:49.1067	5,17	1:41.2586	1:59.2788	1:46.2444	1:51.9690
80%	100%	2:01.2959	5,65	1:53.0612	2:14.1896	1:58.1642	2:04.4277

Indirect	Direct	Productivity	StDev	Minimum	Maximum	Left interval	Right interval
100%	0%	64,31%	0,70%	63,22%	65,81%	63,93%	64,70%
100%	20%	64,38%	0,73%	63,28%	65,92%	63,98%	64,78%
100%	40%	64,46%	0,74%	63,25%	65,95%	64,05%	64,87%
100%	60%	64,47%	0,77%	63,23%	66,14%	64,05%	64,90%
100%	80%	64,34%	0,83%	63,12%	66,08%	63,87%	64,80%
100%	100%	64,03%	0,82%	62,67%	65,80%	63,58%	64,49%
0%	100%	70,78%	0,62%	69,85%	72,08%	70,43%	71,12%
20%	100%	70,08%	0,66%	69,15%	71,48%	69,72%	70,45%
40%	100%	66,03%	0,75%	64,91%	67,65%	65,62%	66,45%
60%	100%	65,47%	0,75%	64,38%	67,10%	65,06%	65,89%
80%	100%	65,22%	0,78%	64,03%	66,91%	64,79%	65,66%

Indirect	Direct	Overtime	StDev	Minimum	Maximum	Left interval	Right interval
100%	0%	2,35%	0,10%	2,16%	2,55%	2,29%	2,41%
100%	20%	2,10%	0,09%	1,93%	2,29%	2,05%	2,15%
100%	40%	1,76%	0,08%	1,64%	1,91%	1,72%	1,81%
100%	60%	1,42%	0,06%	1,35%	1,54%	1,39%	1,46%
100%	80%	1,21%	0,05%	1,13%	1,31%	1,18%	1,24%
100%	100%	1,11%	0,07%	1,02%	1,22%	1,07%	1,15%
0%	100%	0,75%	0,03%	0,70%	0,81%	0,73%	0,77%
20%	100%	1,00%	0,04%	0,95%	1,08%	0,98%	1,02%
40%	100%	1,26%	0,05%	1,19%	1,38%	1,23%	1,29%
60%	100%	1,21%	0,06%	1,11%	1,32%	1,18%	1,24%
80%	100%	1,07%	0,05%	0,99%	1,18%	1,04%	1,10%

Table 3 - KPIs for Experiments with the Appointment Interval

6.3.2 Results Sequence of Appointments

In this section, the results of the experiments performed with the theory on the sequence of appointments is presented. In table 4, the left column indicates whether or not the variability of appointment times is taken into account or not. As can be seen in table 4, taking the variability of appointments into account improves the average waiting time of clients a lot, while it does not influence the other two KPIs significantly.

Variability?	Waiting Time	StDev	Minimum	Maximum	Left interval	Right interval
Yes	5:08.5829	7,91	4:51.9501	5:22.5382	5:04.1987	5:12.9672
No	13:41.8747	15,32	13:18.4871	14:08.5125	13:33.3887	13:50.3606

Variability?	Productivity	StDev	Minimum	Maximum	Left interval	Right interval
Yes	77,17%	0,46%	76,55%	78,28%	76,92%	77,43%
No	76,93%	0,43%	76,38%	77,96%	76,69%	77,17%

Variability?	Overtime	StDev	Minimum	Maximum	Left interval	Right interval
Yes	0,39%	0,020%	0,35%	0,42%	0,38%	0,40%
No	0,42%	0,025%	0,37%	0,48%	0,41%	0,43%

Table 4 - KPIs for Experiments with the Sequence of Appointments

6.3.3 Results Queue Discipline in the Waiting Room

In this section, the results of the experiments performed in line with the theory on queue disciplines in the waiting room is shown. As can be seen in table 5, the queue discipline affects the first KPI, the waiting time, significantly. Though, it does not influence the other KPIs considerably.

Queue Discipline?	Waiting Time	StDev	Minimum	Maximum	Left interval	Right interval
Yes	2:12.0780	6,13	2:01.5945	2:23.1865	2:08.6800	2:15.4761
No	6:35.4594	20,01	6:03.6492	7:17.2792	6:24.3714	6:46.5475
Queue Discipline?	**Productivity**	**StDev**	**Minimum**	**Maximum**	**Left interval**	**Right interval**
Yes	64,03%	0,82%	62,67%	65,80%	63,58%	64,49%
No	63,59%	0,79%	62,28%	65,29%	63,15%	64,02%
Queue Discipline?	**Overtime**	**StDev**	**Minimum**	**Maximum**	**Left interval**	**Right interval**
Yes	1,11%	0,07%	1,02%	1,22%	1,07%	1,15%
No	1,20%	0,07%	1,10%	1,38%	1,16%	1,24%

Table 5 - KPIs for Experiments with the Queue Discipline

6.3.4 Results Combination of the Three Theories

In this section, the best result of the three theories that are used above are combined to test whether it is beneficial to combine those. So, variability of appointment times is taken into account and a queue discipline is applied. From table 6 it becomes clear that once the sequence of the appointments is determined, the indirect appointment interval does not affect the KPIs substantially. By altering the indirect appointment interval, the KPIs only change a little bit. Looking at the 95% confidence interval of the waiting times and productivity numbers, it could even be the case that changing the indirect appointment interval does not affect the KPI at all.

Indirect	Waiting Time	StDev	Minimum	Maximum	Left interval	Right interval
0%	5:11.8022	9,83	4:53.1737	5:32.1092	5:06.3552	5:17.2492
20%	5:10.3437	9,89	4:51.9516	5:30.7936	5:04.8665	5:15.8208
40%	5:04.1658	9,85	4:45.5936	5:24.6862	4:58.7076	5:09.6240
60%	5:01.6226	9,79	4:42.8194	5:21.5683	4:56.1999	5:07.0454
80%	5:04.7933	9,98	4:45.9220	5:24.7104	4:59.2632	5:10.3234
100%	5:08.5829	7,91	4:51.9501	5:22.5382	5:04.1987	5:12.9672
Indirect	**Productivity**	**StDev**	**Minimum**	**Maximum**	**Left interval**	**Right interval**
0%	76,43%	0,47%	75,92%	77,46%	76,17%	76,69%
20%	76,43%	0,47%	75,93%	77,44%	76,17%	76,69%
40%	76,41%	0,47%	75,92%	77,43%	76,15%	76,67%
60%	76,40%	0,47%	75,90%	77,42%	76,14%	76,66%
80%	76,36%	0,47%	75,86%	77,37%	76,10%	76,62%
100%	77,17%	0,46%	76,55%	78,28%	76,92%	77,43%
Indirect	**Overtime**	**StDev**	**Minimum**	**Maximum**	**Left interval**	**Right interval**
0%	0,26%	0,02%	0,22%	0,29%	0,25%	0,27%
20%	0,26%	0,02%	0,22%	0,29%	0,25%	0,27%
40%	0,29%	0,02%	0,24%	0,32%	0,27%	0,30%
60%	0,30%	0,02%	0,27%	0,34%	0,29%	0,31%
80%	0,34%	0,02%	0,30%	0,38%	0,32%	0,35%
100%	0,39%	0,02%	0,35%	0,42%	0,38%	0,40%

Table 6 - KPIs for Experiments with the Three Theories Combined

Now that all experiments have been carried out, conclusions and recommendations can be drawn from the data. In the next chapter, an elaboration about conclusions and recommendations is made. In addition to these, a discussion and suggestions for further research are formulated.

7. Conclusions, Recommendations and Discussion

In this final chapter, the conclusions and recommendations of the simulation study will be presented. Besides that, a critical discussion will be made on this thesis, since there are limitations that might have influenced the results and the accuracy of this simulation study. In addition, an elaboration is made on suggestions for further research. This chapter consists of the following sections:

- 7.1 Conclusions and recommendations
- 7.2 Discussion
- 7.3 Suggestion for further research

7.1 Conclusions and Recommendations

Before the conclusions and recommendations will be presented, a short recap is made on the core problem that was faced at Pro Juventus and discussed in section 1.4: "Pro Juventus has no insights in the effects of variability of the appointment times and the high client focus concerning the planning".

In chapter 6, more insights have been gained with regard to the effects of variability on the appointment planning of Pro Juventus. Additionally, using the scheduling method "sequence of appointments" insights have been gained on how Pro Juventus can change their client focus concerning the planning and which results it will have on the KPIs.

From the results in chapter 6 it can be concluded that combining the three theories and only the theory about the sequence of appointments will result in the best outcomes. However, due to the fact that the scheduling method "sequence of appointments" entails a major disadvantage, the following recommendation is given: Pro Juventus needs to schedule only direct appointment times in their planning. However, they need to take into account that the indirect appointment times still need to be executed on the same day. Therefore it is for example not possible to schedule four hours direct appointment time in the afternoon, since indirect appointment times need to be executed after the direct appointment times for the major part.

If this recommendation will be used, the productivity will increase with 6,75%, while the waiting times of clients will only increase with 25 seconds on average. In addition, the overtime hours that are made by practitioners will decrease from 1,11% to 0,75%. Eventually, it can be concluded that the initial action problem (the high workload of practitioners) will decrease a little bit due to the decrease in overtime hours. However, it can be said that the workload is increasing while the productivity is going to increase. Though, practitioners are still working as much hours as before. The only thing that is going to change is that there is less idle time for practitioners in which they normally try to search for other client related tasks. In addition, it can be concluded that the overall planning process of Pro Juventus will increase while following this recommendation.

7.2 Discussion

In this section, a discussion will be made about the potential shortcomings of this thesis. In this discussion two elements will be discussed: the validation of the simulation model with real world data, and the output of the simulation model.

Validation with Real World Data

Generally, it is very important to validate a simulation model with real world data. However, due to lack of data with regard to the KPIs, this was difficult during this simulation study. For the first KPI, overtime hours, the data that was available was not accurate according to the director of Pro Juventus. So it would happen that practitioners would execute their indirect tasks after working hours, without noting it. For the second KPI, the productivity, there is data available. The value of this data is however lower than the output of the base model of the simulation. This is the case, since practitioners have meetings that are not client related (e.g. staff meetings). Since there is no data from these events, these are not included into the simulation. For the last KPI, the waiting time at the clinic, there is no data at all. However, it is assumed that waiting times in the current situations are very low.

The Output of the Simulation Model

As can be seen in chapter 6, the simulation output with regard to the productivity is generally very low. These low numbers are the result of the interarrival times that are used in the simulation model. From the simulation model, it becomes clear that not all days the timetables of practitioners are completely filled. Therefore, it can be concluded that there have been too few clients in the past to fill the total timetables of all practitioners. If a higher interarrival time was used, the productivity numbers would have increased.

7.3 Suggestions for Further Research

After this research, the task that remains is the implementation of the research outcomes. For future research, it is important for Pro Juventus to keep track of the data they are gathering. It will be convenient if certain data is collected, such as the exact appointment length times, both direct and indirect, preferably rounded in seconds. If this is possible, future data analysis will be more valuable and more reliable than it currently is. Once this data is known, a more exact measure of for example the variability of appointment times can be calculated, which can afterwards be used to improve the planning. If the theory on sequencing of appointments will be applied, future research can provide a tool which enables Pro Juventus to use this method easily. Afterwards, it would be preferable to connect the tool to Medicore. Besides the above mentioned, it would be convenient for further research to look into the effects of the severity of certain appointments. The scheduling of very severe and less severe appointments will however affect the experienced workload of practitioners.

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Appendix A: Distribution of the Specializations

In this appendix, the number of practitioners per function can be seen. Besides that, the number of practitioners per location can be seen. Kampen has two locations, one for youth and one for adults. In the table below these two locations are seen as one.

Function	Wijhe	Kampen	Ommen	Wezep	Total
Psychiatrist	2		1	1	4
Coach	5	5	2	4	16
Psychologist	5	5	1	4	15
Remedial educationalist	2	2	1	3	8
Clinical psychologist	1		1		2
Psychomotor therapist	3	1	1	1	6
Healhcare psychologist	2	3	2	2	9
Parent mentor	1	1		2	4
Trainee	1		1	1	3
Psychologist in training		1			1
Application coordinator		1	1		2
Doctor		1	1	2	4
Total	22	20	12	20	74

Appendix B: Contract Hours per Week per Specialization

In this appendix the contractual working hours per specialization can be found.

Function	Total contract hours per week
Psychiatrist	74
Coach	468
Psychologist	445
Remedial educationalist	236
Clinical psychologist	63
Psychomotor therapist	152
Healhcare psychologist	232
Parent mentor	112
Trainee	96
Psychologist in training	32
Application coordinator	62
Doctor	115

Appendix C: Number of Activities per Appointment Type

In this appendix, the number of activities per appointment type can be found. These numbers are analyzed from the data from the 1st of January 2018 till the 24th of April 2019. As can be seen, the appointment types that occurred less than 100 times are marked with a purple color. These appointment types are in the simulation model seen as "Remaining Appointments".

Appointment type	Number of activities	Appointment type	Number of activities	Appointment type	Number of activities
02	**69**	**3.1.3.2.2**	**17**	7.1	5610
03	**12**	**3.1.3.2.6**	**4**	**7.2**	**52**
04	108	**3.1.3.4.1**	**34**	7.3	13589
05	**9**	**3.1.3.4.2**	**5**	7.4	119
06	234	**3.1.3.5.1**	**1**	7.5	1620
07	**9**	**3.1.3.6.1**	**5**	**A01**	**90**
08	392	**3.1.3.6.2**	**15**	A02	7280
09	**46**	**3.1.3.7.1**	**3**	A03	215
1	615	**3.1.3.8.1**	**27**	A04	1164
10	795	3.1.3.8.2	1283	A05	389
2.1	746	**3.1.3.8.4**	**1**	**A06**	**41**
2.12	527	**3.1.3.8.5**	**1**	A07	204
2.13	531	**3.1.3.8.6**	**5**	**A08**	**22**
2.2	**3**	**3.1.3.8.7**	**24**	**A09**	**45**
2.3	469	3.1.4.1	5360	A10	844
2.4	**11**	**3.1.4.2**	**25**	**A11**	**29**
2.5	**52**	3.1.4.4	129	**A12**	**21**
2.6.1	101	**3.1.4.5**	**2**	A13	1000
2.6.2	**20**	3.1.4.6	882	A14	6366
2.6.3	246	**3.1.4.7**	**3**	A15	5256
2.9	**2**	3.2	1988	A16	899
3.1.1.1	10519	**3.4.8.1**	**6**	A17	484
3.1.1.2	512	**3.4.8.7**	**2**	A18	194
3.1.1.4	115	**4.1.1**	**13**	A19	9229
3.1.1.5	**25**	**4.1.5**	**1**	A20	2989
3.1.1.6	190	**4.1.6**	**1**	A21	3287
3.1.1.7	**51**	4.2.1	130	A22	13692
3.1.2.1	107	**4.2.4**	**31**	A23	630
3.1.2.2	**96**	**4.2.5**	**3**	**A24**	**55**
3.1.2.4	136	**4.2.6**	**3**	**F003**	**20**
3.1.2.5	**14**	**4.6.1**	**5**	**NS01**	**38**
3.1.2.6	**39**	**5.1**	**1**	**PJE004**	**1**
3.1.2.7	**1**	**6.1**	**3**	**PJE005**	**1**
3.1.3.2.1	163	**6.7**	**1**	**PJE011**	**14**

Appendix D: Appointment Types per Specialization

In this appendix, the appointment types that each specialization can perform can be found. As an example it can be seen that a parent mentor and a trainee cannot perform appointment type 1, while all the other specializations can.

Coach	Psychiatrist	Psychologist	Remedial educationalist	Clinical psychologist	Psychomotor therapist	Healhcare psychologist	Parent mentor	Trainee	Psychologist in training	Application coordinator	Doctor
1	1	1	1	1	1	1	10	2.12	1	1	1
4	6	4	4	4	6	4	2.1	2.6.1	4	4	4
6	8	6	6	6	10	6	3.1.1.1	3.1.1.1	6	8	10
8	10	8	8	8	2.1	8	3.1.1.4	7.1	10	10	2.1
10	2.1	10	10	10	2.12	10	3.1.1.6	7.3	2.1	2.1	2.12
2.1	2.12	2.1	2.1	2.1	3.1.1.1	2.1	3.1.2.1	A02	2.12	3.1.1.1	2.13
2.12	2.13	2.12	2.12	2.12	3.1.1.2	2.12	3.1.2.4	A04	2.13	3.1.1.4	3.1.1.1
2.13	2.3	2.13	2.13	2.13	3.1.2.1	2.13	3.1.3.8.2	A05	2.3	3.1.2.4	3.1.1.4
2.3	3.1.1.1	2.3	2.3	2.3	3.1.4.1	2.3	3.1.4.1	A07	2.6.1	3.1.4.1	3.1.2.1
3.1.1.1	3.1.1.2	2.6.1	2.6.1	2.6.3	3.1.4.6	2.6.1	3.1.4.4	A14	3.1.1.1	3.1.4.4	3.1.2.4
3.1.1.2	3.1.1.4	2.6.3	2.6.3	3.1.1.1	7.1	2.6.3	3.1.4.6	A15	3.1.4.1	3.1.4.6	3.1.4.1
3.1.1.4	3.1.1.6	3.1.1.1	3.1.1.1	3.1.1.2	7.3	3.1.1.1	7.1	A16	7.3	4.2.1	3.1.4.6
3.1.1.6	3.1.2.4	3.1.1.2	3.1.1.2	3.1.1.6	7.4	3.1.1.2	7.3	A21	7.5	7.1	3.2
3.1.2.1	3.1.3.8.2	3.1.1.4	3.1.1.4	3.1.2.1	7.5	3.1.1.4	7.4	A22	A03	7.3	7.1
3.1.2.4	3.1.4.1	3.1.1.6	3.1.1.6	3.1.3.2.1	A02	3.1.1.6	7.5		A05	7.4	7.3
3.1.3.8.2	3.1.4.4	3.1.2.1	3.1.2.1	3.1.3.8.2	A03	3.1.2.1	A02		A07	7.5	7.4
3.1.4.1	3.1.4.6	3.1.2.4	3.1.2.4	3.1.4.1	A04	3.1.2.4	A04		A10	A02	7.5
3.1.4.4	3.2	3.1.3.8.2	3.1.3.8.2	3.1.4.4	A07	3.1.3.8.2	A07		A21	A04	A02
3.1.4.6	4.2.1	3.1.4.1	3.1.4.1	3.1.4.6	A10	3.1.4.1	A10		A22	A13	A03
4.2.1	7.1	3.1.4.4	3.1.4.4	3.2	A13	3.1.4.4	A13			A14	A04
7.1	7.3	3.1.4.6	3.1.4.6	4.2.1	A14	3.1.4.6	A14			A15	A07
7.3	7.4	4.2.1	3.2	7.1	A15	3.2	A15			A16	A10
7.4	7.5	7.1	7.1	7.3	A16	7.1	A16			A17	A13
7.5	A02	7.3	7.3	7.4	A17	7.3	A17			A18	A14
A02	A03	7.4	7.4	7.5	A18	7.4	A18			A19	A15
A04	A04	7.5	7.5	A02	A19	7.5	A19			A20	A16
A07	A05	A02	A02	A03	A20	A02	A20			A21	A17
A10	A07	A03	A03	A10	A21	A03	A21			A22	A18
A13	A10	A04	A04	A13	A22	A04	A22			A23	A19
A14	A13	A05	A05	A14		A05					A20
A15	A14	A07	A07	A15		A07					A21
A16	A15	A10	A10	A18		A10					A22
A17	A16	A13	A13	A19		A13					
A18	A17	A14	A14	A21		A14					
A19	A18	A15	A15	A22		A15					
A20	A19	A16	A16			A16					
A21	A20	A17	A17			A17					
A22	A21	A18	A18			A18					
A23	A22	A19	A19			A19					
	A23	A20	A20			A20					
		A21	A21			A21					
		A22	A22			A22					
			A23			A23					

Appendix E: Appointment Planning

In the picture below an example can be found of planning multiple appointments in Medicore. In this planning, an appointment should take place every week for five weeks long. As can be seen, Medicore tries to plan with regularity: every appointment on the same day of the week on the same time. If the practitioner already has something scheduled at that moment, Medicore skips that week and plans the appointment the next week.

Bevestig afspraak

afspraaksoort:	Coaching VW
kliniek:	Pro Juventus
patiënt:	Dhr. T. Abcd-Test (01-01-2010)
uitvoerder:	
medewerkers:	-
resources:	-
herhaling:	Wekelijks: iedere week
aantal afspraken:	5
uitzonderingen:	woensdag 22 mei 2019; woensdag 5 juni 2019; woensdag 19 juni 2019; woensdag 3 juli 2019

Afspraak 1

datum / tijd: woensdag 15 mei 2019 - 09:45 - 11:00

Afspraak 2

datum / tijd: woensdag 29 mei 2019 - 09:45 - 11:00

Afspraak 3

datum / tijd: woensdag 12 juni 2019 - 09:45 - 11:00

Afspraak 4

datum / tijd: woensdag 26 juni 2019 - 09:45 - 11:00

Afspraak 5

datum / tijd: woensdag 10 juli 2019 - 09:45 - 11:00

☐ verzend communicatie

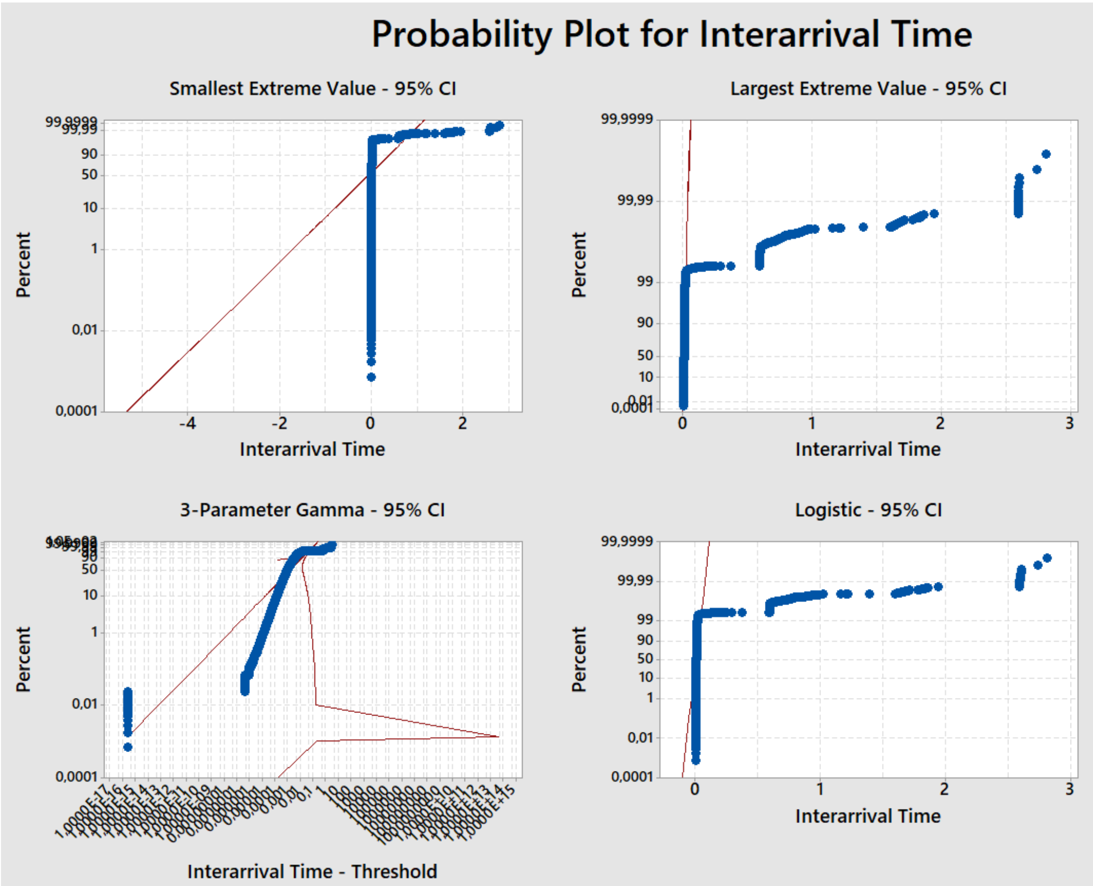
ok annuleren

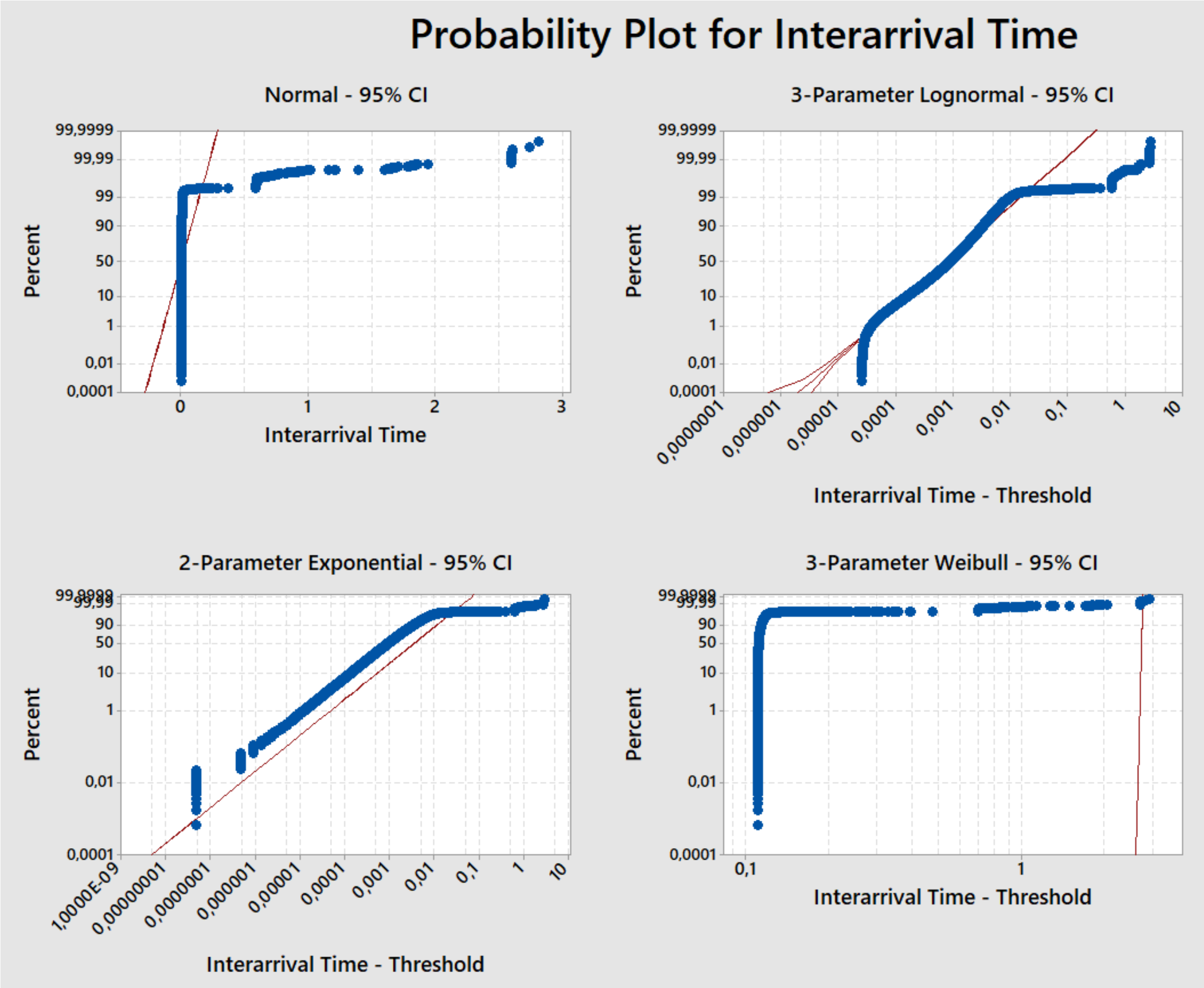
Appendix F: Minitab

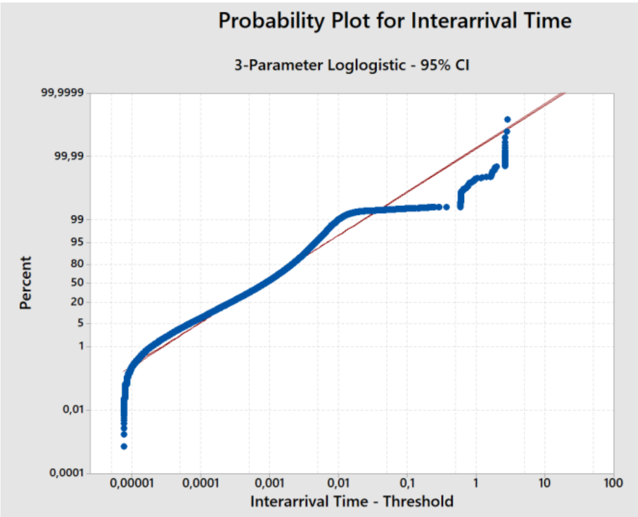
As can be seen in the figures below, the data does not match one of the distributions. First of all, all the p-values calculated by Minitab are too small to fit a distribution. Besides that, the data points in the probability plots do not follow the black lines. Therefore, histograms are used as input variables.

Goodness of Fit Test

Distribution	AD	P
Normal	37088,891	<0,005
3-Parameter Lognormal	378,492	*
2-Parameter Exponential	50976,085	<0,010
3-Parameter Weibull	203722,839	<0,005
Smallest Extreme Value	40627,157	<0,010
Largest Extreme Value	23667,567	<0,010
3-Parameter Gamma	12525,178	*
Logistic	30466,693	<0,005
3-Parameter Loglogistic	341,469	*




Probability Plot for Interarrival Time
Normal - 95% CI
3-Parameter Lognormal - 95% CI
2-Parameter Exponential - 95% CI
3-Parameter Weibull - 95% CI
Percent
Interarrival Time
Interarrival Time - Threshold


Probability Plot for Interarrival Time
3-Parameter Loglogistic - 95% CI
Percent
Interarrival Time - Threshold

Appendix G: Interarrival Times Distribution

In the table below, the interarrival times distribution is shown. Since the histogram has in total more than 1000 bins, not the whole histogram is shown in this appendix. These high bins are taken into account, since outliers that occur in real life also need to be included in the simulation model.

Left bound	Right bound	Frequency	Left bound	Right bound	Frequency	Left bound	Right bound	Frequency
0.0000	2:19.8096	43608	58:15.2389	1:00:35.0484	6	1:56:30.4777	1:58:50.2873	4
2:19.8096	4:39.6191	23773	1:00:35.0484	1:02:54.8580	9	1:58:50.2873	2:01:10.0968	1
4:39.6191	6:59.4287	13437	1:02:54.8580	1:05:14.6675	12	2:01:10.0968	2:03:29.9064	0
6:59.4287	9:19.2382	7761	1:05:14.6675	1:07:34.4771	11	2:03:29.9064	2:05:49.7160	4
9:19.2382	11:39.0478	4651	1:07:34.4771	1:09:54.2866	3	2:05:49.7160	2:08:09.5255	3
11:39.0478	13:58.8573	2837	1:09:54.2866	1:12:14.0962	9	2:08:09.5255	2:10:29.3351	0
13:58.8573	16:18.6669	1856	1:12:14.0962	1:14:33.9057	5	2:10:29.3351	2:12:49.1446	3
16:18.6669	18:38.4764	1200	1:14:33.9057	1:16:53.7153	4	2:12:49.1446	2:15:08.9542	2
18:38.4764	20:58.2860	862	1:16:53.7153	1:19:13.5249	7	2:15:08.9542	2:17:28.7637	2
20:58.2860	23:18.0955	560	1:19:13.5249	1:21:33.3344	7	2:17:28.7637	2:19:48.5733	2
23:18.0955	25:37.9051	406	1:21:33.3344	1:23:53.1440	1	2:19:48.5733	2:22:08.3828	0
25:37.9051	27:57.7147	295	1:23:53.1440	1:26:12.9535	7	2:22:08.3828	2:24:28.1924	0
27:57.7147	30:17.5242	205	1:26:12.9535	1:28:32.7631	3	2:24:28.1924	2:26:48.0019	2
30:17.5242	32:37.3338	175	1:28:32.7631	1:30:52.5726	2	2:26:48.0019	2:29:07.8115	1
32:37.3338	34:57.1433	111	1:30:52.5726	1:33:12.3822	4	2:29:07.8115	2:31:27.6211	1
34:57.1433	37:16.9529	87	1:33:12.3822	1:35:32.1917	5	2:31:27.6211	2:33:47.4306	2
37:16.9529	39:36.7624	59	1:35:32.1917	1:37:52.0013	5	2:33:47.4306	2:36:07.2402	2
39:36.7624	41:56.5720	43	1:37:52.0013	1:40:11.8108	1	2:36:07.2402	2:38:27.0497	0
41:56.5720	44:16.3815	48	1:40:11.8108	1:42:31.6204	2	2:38:27.0497	2:40:46.8593	2
44:16.3815	46:36.1911	34	1:42:31.6204	1:44:51.4300	2	2:40:46.8593	2:43:06.6688	1
46:36.1911	48:56.0006	30	1:44:51.4300	1:47:11.2395	3	2:43:06.6688	2:45:26.4784	1
48:56.0006	51:15.8102	35	1:47:11.2395	1:49:31.0491	2	2:45:26.4784	2:47:46.2879	1
51:15.8102	53:35.6198	23	1:49:31.0491	1:51:50.8586	1	2:47:46.2879	2:50:06.0975	1
53:35.6198	55:55.4293	14	1:51:50.8586	1:54:10.6682	3	2:50:06.0975	2:52:25.9070	0
55:55.4293	58:15.2389	8	1:54:10.6682	1:56:30.4777	3	2:52:25.9070	2:54:45.7166	0

Appendix H: Appointment Type Distribution

Below the appointment types with corresponding chances of occurrence relative to the total number of appointments can be seen.

Appointment Type	Chance
4	0,11%
6	0,23%
8	0,38%
1	0,60%
10	0,78%
2.1	0,73%
2.12	0,51%
2.13	0,52%
2.3	0,46%
2.6.1	0,10%
2.6.3	0,24%
3.1.1.1	10,27%
3.1.1.2	0,50%
3.1.1.4	0,11%
3.1.1.6	0,19%
3.1.2.1	0,10%
3.1.2.4	0,13%
3.1.3.2.1	0,16%
3.1.3.8.2	1,25%
3.1.4.1	5,23%
3.1.4.4	0,13%
3.1.4.6	0,86%
3.2	1,94%

Appointment Type	Chance
4.2.1	0,13%
7.1	5,47%
7.3	13,26%
7.4	0,12%
7.5	1,58%
A02	7,10%
A03	0,21%
A04	1,14%
A05	0,38%
A07	0,20%
A10	0,82%
A13	0,98%
A14	6,21%
A15	5,13%
A16	0,88%
A17	0,47%
A18	0,19%
A19	9,01%
A20	2,92%
A21	3,21%
A22	13,36%
A23	0,61%
Remaining	1,10%

Appendix I: Contractual and Actual Working Hours

In the table below, both the contractual and the actual working hours can be found. As can be seen, the actual working hours are rounded to half hours. Besides the above mentioned data, the number of days that a practitioner is working 8 hours (a full working day) and the remaining working hours can be seen.

Practitioner	Contract hours	Working hours	Rounded working hours	Full days	Remaining hours
Psychiatrist1	36	30,03508	30	3	6
Psychiatrist2	36	30,03508	30	3	6
Psychiatrist3	20	16,68615	16,5	2	0,5
Psychiatrist4	18	15,01754	15	1	7
Coach1	36	30,03508	30	3	6
Coach2	36	30,03508	30	3	6
Coach3	32	26,69785	26,5	3	2,5
Coach4	32	26,69785	26,5	3	2,5
Coach5	32	26,69785	26,5	3	2,5
Coach6	32	26,69785	26,5	3	2,5
Coach7	32	26,69785	26,5	3	2,5
Coach8	32	26,69785	26,5	3	2,5
Coach9	32	26,69785	26,5	3	2,5
Coach10	28	23,36062	23,5	2	7,5
Coach11	28	23,36062	23,5	2	7,5
Coach12	24	20,02338	20	2	4
Coach13	24	20,02338	20	2	4
Coach14	24	20,02338	20	2	4
Coach15	24	20,02338	20	2	4
Coach16	20	16,68615	16,5	2	0,5
Psychologist1	36	30,03508	30	3	6
Psychologist2	36	30,03508	30	3	6
Psychologist3	36	30,03508	30	3	6
Psychologist4	32	26,69785	26,5	3	2,5
Psychologist5	32	26,69785	26,5	3	2,5
Psychologist6	32	26,69785	26,5	3	2,5
Psychologist7	31	25,86354	26	3	2
Psychologist8	28	23,36062	23,5	2	7,5
Psychologist9	28	23,36062	23,5	2	7,5
Psychologist10	28	23,36062	23,5	2	7,5
Psychologist11	28	23,36062	23,5	2	7,5
Psychologist12	26	21,692	21,5	2	5,5
Psychologist13	24	20,02338	20	2	4
Psychologist14	24	20,02338	20	2	4
Psychologist15	24	20,02338	20	2	4
RE1	36	30,03508	30	3	6
RE2	32	26,69785	26,5	3	2,5

Practitioner	Contract hours	Working hours	Rounded working hours	Full days	Remaining hours
RE3	32	26,69785	26,5	3	2,5
RE4	32	26,69785	26,5	3	2,5
RE5	32	26,69785	26,5	3	2,5
RE6	24	20,02338	20	2	4
RE7	24	20,02338	20	2	4
RE8	24	20,02338	20	2	4
CP1	36	30,03508	30	3	6
CP2	27	22,52631	22,5	2	6,5
PT1	32	26,69785	26,5	3	2,5
PT2	24	20,02338	20	2	4
PT3	24	20,02338	20	2	4
PT4	24	20,02338	20	2	4
PT5	24	20,02338	20	2	4
PT6	24	20,02338	20	2	4
HPsyc1	32	26,69785	26,5	3	2,5
HPsyc2	32	26,69785	26,5	3	2,5
HPsyc3	28	23,36062	23,5	2	7,5
HPsyc4	24	20,02338	20	2	4
HPsyc5	24	20,02338	20	2	4
HPsyc6	24	20,02338	20	2	4
HPsyc7	24	20,02338	20	2	4
HPsyc8	24	20,02338	20	2	4
HPsyc9	20	16,68615	16,5	2	0,5
PM1	32	26,69785	26,5	3	2,5
PM2	32	26,69785	26,5	3	2,5
PM3	24	20,02338	20	2	4
PM4	24	20,02338	20	2	4
Trainee1	32	26,69785	26,5	3	2,5
Trainee2	32	26,69785	26,5	3	2,5
Trainee3	32	26,69785	26,5	3	2,5
PsyInTrain1	32	26,69785	26,5	3	2,5
ApplCoor1	32	26,69785	26,5	3	2,5
ApplCoor2	30	25,02923	25	3	1
Doctor1	36	30,03508	30	3	6
Doctor2	36	30,03508	30	3	6
Doctor3	31	25,86354	26	3	2
Doctor4	12	10,01169	10	1	2

Appendix J: Cumulative Probabilities of Assignment to Specialization

In this appendix, the cumulative probabilities of assigning a client to a certain specialization can be found. To clarify this an example will be given: if a client needs an appointment type 3.1.1.1 and the random number that is generated by the simulation software is equal to 0,67, the client will be assigned to the specialization Parent Mentor (PM).

Function	04	06	08	1	10	2.1	2.12	2.13	2.3	2.6.1	2.6.3	3.1.1.1	3.1.1.2	3.1.1.4	3.1.1.6	3.1.2.1
Psychiatrist	0,0000	0,0633	0,0681	0,0574	0,0706	0,0543	0,0564	0,0647	0,0694	0,0000	0,0000	0,0518	0,0645	0,0618	0,0660	0,0000
Coach	0,2831	0,3326	0,3577	0,3018	0,0706	0,2852	0,2966	0,3398	0,3644	0,0000	0,0000	0,2723	0,3388	0,3247	0,3469	0,2567
Psychologist	0,5523	0,5886	0,6330	0,5342	0,3560	0,5047	0,5249	0,6014	0,6450	0,4275	0,4559	0,4819	0,5996	0,5747	0,6140	0,5008
RE	0,6951	0,7244	0,7791	0,6574	0,5074	0,6211	0,6460	0,7402	0,7938	0,6542	0,6977	0,5930	0,7380	0,7073	0,7557	0,6303
CP	0,7332	0,7606	0,8181	0,6903	0,5478	0,6522	0,6783	0,7772	0,8335	0,6542	0,7623	0,6227	0,7749	0,7073	0,7935	0,6648
PT	0,7332	0,8481	0,8181	0,7697	0,6453	0,7272	0,7563	0,7772	0,8335	0,6542	0,7623	0,6943	0,8640	0,7073	0,7935	0,7482
HPsyc	0,8736	0,9816	0,9616	0,8909	0,7941	0,8416	0,8753	0,9136	0,9798	0,8770	1,0000	0,8036	1,0000	0,8376	0,9328	0,8755
PM	0,8736	0,9816	0,9616	0,8909	0,8659	0,8969	0,8753	0,9136	0,9798	0,8770	1,0000	0,8563	1,0000	0,9006	1,0000	0,9369
Trainee	0,8736	0,9816	0,9616	0,8909	0,8659	0,8969	0,9246	0,9136	0,9798	0,9693	1,0000	0,9016	1,0000	0,9006	1,0000	0,9369
PsyInTrain	0,8929	1,0000	0,9616	0,9076	0,8865	0,9127	0,9410	0,9324	1,0000	1,0000	1,0000	0,9166	1,0000	0,9006	1,0000	0,9369
ApplCoor	0,9304	1,0000	1,0000	0,9399	0,9262	0,9433	0,9410	0,9324	1,0000	1,0000	1,0000	0,9458	1,0000	0,9354	1,0000	0,9369
Doctor	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000

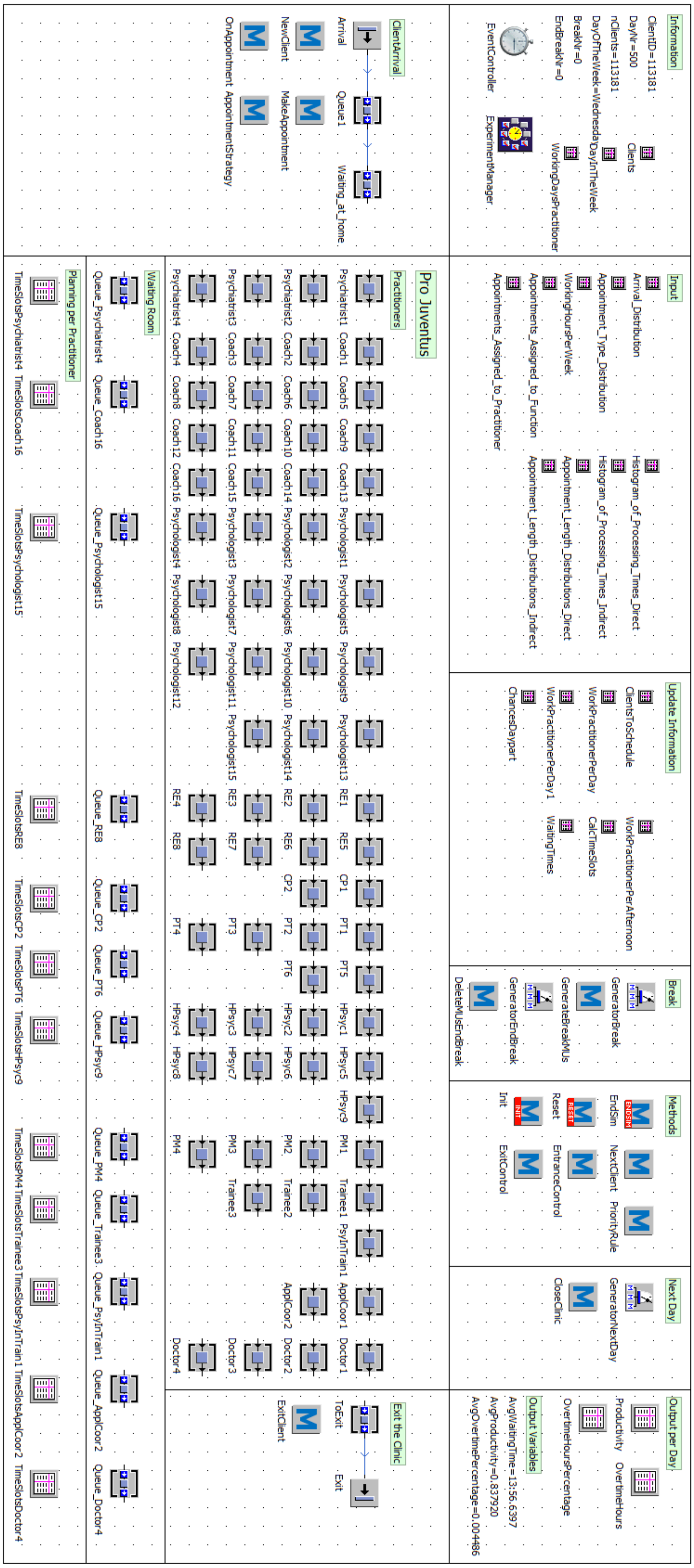
Function	3.1.2.4	3.1.3.2.1	3.1.3.8.2	3.1.4.1	3.1.4.4	3.1.4.6	3.2	4.2.1	7.1	7.3	7.4	7.5	A02	A03	A04
Psychiatrist	0,0618	0,0000	0,0660	0,0543	0,0637	0,0551	0,1455	0,0958	0,0526	0,0518	0,0551	0,0543	0,0526	0,0794	0,0542
Coach	0,3247	0,0000	0,3469	0,2852	0,3345	0,2897	0,1455	0,5035	0,2764	0,2723	0,2897	0,2852	0,2764	0,0794	0,2850
Psychologist	0,5747	0,0000	0,6140	0,5047	0,5920	0,5128	0,1455	0,8911	0,4892	0,4819	0,5128	0,5047	0,4892	0,4007	0,5044
RE	0,7073	0,0000	0,7557	0,6211	0,7286	0,6311	0,4577	0,8911	0,6021	0,5930	0,6311	0,6211	0,6021	0,5711	0,6208
CP	0,7073	1,0000	0,7935	0,6522	0,7650	0,6627	0,5410	0,9460	0,6322	0,6227	0,6627	0,6522	0,6322	0,6166	0,6208
PT	0,7073	1,0000	0,7935	0,7272	0,7650	0,7388	0,5410	0,9460	0,7049	0,6943	0,7388	0,7272	0,7049	0,7264	0,6958
HPsyc	0,8376	1,0000	0,9328	0,8416	0,8993	0,8551	0,8479	0,9460	0,8159	0,8036	0,8551	0,8416	0,8159	0,8939	0,8102
PM	0,9006	1,0000	1,0000	0,8969	0,9641	0,9113	0,8479	0,9460	0,8694	0,8563	0,9113	0,8969	0,8694	0,8939	0,8654
Trainee	0,9006	1,0000	1,0000	0,8969	0,9641	0,9113	0,8479	0,9460	0,9154	0,9016	0,9113	0,8969	0,9154	0,8939	0,9127
PsyInTrain	0,9006	1,0000	1,0000	0,9127	0,9641	0,9113	0,8479	0,9460	0,9154	0,9166	0,9113	0,9127	0,9154	0,9170	0,9127
ApplCoor	0,9354	1,0000	1,0000	0,9433	1,0000	0,9424	0,8479	1,0000	0,9450	0,9458	0,9424	0,9433	0,9450	0,9170	0,9433
Doctor	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000

Function	A05	A07	A10	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	Remaining
Psychiatrist	0,0956	0,0551	0,0560	0,0551	0,0526	0,0526	0,0542	0,0569	0,0551	0,0551	0,0569	0,0518	0,0518	0,0993	0,0518
Coach	0,0956	0,2893	0,2941	0,2897	0,2764	0,2764	0,2850	0,2992	0,2897	0,2897	0,2992	0,2723	0,2723	0,5217	0,2723
Psychologist	0,4822	0,5120	0,5206	0,5128	0,4892	0,4892	0,5044	0,5295	0,5128	0,5128	0,5295	0,4819	0,4819	0,5217	0,4819
RE	0,6872	0,6301	0,6407	0,6311	0,6021	0,6021	0,6208	0,6517	0,6311	0,6311	0,6517	0,5930	0,5930	0,7347	0,5930
CP	0,6872	0,6301	0,6728	0,6627	0,6322	0,6322	0,6208	0,6517	0,6627	0,6627	0,6517	0,6227	0,6227	0,7347	0,6227
PT	0,6872	0,7062	0,7501	0,7388	0,7049	0,7049	0,6958	0,7303	0,7388	0,7388	0,7303	0,6943	0,6943	0,7347	0,6943
HPsyc	0,8888	0,8223	0,8682	0,8551	0,8159	0,8159	0,8102	0,8504	0,8551	0,8551	0,8504	0,8036	0,8036	0,9440	0,8036
PM	0,8888	0,8784	0,9252	0,9113	0,8694	0,8694	0,8654	0,9084	0,9113	0,9113	0,9084	0,8563	0,8563	0,9440	0,8563
Trainee	0,9722	0,9264	0,9252	0,9113	0,9154	0,9154	0,9127	0,9084	0,9113	0,9113	0,9084	0,9016	0,9016	0,9440	0,9016
PsyInTrain	1,0000	0,9424	0,9415	0,9113	0,9154	0,9154	0,9127	0,9084	0,9113	0,9113	0,9084	0,9166	0,9166	0,9440	0,9166
ApplCoor	1,0000	0,9424	0,9415	0,9424	0,9450	0,9450	0,9433	0,9405	0,9424	0,9424	0,9405	0,9458	0,9458	1,0000	0,9458
Doctor	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000

Appendix K: Cumulative Probabilities of Assignment to a Practitioner

In the table below, the cumulative probabilities of assigning a client to a practitioner within a certain specialization can be seen. To clarify this an example will be given: if a client is already assigned to the specialization Psychologist and the random number that is generated by the simulation software is equal to 0,92, the client will be assigned to Psychologist number 14.

PractitionerNumber	Psychiatrist	Coach	Psychologist	RE	CP	PT	HPsyc	PM	Trainee	PsyInTrain	ApplCoor	Doctor
1	0,3273	0,0769	0,0809	0,1525	0,5714	0,2105	0,1379	0,2857	0,3333	1,0000	0,5161	0,3130
2	0,6545	0,1538	0,1618	0,2881	1,0000	0,3684	0,2759	0,5714	0,6667	1,0000	1,0000	0,6261
3	0,8364	0,2222	0,2427	0,4237	1,0000	0,5263	0,3966	0,7857	1,0000	1,0000	1,0000	0,8957
4	1,0000	0,2906	0,3146	0,5593	1,0000	0,6842	0,5000	1,0000	1,0000	1,0000	1,0000	1,0000
5	1,0000	0,3590	0,3865	0,6949	1,0000	0,8421	0,6034	1,0000	1,0000	1,0000	1,0000	1,0000
6	1,0000	0,4274	0,4584	0,7966	1,0000	1,0000	0,7069	1,0000	1,0000	1,0000	1,0000	1,0000
7	1,0000	0,4957	0,5281	0,8983	1,0000	1,0000	0,8103	1,0000	1,0000	1,0000	1,0000	1,0000
8	1,0000	0,5641	0,5910	1,0000	1,0000	1,0000	0,9138	1,0000	1,0000	1,0000	1,0000	1,0000
9	1,0000	0,6325	0,6539	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
10	1,0000	0,6923	0,7169	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
11	1,0000	0,7521	0,7798	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
12	1,0000	0,8034	0,8382	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
13	1,0000	0,8547	0,8921	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
14	1,0000	0,9060	0,9461	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
15	1,0000	0,9573	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
16	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000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EndBreakNr=0
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DayInTheWeek
WorkingDaysPractitioner
EventController
ExperimentManager
Input
Arrival_Distribution
Appointment_Type_Distribution
WorkingHoursPerWeek
Appointments_Assigned_to_Function
Appointments_Assigned_to_Practitioner
Histogram_of_Processing_Times_Direct
Histogram_of_Processing_Times_Indirect
Appointment_Length_Distributions_Direct
Appointment_Length_Distributions_Indirect
Update Information
ClientsToSchedule
WorkPractitionerPerDay
WorkPractitionerPerDay1
ChancesDaypart
WorkPractitionerPerAfternoon
CalcTimeSlots
WaitingTimes
Break
GeneratorBreak
GenerateBreakMUs
GeneratorEndBreak
DeleteMUsEndBreak
Methods
EndSim
NextClient
PriorityRule
Reset
EntranceControl
Init
ExitControl
Next Day
GeneratorNextDay
CloseClinic
Output per Day
Productivity
OvertimeHours
OvertimeHoursPercentage
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AvgProductivity=0.837920
AvgOvertimePercentage=0.00486
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Arrival
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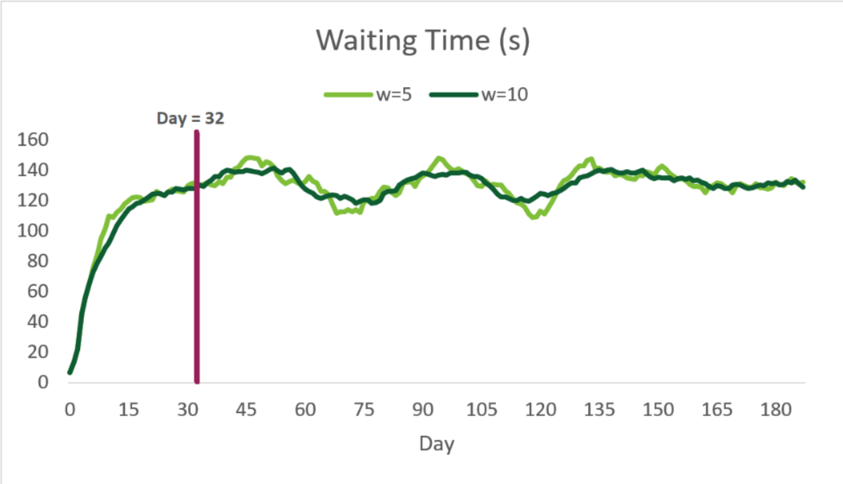
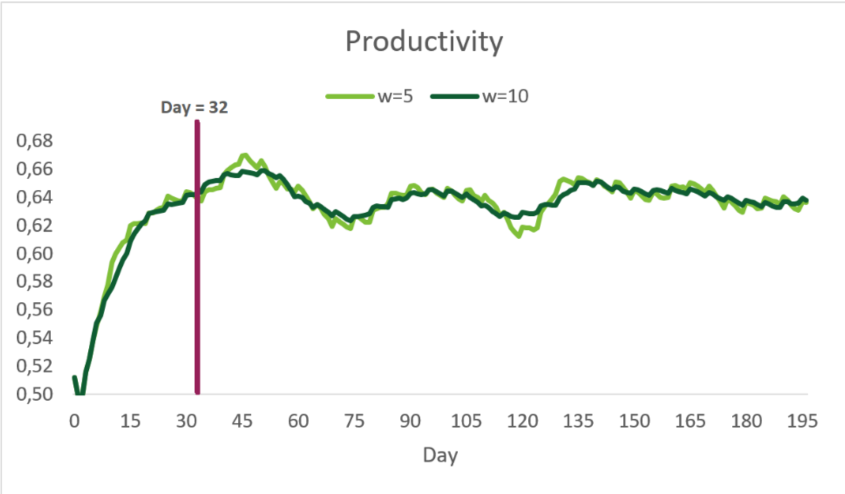
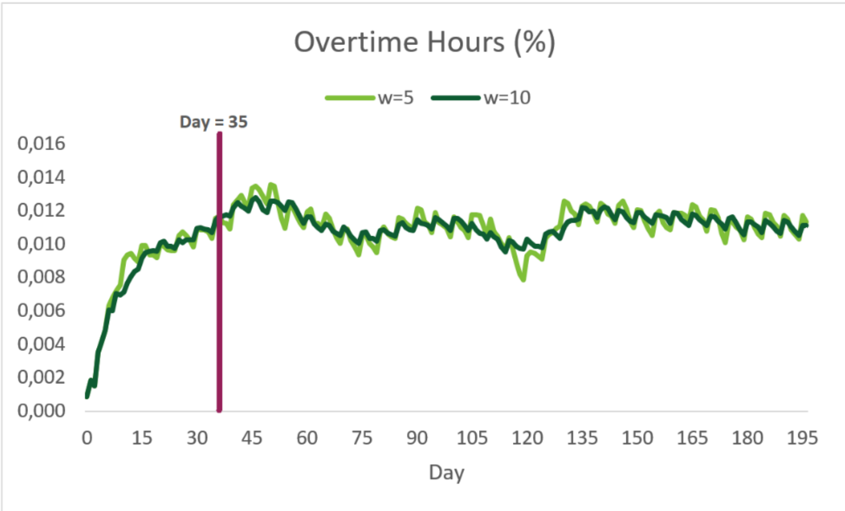
Waiting_at_home
NewClient
MakeAppointment
OnAppointment
AppointmentStrategy
Pro Juventus
Practitioners
Waiting Room
Planning per Practitioner
Exit the Clinic
ToExit
Exit
ExitClient

Appendix M: Warm-up period

In this appendix the graphs of the graphical method to find the warm-up period can be found for the three KPIs that are used.







Appendix N: Number of Replications

In this appendix the number of replications that are needed in order to flatten the cumulative mean of the three KPIs can be seen.