Analysis and improvement of capacity management in a physiotherapy organization

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Master Thesis

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Abstract

Growing demand for physiotherapy has lead to the interest in improving capacity management and planning at large physiotherapy organization. At FysioHolland the current capacity and utilization of resources are largely undiscovered. Furthermore, the increasing demand asks for more efficient utilization of resources. This master thesis aims to define the current capacity and utilization of the organization. Whereafter the effect of different planning and appointment scheduling decisions and strategies will be assessed.

Initial data analysis will provide the insights to define the current capacity and utilization. Consecutively, a simulation study is designed to analyze the effect of a strategic change in appointment scheduling on two use-case practices. The results of the data analysis and simulation study are underlined and accompanied by interviews conducted with employees from multiple practices.

The results of the data analysis defined and explored important factors regarding the capacity of therapists. Also, multiple improvements of the utilization analysis are obtained. Lastly, operational differences within the organization are detected and process standardization is proposed. The simulation study shows the behavior of the planning system under more rigid planning rules. Moreover, it shows the importance of the environment of the specific practice, regarding the feasibility of the proposed appointment scheduling strategy.

Executive summary

Introduction and problem definition
The growth of population, aging, and technological development are just some of the factors causing a growing demand for healthcare. The Dutch government is trying to relieve the pressure on hospitals by stimulating preventive healthcare such as physiotherapy (CBS (2020)). Matching supply and demand, decreasing waiting times, and managing capacity in a healthcare environment is a widely studied subject. However, the shift from demand to preventive healthcare like physiotherapy creates a new area of interest. Physiotherapy organizations recognize this increase in demand and are thereby starting to professionalize by working together with other healthcare providers and grow in size to be able to innovate the world of physiotherapy.

This research is conducted at FysioHolland. FysioHolland is a prime example of a large physiotherapy organization aiming to innovate its processes and improve capacity management and planning to keep up with the growing demand. To be able to do so, they have to tackle a number of problems that the organization is currently facing:

- There is a lack of usage and understanding of the data relating to the capacity of therapists and practices
- The accuracy and completeness of the current utilization analysis is unknown
- The differences in operations between practices and individual therapists needs to be examined
- The current capacity could be utilized better using different planning and appointment scheduling strategies

Research questions and methodology
The aim of this research is to overcome the previously mentioned problems by answering three research questions. Each research question is now introduced together with the methodology used to answer the concerned research question.

1. *What is the current capacity and utilization of the therapists and practices?*

There needs to be more understanding of the different factors defining the capacity of a therapist. Data exploration on historic client arrivals, categorization and definition of therapists, and the structure of treatment episodes will be executed to provide this understanding. Consecutive data analysis will assess and improve the current utilization analysis. During this analysis operational difference between practices are therapists will arise, leading to the next research question:

2. *What is the effect of introducing a traditional, standardized appointment scheduling system on therapist capacity and utilization?*

The data exploration and analysis will describe the operational differences, as well as their possible effect on the capacity and utilization. Standardization of these operations will be proposed. The outcome of the data analysis will then be used to provide the input needed to answer the last research question:

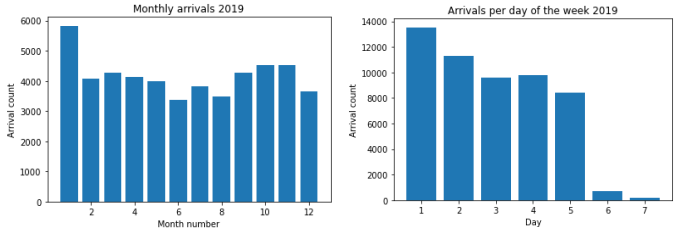
3. *What are the effects of different appointment scheduling strategies on the capacity and utilization of therapists while ensuring acceptable waiting times for clients?*

The proposed appointment scheduling strategy for this research question is a new form of triage by senior therapists. The triage by senior therapist includes specializing senior therapist to do intakes after which clients are assigned to junior or medior therapist for the remainder of their treatments. This research question will be answered using a simulation study, of which the input parameters will be defined by the outcome of the previous data analysis.

The results of all these research questions will be underlined and accompanied by a brief qualitative study. This study includes the conduction of interviews with employees of different

practices regarding the operational differences and the outcomes of this study.

Data analysis
The data analysis provides an initial overview of the data infrastructure of FysioHolland, together with a description of the data relevant to this research. The data exploration includes three different topics: client arrivals, therapist specific data, and client treatment data. The client arrivals contain both monthly and daily patterns. These observations are underlined by comparing data from multiple years, aggregated over multiple practices, and from individual practices. The aggregated monthly and daily arrivals from multiple practices for 2019 are presented in Figure 1.

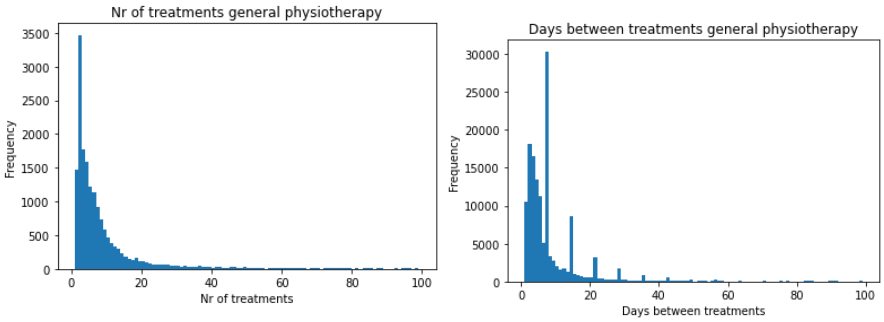


(a) Monthly client arrivals (b) Daily client arrivals

Figure 1: Aggregated client arrivals from multiple practices in 2019

Therapists are categorized based on their specializations. All therapists are able to perform general physiotherapy, an additional master's degree will provide them a specialization in either: edema, pelvis, psychosomatic, oncology, children, manual, and geriatric. There are more specializations and expertise in which therapists could be categorized. However, this data is either irretrievable or can not be linked to specific clients and treatment types and is therefore not useful for this research. The data gathering process regarding therapist availability has been initiated recently. This is a manual error-prone process of which the downfalls will be further discussed.

The data exploration of client treatment information includes the intake process, the number of treatments in a treatment episode, the time between treatment, and the treatment duration. Three different ways of performing the initial intake and treatment of a client have been identified. The most used and preferred intake method includes a double appointment block in which the intake and first treatment are combined. The number of treatments within a treatment episode is explored and split into the different treatment types and client age groups. The results show that there are significant differences in the number of treatments in an episode for these different groupings. This indicates that the clients can not be seen as a homogeneous group and that the structure of treatment episodes with regard to the number of treatments and the time between these treatments should be taken into account. An example of this data regarding general physiotherapy treatments is given in Figure 2.



(a) Number of appointment in a treatment episode

(b) Number of days between treatments

Figure 2: Treatment episode information regarding general physiotherapy

At last, the data regarding historic treatment duration shows a significant difference in the used treatment duration between practices and between therapists. Often this difference is caused by the two different agenda types, an agenda with 30-minute blocks and an agenda with 25-minute blocks. Furthermore, the actual treatment duration often deviates from the predefined treatment duration.

The data analysis shows inaccuracies in the current utilization analysis caused by three factors: group treatments, double bookings and the difference between predefined and actual treatment duration. Two changes in the current utilization analysis are proposed to overcome these inaccuracies. These changes involve the use of actual treatment duration instead of the predefined treatment duration, and the use of the exact appointment time to account for double bookings, and group treatments. The difference between the current utilization analysis, the improved analysis, and the improved analysis including the standardization of treatment duration for one practice are presented in Figure 3.

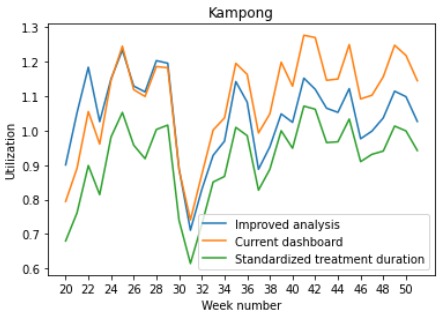


Figure 3: Difference in utilization between the current dashboard, the improved analysis and the improved analysis with standardized treatment duration for Kampong

Some results of the utilization analysis show cases of extreme high utilization (over 300%), mainly occurring at therapists with low availability. This underlines the inaccuracy of therapist availability data caused by the data gathering process. Lastly, the utilization of specialized therapists shows opportunities to free up specialized capacity by sharing clients in need of general physiotherapy with underutilized therapists.

Simulation study
The simulation study is designed using the output of the data analysis of two use-case practices. Client arrivals are generated according to the patterns established and these clients will be assigned to the therapists with the lowest utilization. This assignment takes needs for specializations into account. The output of the simulation will show the practice- and therapist utilization as well as the waiting time of every appointment. Scenario 1 shows that this rigid planning rule causes excessive waiting times at therapists with low availability. Also, in this baseline scenario, practice 1 has significantly higher therapist utilization than practice 2. Scenario 2 shows that a rule including a maximum number of clients in the portfolio of a low available therapist overcomes the excessive waiting time observed in scenario 1. Scenario 3 introduces the new client assignment rule where only senior therapists execute intakes after which the client gets reassigned according to the therapist utilization. The results of this scenario show a significant difference between the two use-case practices of this simulation study. Practice 1 operates under high utilization and has a limited capacity of senior therapists, while practice 2 operates at lower utilization with an abundance of senior therapists. The new rule involves fixing a certain amount of senior therapist time for intake appointments based on peak arrival rates. Whenever arrival rates are low the therapist will thus be under-utilized. Given the fact that practice 1 has a high utilization, there is not enough spare capacity to compensate for this under-utilization of some resources. At practice 2 the new rule is deemed feasible.

Qualitative verification
The conducted interviews lead to a number of interesting insights into the difference between current planning operations at different practices and the proposed planning changes. Regarding the current planning operations, a physical distance between the planning team and the practice can have negative effects on planning operations. This is caused by a lack of practice-specific knowledge at the planning team. Also, local initiatives of sharing clients between therapists could be a tool to save scarce capacity in periods of high utilization. However, this way of working has to align with the therapist's preferred way of performing his daily operations. With regard to the proposed changes in planning, the feasibility of the new client assignment rule studied in scenario 3 of the simulation study is dependant on the influx of new clients. The influx should match with the capacity of senior therapists. On the one hand to properly fill the therapist's agendas, and on the other hand to be able to satisfy the demand. Work satisfaction of senior therapists and the importance of involvement in intake appointments for the learning process of junior and medior therapists should be taken into account. Lastly, while standardizing the treatment duration the following factors should be taken into account: the need for the personal attention of certain clients, work pressure, and the clarity of the therapist's agenda.

Conclusion and recommendations
The data exploration provides an overview of the factors defining the capacity of therapists and practices. These factors include the therapist availability, therapist specialization, and client treatment information (number of treatments required, the time between treatments and treatment duration). The consecutive data analysis leads to an improved and more detailed utilization analysis. The data analysis also detected differences of operation and thereby possibilities of standardization regarding the topics of treatment duration, intakes, and the trajectory of the client through a treatment episode. Lastly, the simulation study showed the effects of a more rigid planning rule and the introduction of the new client assignment strategy. This new strategy is feasible for a practice with sufficient senior therapist capacity, while not operating under extreme high utilization. The use-case practice that posed the opposite properties resulted in a significant increase in waiting time.

There are some recommendations directly resulting from the answers to the research questions. Firstly the therapist availability data gathering process should be changed, resulting in accurate and up-to-date data. The proposed improvement of the utilization analysis should be applied. Leading to a more accurate analysis and enabling the possibility of saving scarce specialist resources when possible. The process standardization regarding intakes and treatment duration should be considered, dependent on the strategic decision to localize or centralize the operation management. Lastly, an appropriate practice should be selected to launch a pilot of the new client assignment strategy. This practice should not be close to full utilization and sufficient senior therapist capacity has to be available. The last two recommendations, not directly linked to any research question, are: create a retrievable database of therapist expertise and specializations and enable administrative double bookings for practice clients.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Population growth, aging, and technological development are just some of the factors causing a growing demand for healthcare. The Dutch government is trying to relieve the pressure on hospitals by stimulating preventive healthcare such as physiotherapy (CBS (2020)). Matching supply and demand, decreasing waiting times, and managing capacity in a healthcare environment is a widely studied subject. However, the shift from demand to preventive healthcare like physiotherapy creates a new area of interest. Physiotherapy organizations recognize this increase in demand and are thereby starting to professionalize by working together with other healthcare providers and grow in size to be able to innovate the world of physiotherapy.

A prime example of such an organization and subject of this research is FysioHolland. FysioHolland is foreseeing an increase in demand and a need to innovate their processes and organization to keep up. The size of FysioHolland together with their central management makes this organization an interesting use-case for this capacity management and planning research.

1.1 Company introduction

FysioHolland is a nationwide physiotherapy organization located in the Netherlands. FysioHolland strives to minimize the time that physiotherapists spend on activities other than providing healthcare. Therefore all therapists are supported by a central service team. The organization has been founded in 2009 and has grown ever since by taking over physiotherapy practices all over the Netherlands. The organization today consists of 113 locations and a central service team located in Nieuwegein.

FysioHolland's mission is to make people healthy and active. They want to accomplish their mission by offering physiotherapeutic care with a therapeutic and economical responsible vision and strategy. FysioHolland wants to be a market leader and retain its current status as a forerunner in the market. The vision of FysioHolland is to finance efficient and high-quality physiotherapeutic care, where online and offline care is increasingly intertwined, and self-management of the client takes an important part. This type of care is made possible by larger, entrepreneurial enterprises and collaborations between these enterprises. This explains why FysioHolland has a high level of multidisciplinary collaboration with (para)medical specializations such as dieticians, psychologists, general practitioners, and hospitals. These collaborations lead to more efficient and better-organized care and a better and quicker result for the client.

1.2 Introduction to operations of interest

This section will give a first introduction to the operations of departments and processes of interest for this study. This information has been gathered during meetings with important stakeholders from these processes including management, planning personnel, financial/operational controllers, data warehouse owners, and therapists.

1.2.1 Planning team

As mentioned before all therapists employed by FysioHolland are supported by a central service team. This facility includes a planning team. On average this team consists of six employees working from Monday until Friday. The tasks executed by this team are all forms of contact with clients and planning of therapist agendas. Clients can reach the service team by either calling, emailing, or chatting (WhatsApp). During this interaction, the main goal will be to schedule an appointment with a therapist. If the caller is a new client, the client's information will be entered into the planning system (Intramed). Subsequently, the client is assigned to a location and therapist and a first intake appointment is scheduled. An intake is also required if an existing client calls with a new complaint. If an existing client with a familiar complaint calls, an appointment is immediately scheduled at their preassigned therapist and location. Planning employees are assumed to be able to judge whether treatment needs to be performed by a specialist. The scheduling of agents for the planning team is now based on perceived workload by the employees and there is no existing analysis of the actual workload.

Some locations and therapists prefer to keep client contact within their clinic, thereby including planning activities. For this reason, some clinics barely make use of the planning support from the service teams. These clinics have their own planning and communications staff. These operations are summarized in Figure 1.1.

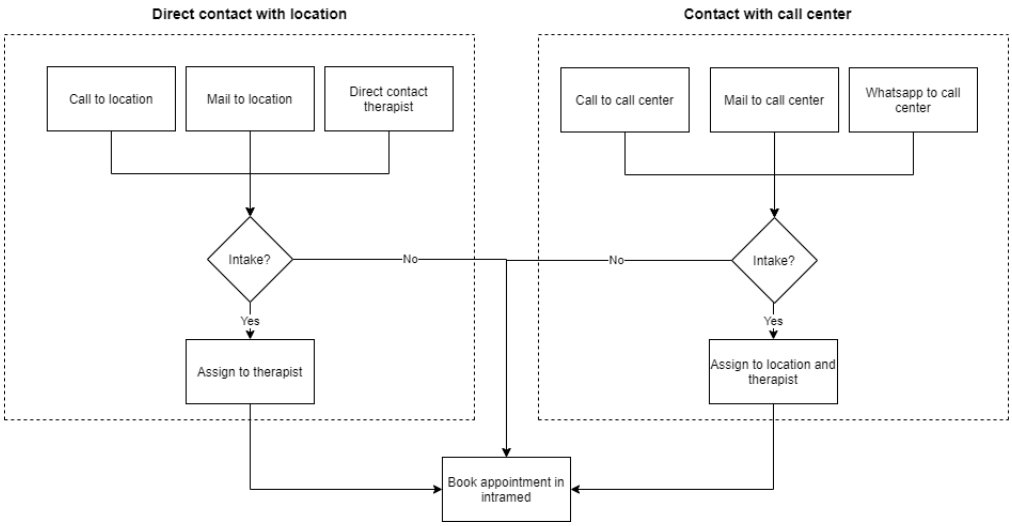


Figure 1.1: Summary of planning operations

1.2.2 Capacity, appointment scheduling and patient flow logistics

The exact manner in which capacity is planned, appointments are scheduled, and patients flow through the system varies widely throughout the organization. This section will introduce a first grasp of the different variations and current ways of working.

The exact capacity of therapists, locations, and the organization is currently unknown. The rules for appointment scheduling vary per clinic and therapist. Appointment duration can be varied based on therapist preferences, treatment types, and clinic standards. However, the general rule is a standard duration of 25- or 30 minutes. Currently, a pilot is being deployed to

change the appointment scheduling rule to standard 25-minute blocks. The most common deviation from this standard appointment occurs when an intake appointment is being planned. Most therapists prefer to book a double block to be able to assess the problem (first block) and execute the first treatment (second block).

During first contact with a client, the client will be assigned to the closest location to their home address. Then a therapist will be assigned taking into account any need for specializations and agenda availability of the therapists. Consequently, the client will be offered the first available slots and an appointment is planned. For complex complaints it is preferred that an experienced therapist is present at the intake appointment, after which regular treatments can be taken over by any therapist. However, this is not a standardized planning rule yet. After a client has been assigned to a therapist this client-therapist assignment does not change in general. The only reasons to change to a new therapist are needs for specialisms or client complaints about the therapist. A client file consists of treatment episodes. Different treatment episodes can be made regarding different complaints and treatment trajectories. Each of these treatment episodes in their turn consists of individual treatments. After a treatment episode is being closed, the dossier can be closed and the client leaves the system. Therapists are categorized into three general categories, namely junior, medior and senior. This categorization is based on their experience expressed in the number of years working as a therapist for FysioHolland. The definition of this categorization is currently under revision and needs to be further examined.

1.3 Problem definition

This section will present the problem definition of this study. The problem definition will be described by multiple problem statements with the corresponding substantiation. Consecutively, this problem definition will be translated into three research questions.

1. *There is a lack of usage and understanding of the data relating to the capacity of therapists and practices*

FysioHolland has been growing extremely fast. However, in terms of process optimization, the business has not always been able to keep up. The (growing) size and central management of FysioHolland offers a unique environment in physiotherapy. There is an abundance of data available within the company and management is eager to use this to explore and improve treatment processes and capacity utilization within FysioHolland.

The company started exploring the available data but is still in the early phase. There needs to be a better understanding of the data by identifying and exploring the different factors that influence the capacity. This will be necessary to be able to execute accurate analysis when it comes to the capacity of therapists and practices.

2. *The accuracy and completeness of the current utilization analysis is unknown*

During this research, the company has been working on an initial analysis of therapist and practice utilization. However, the accuracy and completeness of the analysis are unknown. First insights into this utilization analysis lead to possible improvement directions. Also, the current analysis can be extended with information regarding the performed treatments in terms of specializations, possibly leading to useful insights.

An accurate and complete utilization analysis will help the overall management of different practices. It can identify capacity crunches, thereby triggering a possible action to increase in resources. On the other hand, a low practice utilization can lead to an effort to increase the influx of new clients for these practices by for instance stimulating marketing in these areas.

3. *The differences in operations between practices and individual therapists need to be examined*

The extreme growth of FysioHolland together with the differences in setup (size, ways of working, the mix of resources, etc.) at different practices lead to many operational differences. Initial meetings with different stakeholders already indicated a wide variety in operations between practices as well as between different individual therapists. Taking into account FysioHolland's central management and planning, these differences could lead to difficulties in the manageability of the organization. Exploring and understanding these operational differences is important. Also, the identification of differences in operations could help to make decisions in either centralizing or decentralizing operations of different departments.

4. *The current capacity could be better utilized using different planning and appointment scheduling strategies*

As seems to be common in healthcare institutions, processes and ways of working are simply being continued as they have always been executed. FysioHolland senses that the demand for care keeps growing but the business will not be able to supply the growing amount of care that is required. Therefore it is important to use the available capacity to its full potential. Management is convinced that there are ways to improve the capacity and its utilization. They base this on the fact that that there is a big difference in productivity and thereby revenue among different clinics and therapists.

Management proposes a strategic change in planning and scheduling rules as a tool to improve utilization. This strategical change includes the introduction of different rules for assigning clients to therapists. Currently, there are no clear assignment rules except for an effort to assign a client to a therapist based on the therapist's availability and the best match between the client's complaint and the therapist's expertise. Using the expert knowledge of experienced therapists during the initial examination of the complaint and thereafter assigning clients to other therapists could lead to a more efficient way of utilizing capacity and saving capacity of scarce resources (specialists and experienced therapists).

1.4 Research questions

The initial insights in the operations of interest together with the problem definition lead to the three research questions presented in this section.

Problem statements 1 and 2 both indicated a need for analysis and thereby understanding of the capacity and utilization of therapists and practices. The initial efforts to solve these problems will also be important to solve problem statement 4, where the utilization of current capacity with regard to planning and appointment scheduling is being questioned. This leads to the following research question:

1. *What is the current capacity and utilization of the therapists and practices?*

There needs to be more understanding of the different factors defining the capacity of a therapist. Also, the current utilization analysis should be assessed and extended. This analysis now

only includes the number of available hours for physiotherapy treatments per therapist and compares this to the number of hours in which treatments are performed. A more in-depth analysis is preferred. This analysis would include capacity and utilization of therapists including details like specializations and treatment types. When these results are obtained, capacity utilization of different therapists and locations can be aggregated to obtain the capacity of entire practices. These insights will be used to find bottlenecks and room for improvement for the remainder of this study.

Problem statement 3 introduced the difference in the current rules for planning and appointment scheduling and the fact that these differences are highly dependent on different situations, practices, and therapists. This leads to the need for the introduction of a standardized and traditional appointment scheduling system. This appointment scheduling system will include standardized operations and planning rules that are easy to implement. The following research question is introduced:

2. *What is the effect of introducing a traditional, standardized appointment scheduling system on therapist capacity and utilization?*

The effects on the capacity and utilization of resources will be researched. This intermediate step is also a necessary building block for more advanced systems as first mentioned in problem statement 4. Moreover, this could be a critical step for the manageability of the organization if it keeps growing at its current rate.

The final goal of this study is to assess the effect of different appointment scheduling strategies on the utilization of current capacity as introduced in problem statement 4. As these changes are all based on management suggestions, the capacity analysis used as a basis for this study will indicate whether these improvements are viable and what other improvement directions can be researched:

3. *What are the effects of different appointment scheduling strategies on the capacity and utilization of therapists while ensuring acceptable waiting times for clients?*

The proposed appointment scheduling strategy for this research question is a new form of triage by senior therapists. The triage by senior therapist includes specializing senior therapist to do intakes after which clients are assigned to junior or medior therapist for the remainder of their treatments. This is a way of smoothing the patient flow and creating more available capacity for senior therapists. Also, senior therapists are assumed to become more skilled in their task of doing intakes and root causes for physical complaints are earlier established. In time, this could increase the inflow of clients to the system. Subsequently other therapist can become specialists on specific treatment types to improve their capacity and productivity. In short, it will create predefined client streams, thereby enabling a more organized and streamlined treatment process.

To be able to answer this research question a new performance measure needs to be introduced. Waiting time for clients is currently not measured within FysioHolland but it is deemed important. While capacity needs to be utilized to full extend, it is important that a sufficient level of quality is ensured.

1.5 Scope and research goals

This section will define the scope of the study. The organization is split into a centralized service team and the different practices scattered throughout the Netherlands. The majority of this research will be conducted in close collaboration with the service team. Figure 1.2 gives a schematic overview of the organization with the departments included throughout this study highlighted in green. Note that planning is one of the main subjects of the study and operations regarding this subject are mostly fulfilled by the service team. However, some practices have their own (inhouse) planning and scheduling team.

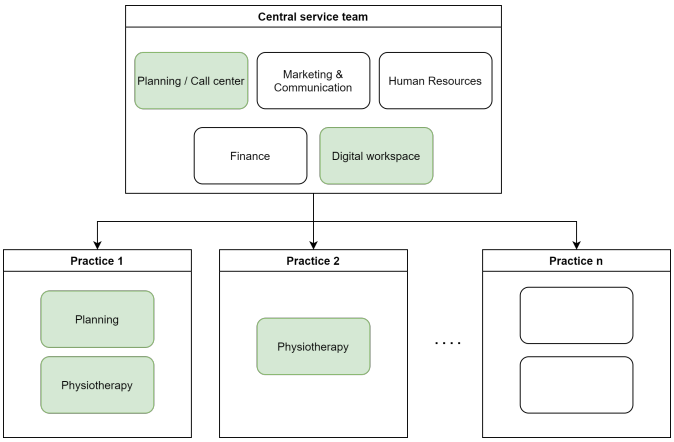


Figure 1.2: Schematic overview of departments within FysioHolland

The main process included in the study will logically be appointment scheduling. Different specializations, treatment types, and treatment duration will be taken into account. On the other hand, more technical medical details regarding client treatments will be out of scope of this research.

The relations and dependencies between resources within a practice will be studied, where the qualifications of therapists are a factor that will be taken into account as well. Some practices may be close to each other which would enable resource sharing and client assignment between these practices. This is however out of the scope of this research. The inclusion and exclusion of these factors are given in Table 1.1.

In scope	**Out of scope**
Appointment scheduling	Medical treatment details
Treatment duration	Physical capacity limitations of practices
Resource sharing within a practice	Resource sharing between different practices
Specializations and treatment tpes	Therapist expertise
Therapist experience qualifications	

Table 1.1: Scope of research

The following research goals are defined:

- Provide insights and structure to the available data regarding client treatments, capacity and utilization of therapists

- Establish operational standards on a practice level
- Identify bottlenecks in the planning process
- Assess the feasibility and effects of strategical appointment scheduling changes
- Extending current literature on high-level capacity analysis in a healthcare environment
- Add a new research environment of a large scale, nationwide physiotherapy organization

1.6 Thesis outline

The remainder of this thesis consists of the following components. In Chapter 2 the relevant literature in the field of capacity management and appointment planning will be presented. Chapter 3 will present the design of the thesis and the used methodologies to answer the research questions. Chapter 4 will contain a description of the data and the main data analysis performed during this research. Consecutively the outcomes of this data analysis will be used as a basis for the simulation study presented in Chapter 5. The gathered qualitative data on current operations, research outcomes and proposed scenario's are presented and discussed in Chapter 6. Finally, the conclusions and recommendations of the this research are presented in Chapter 7.

Chapter 2

Literature review

This section will present an overview of existing literature on topics relevant to this research. Sectopn 2.1 includes studies on the analysis of capacity in healthcare settings, section 2.2 discusses different simulation studies conducted in healthcare settings.

2.1 Capacity analysis

Research question 1 involves the analysis of the current capacity and its utilization. Most studies present elaborate methods of improvements in operations to increase capacity and utilization. However birds-eye view studies with an analysis of capacity in healthcare environments are not often conducted. In this section a few relevant methods from the literature on this subject will be introduced.

A popular subject in the field of capacity studies in a healthcare environment is operation room- and hospital bed capacity. van Oostrum et al. (2008) and Bagust et al. (1999) are prime examples of research studying bed and surgical room requirements taking into account fluctuating demand and emergency treatments.

A more generalizable study on capacity management has been conducted by Bamford and Chatziaslan (2009), where the perceived and actual problems of measuring capacity at a UK hospital are discussed. A listing of different problems regarding capacity measurement is given, which need to be taken into account for this research. These problems include confusion of capacity and capacity utilization, an incomplete view of capacity, disregarding interaction between the capacity of a single organization and that of the whole industry, the product- or service mix, the product- or service specifications, and capacity leakages. The study answers questions like: 'How is Capacity defined and measured at the hospital outpatient department?', 'What are the main issues with measuring and reporting operational performance at the outpatient department?' and 'How can the measurement and reporting of performance at the outpatient department be improved for the benefit of all stakeholders (patients, providers, payers)?'.

Vissers and Beech (2005) present a list of the desired state of knowledge on processes in a hospital surgery environment. This desired state of knowledge is assumed to be the minimum to be able to model the behavior of the system and assess whether capacity matches demand and execute analysis of other planning problems. Translating this list to the environment of this study it would look as follows:

- The number of therapists
- The total annual workload of all therapists
- Waiting time for an appointment
- Main patient groups served by the therapists
- The trajectories of patients within patient groups
- The number of patients served within patient groups and the distribution over trajectories
- The completion time of a trajectory

This data can be used to map and describe the current processes within FysioHolland. From these constructs, only the number of therapists and their annual workload are (partly) known. Information about different patient groups and the client trajectories is available but has not been

explored. Looking at the supply (therapists), this would include insight into the different available specializations and treatment types. From the demand side (clients), this includes the number of needed treatments, the time for these treatments, and the time in between treatments as well as the homogeneity of the clients. The understanding and exploration of these constructs are needed to define the capacity and utilization of therapists and practices as well as enabling more advanced analysis. Client waiting time is also a factor that is listed above. This performance measure is currently not tracked at FysioHolland but it will be introduced in this research. Furthermore Vissers and Beech (2005) provides a conceptual framework of planning and control processes (Figure 2.1).

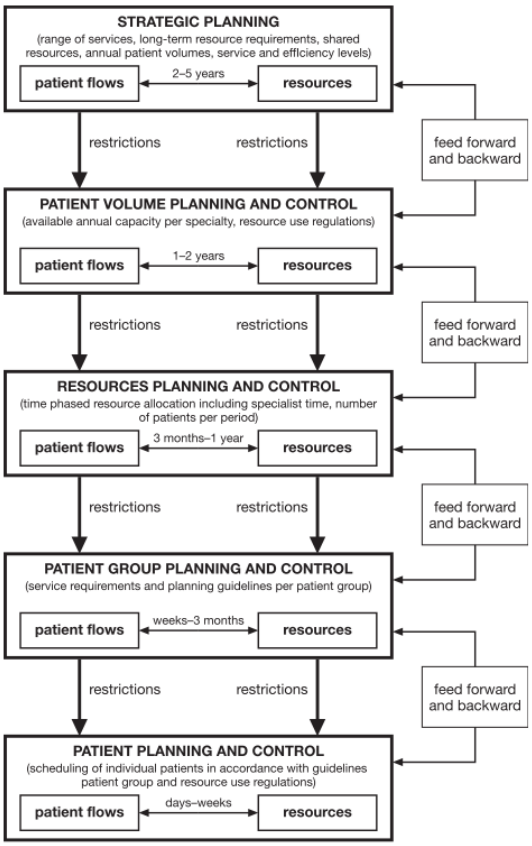


Figure 2.1: Conceptual framework of health OM planning and control processes (Vissers and Beech (2005))

Isken (2002) presented different methodologies for the analysis and modeling of occupancy and thereby capacity in a healthcare setting. The foundation of this study is set by the theory that occupancy can be viewed as inventory-on-hand or work-in-process of requests for service or capacity. Insufficient capacity will lead to waiting time for patients, loss of sales, and a poor quality rating by clients. Well organized organizational data and analytical tools can help management to make the right decisions when it comes to planning and management of capacity.

The studies discussed in this section will provide background as well as a guideline for the capacity analysis conducted during this research. To determine the effect of different appointment

scheduling strategies on the system, simulation studies are a commonly used tool. The coming section will provide insights into the current state of the literature regarding this topic.

2.2 Simulation in healthcare

In general studies regarding appointment scheduling can be divided into bottleneck analysis studies, queueing models, and simulation. The majority of appointment scheduling studies in a healthcare setting use mathematical optimization or queuing models and focus on the micromanaging of outpatient departments (examples by Green (2006) and Ahmadi-Javid et al. (2017)). This micromanagement includes reduction of waiting times and overtime, which most of the time is a matter of minutes. Simulation provides a tool to analyze a department as a whole enabling the researcher to study the environment on a macro level, which is more applicable to this study. For this reason, the literature review will note emphasize the micromanagement studies present in current literature.

The extensive analysis of academic literature on simulation and modeling in health care by Brailsford et al. (2016) show that simulation methods are often used when it comes to planning and system/resource utilization. Most commonly these kinds of studies have a conceptual model as a result that can be specified for a practical context. Jun et al. (1999) describe discrete-event simulation as an operational research technique that allows the end-user to assess the efficiency of existing health care delivery systems and to asses the effect of implementing new systems. Discrete event simulation can also be used to forecast the impact of changes in patient flows, to examine resource needs, or to investigate the complex relationships among different model variables.

Cayirli and Veral (2003) give a review of the literature on outpatient scheduling in healthcare. Methodologies are divided into two categories, static and dynamic. The static case is described as a system in which all decisions must be made before the beginning of a clinic session. In the dynamic case, the schedule of arrivals is continuously being revised throughout a clinic session based on the current state of the system. In general, in healthcare settings, the static variant of the problem is most applicable. However, in a case where walk-ins and cancellations happen frequently the dynamic case could become preferable.

Most literature is based on outpatient clinics. An outpatient is a patient who receives any sort of medical care while not being admitted to the hospital. For instance, if you book an appointment for a consultation at a hospital you will be classified as an outpatient. In a physiotherapy environment patients book an appointment with a therapist at a location and return home afterward. A physiotherapy clinic can thus be seen as an outpatient clinic. It is important to define the settings of the outpatient clinics in our case as clear as possible. As can been seen in the literature the designs of an appointment system (AS) varies widely based on the conditions of the outpatient clinic. These conditions range from a simple case where patients are scheduled for one single service at one single doctor (server) with stochastic processing times. More complex systems arise when no-shows, walk-ins, emergency treatments, multiple servers, and multiple services are taken into account.

Rising et al. (1973) were among the pioneers when it comes to simulation studies in healthcare outpatient departments. This study was one of the first to attempt demand smoothing by changing appointment scheduling, using physician pooling to match demand with capacity, and compare simulation results with real-world data from these real-world process changes. The targets of this study were to reduce waiting times, reduce overtime, reduce idle time and reduce

crowding in waiting rooms and the facility overall.

A more holistic discrete-event simulation model to analyze operations and a centralized information center of a physician network was developed by Swisher et al. (2001). This model is used to evaluate different operating policies. Finally, a fractional factorial design was executed to determine the effect of these policies on the clinic's effectiveness. The simulation model consisted of a clinic layout, medical personnel involved, and different patient types. A centralized information center was added to execute the scheduling and claim processing operations for multiple clinics. The results indicate that this clinical environment is sensitive to changes in patient mix and scheduling rules. Also in some situations, staffing can be reduced without a notable impact on patient service time, clinic overtime, and physician utilization.

Akin et al. (2013b) is an extension on Akin et al. (2013a) where a simulation study was executed regarding capacity management and scheduling decision in a healthcare outpatient environment with multiple patient classes. The model studied the effect of different appointment windows on the maximum time between appointment request date and actual appointment date, capacity utilization, patient access, and financial rewards. The appointment windows are defined by the time in which a patient of a class should be seen. The results underline the importance of choosing the appropriate appointment windows by showing that every performance indicator can be improved compared to their baseline model.

A common result among multiple simulation studies in healthcare outpatient departments is an optimal ratio between the physical capacity of a facility (examination rooms, hospital beds, surface area, etc.) and personnel. Both White et al. (2011) and Berg et al. (2010) used a simulation study in which one of the major results was an optimal ratio between these two variables. White et al. (2011) also showed the importance of deciding on the right capacity-, patient flow- and scheduling policies in an integrated fashion. They found optimal policies for a variety of settings and significant interactions between different capacity and appointment scheduling policies.

A two-phased study in the form of an analytical queueing model followed up by a simulation model was developed by Elkhuizen et al. (2007) to find the required capacity to meet a norm seeing every patient within two weeks. The analytical queueing model was used to gain a quick inside into the capacity needed to meet this norm after which more in-depth analytics were subtracted from the simulation study. Similarly, Rau et al. (2013) analyzed the required capacity regarding different patient mix and arrival rates in a Taiwanese physical therapy clinic. The baseline of the simulation showed that the clinic was running close to the maximum capacity during the busiest weeks of the year.

Although non of these studies can be used as an exact blueprint for the situation of this study, they all closely represent similar simulation studies in healthcare environments. Methodologies and results can be used to shape the design of this research and provide a rough framework.

Useful modeling decisions regarding the arrivals of non-homogeneous client groups and the definition of performance measures are taken from the studies mentioned in this section. The arrivals of different client groups, thereby requesting different services, are often split based on the treatment trajectory they follow. While modeling the environment of the simulation this arrival process is defined using historic ratios of the client groups and their usage of different resources. This method can be used to model the arrivals of clients requesting different specializations in this research. Waiting time and utilization are frequently used performance measures throughout the studies evaluated in this literature research. The definition of these performance measures can be used. Waiting time is often split between the waiting time of the first appointment and

the waiting time of the follow-up appointment. Where the first mentioned waiting time is often referred to as access time. The importance of splitting these different waiting time is relevant to the environment of this study as well.

The main difference between the healthcare environment of this research in comparison to the studies mentioned throughout this section is the setup of the treatment trajectory. The current state of the literature mostly involves treatment trajectories containing one service or multiple services executed during a short period of time. In this research, the entire treatment trajectory of the client is modeled, thereby sometimes including a large number of services and spanning over a long period. Modeling these treatment trajectories requires a different approach than the studies mentioned throughout.

Chapter 3

Methodology

This section will introduce the methodology used to answer the research questions presented in chapter 1. Research questions 1 and 2 involve capacity analysis and standardization of operations, consequently research question 3 deals with more advanced system analysis and the effects of other appointment scheduling rules. The setup of this research including the topics covered is summarized in Figure 3.1.

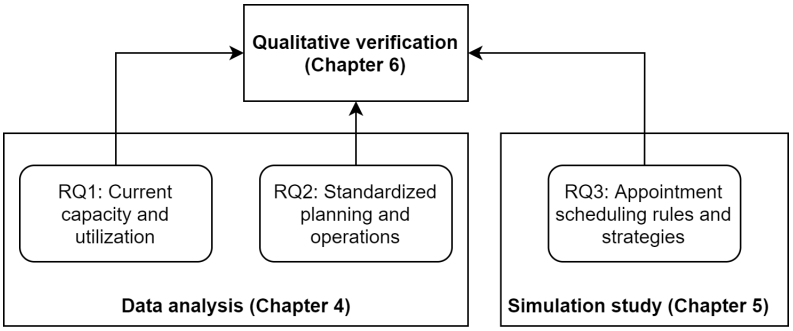


Figure 3.1: Summary of research setup

The first two research questions will be answered by an initial data analysis. The last research question involves analyzing the effects of multiple planning- and appointment scheduling strategies, a simulation model will serve to answer this research question. All of the results regarding the research questions will be further substantiated by interviews with therapists.

3.1 Data analysis

Before being able to answer the first two research questions it is important to explore the environment of current operations. This includes the process of arriving clients, the categorization and definition of different kinds of therapists, and the structure of treatment episodes. The latter including the treatment duration, number of treatments within an episode, and time between treatments.

The data analysis and understanding of these constructs will lead to an improved utilization analysis. After this initial utilization analysis, the variance caused by different ways of working between practices and individual therapists can be reduced by standardizing treatment operations within a practice. The outcomes of this analysis will also provide input for the simulation model to come. Moreover, it will expose inaccuracies and the absence of useful data leading to useful recommendations.

3.2 Simulation study

The goal of the simulation study is to get a more in-depth view of the planning process and possible bottlenecks in different scenarios. The outcome of the data analysis will be used to design the simulation study. The baseline scenario will introduce a fixed planning rule, all other parameters of the simulation will be set to mimic the behavior of the real-world environment. From

the results of this first simulation scenario, possible capacity crunches and planning complexities can be identified. Consecutively new scenarios will be designed to overcome the complexities found in the initial scenario.

The last scenario of this simulation study has been introduced in problem statement 4 of section 1.3 and research question 3 of section 1.4. This scenario will involve a more advanced client assignment rule. The initial triage of a client will be performed by the most experienced therapists, who will then assign the remaining treatments to less experienced therapists.

Throughout the entire simulation study, the data of two use-case practices will define the environmental factors. These factors include the arrival rates of clients, the ratio of requested treatment types, treatment episode information, and the qualification and availability of therapists. The independent factors in each of the scenarios are planning- and client assignment rules, while the performance measures are therapist/practice utilization and client waiting time.

3.3 Qualitative verification

To further explore operational differences between practices and perform a qualitative verification of the results of this study, interviews are conducted. Employees with different roles over multiple practices will be interviewed in a semi-structured way. The general structure and questions asked in each interview can be found in Appendix A. The exact structure of the interviews is different per interviewee. When interesting topics or opinions occur, these subjects are further explored in an open conversation.

Although the operational standards, as well as the differences between practices, have been introduced in section 1.2, the interviews will start with questions defining the current operations regarding the interviewee and the practice of the concerned interviewee. This can lead to insights into the difference between the practices involved in the interviews and conclusions on the effects of these differences can be drawn. This part of the interview is inspired by the variety of ways of working within FysioHolland leading to difficulties as well as opportunities. Central management and planning might be difficult while local initiatives and problem-solving can lead to opportunities for multiple practices.

The latter of the interviews will be used to verify the results of the analysis and simulation study. These results will lead to some practical recommendations and strategic changes. The effect of the deployment of these new rules and ways of working will lead to different responses within the organization. The goal of this part of the interviews is to find out how the interviewees would feel about these operational and strategic changes and what possible pros and cons could be in their point of view.

Chapter 4

Data analysis

4.1 Data selection

This section will present the process of data selection as a basis for the subsequent data analysis. The section will include the data infrastructure, a description of the gathered data, the data cleaning process, and a specific principle that is important for the comparison of company results at different points of time (the like-for-like principle).

4.1.1 Data infrastructure

The main source of the data used for this research comes from Intramed. Intramed is the planning system used by FysioHolland in which almost all information regarding performed treatments is stored. Data from this system is exported daily and initial preparation of the data is performed using a Google Cloud service called Cloud Dataprep. In close collaboration with data owners, the design of this data export has been altered multiple times throughout this study to be able to gather all required data.

After this initial preparation, the data is imported to Google BigQuery and Google Storage. Google Storage will act as a backup and in Google BigQuery the data is further transformed to be used for business intelligence and data visualization. To be able to execute this last step of data visualization and BI some other data sources containing company information and tariffs are imported from a centralized Google Drive. The data visualization is performed using Google Data Studio. This data structure is presented in Figure 4.1. Although the AGB-register is not used internally, it is included in this figure because it is of importance for the remainder of the research. The information retrieved from this database will be introduced in the next section.

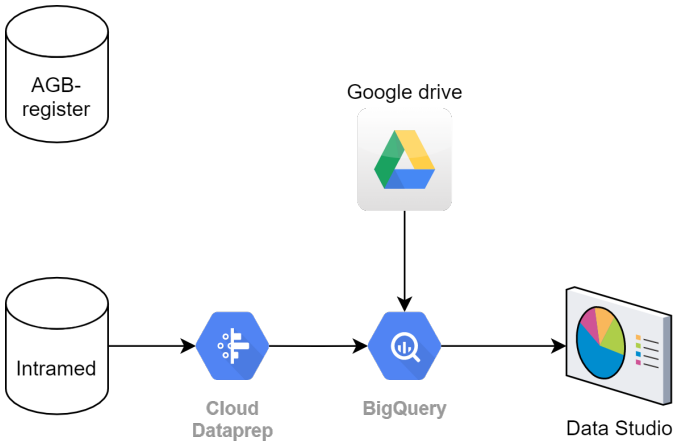


Figure 4.1: Data structure

4.1.2 Data description

The main source of data used for this research is BigQuery. As can be seen from Figure 4.1 there has been an initial data preparation and addition of data performed. Each treatment has a row with all the recorded data for this treatment, this includes 120 columns of stored data

per treatment. The most relevant information per treatment is presented in Table 4.1. This selection is of relevant information is made corresponding to the scope of the research presented in section 1.5.

Variable	Description
Cluster	The cluster of the practice where the treatment was performed
Gender	Gender of client
Name therapist	Name of main therapist of the client
Name treating therapist	Name of therapist that performed this treatment
Starting date	Starting date of the treatment episode
Ending date	Ending date of the treatment episode
Status	File open or closed
Referral code	Code indicating the complaint area and complaint type
Date	Date of treatment
Administration date	Date of first client administration in the system
Time	Starting time of treatment
Duration	Duration of treatment
Treatment code	Code indicating the type of treatment performed
Practice name	Name of practice where treatment was performed
Client number	Unique identifier of client
Treatment number	Unique identifier of individual treatment
Treatment series number	Unique identifier of treatment series
Treatment episode number	Unique identifier of treatment episode
Age category	Age category of client
Intake	Binary value indicating whether treatment is an intake
Predefined duration	Predefined treatment duration
Internal tarrif	Tarrif for treatment

Table 4.1: Available data per treatment

The required therapist information had to be retrieved separately. Information on therapist specialization was retrieved from the online AGB-register (Table 4.2). This register contains information on any kind of healthcare provider in the Netherlands using a unique AGB-number as an identifier.

Variable	Description
AGB-number	Unique identifier per therapist
Qualification	Qualification for different type of treatments (specializations)
Therapist name	Name of therapist
Working at	Practices where therapist is currently active

Table 4.2: Therapist specialization data from AGB-register

The therapist's availability is obtained from a separate data source from the internal Google Drive Storage. This file is updated manually every month by therapists and their managers. The information obtained from this source is given in Table 4.3.

Variable	Description
Therapist name	Name of therapist
Week number	Week number
Daily availability	Number of hours available for treatments per day
Practice	Practice where available hours can be used
Cluster	Cluster of the practice

Table 4.3: Therapist availability data

4.1.3 Data cleaning

A significant amount of data cleaning is performed automatically after the daily data exports. This part of the data cleaning process will not be further explained. The additional data cleaning steps performed for this research are the following:

- Missing values duration: A significant number of records have a treatment duration of 0 (5.10%). There are two possible reasons for a missing value in the duration field. Firstly an administrative error by either the planner or therapist, where the predefined treatment duration values have been removed accidentally. Secondly, a predefined duration can be missing when a new treatment code has just been created. In some instances there is a quick need for a new treatment type and the administration of this new treatment type has not been completed entirely. Due to the large number of missing values, it would be inappropriate to delete all records with a missing value. The time spent by the therapist would be underestimated in many situations. Instead, the missing values are replaced by the predefined duration. Wherever this predefined duration was missing in the general administration of a treatment type, this administration has been updated by the owner of the data warehouse. Thereby automatically updated all records including the concerned treatment type.
- Removal of non-treatment records: There are a number of records with activities that do not require time by a therapist but are recorded for administrative purposes. Examples of these kinds of records are sports subscriptions and sales of products. All these records can be identified by having a predefined duration of 0. These records are removed from the dataset.

4.1.4 The like-for-like principle

The like-for-like (LFL) principle is introduced to secure the accuracy of any analysis performed where comparisons are made over time. The portfolio of the different practices owned by FysioHolland changes over time because of mergers, acquisitions, and disposals. If, for instance, a comparison of turnover between 2020 and 2019 for the month of January needs to be performed, the exact same practices must be included in this comparison. When a new acquisition in January 2020 is included in this comparison it would indicate a large turnover increase comparing 2020 to 2019. To exclude the effect of new mergers, acquisitions, or disposals the practice needs to be in FysioHolland's portfolio for both periods included in the comparison. This principle will be used in this research.

4.2 Data exploration

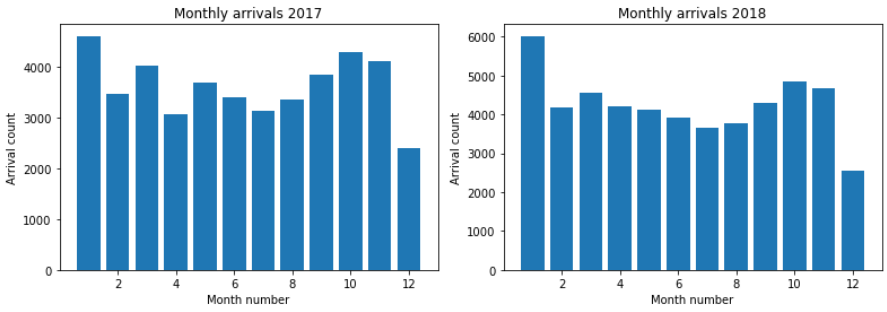
In this section, the exploration of relevant datasets for this study will be presented and discussed. These datasets are divided into different topics: client arrival data, therapist specific data, and client treatment data. Throughout this section, two practices will act as use-cases. These practices are Kampong and Amsterdam - Oosterpark (Blasiusstraat) and will from now on be referred to as practice 1 and practice 2. Those two specific practices are selected because of sufficient data availability. Also, both practices are relatively big while still differing in size, thereby posing possible interesting differences in results.

4.2.1 Client arrivals

Whenever a client first contacts the planning team, their data is entered into the planning system. After completion of this process, the date of entry is stored. This data only consists of a date stamp, the exact time of arrival is not available. This data field has been introduced as the administration date in subsection 4.1.2. This administration data is used throughout this section to count the client arrivals.

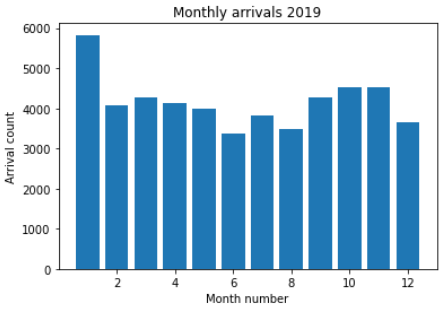
Expert opinion from financial operators and physiotherapists indicated a daily and monthly pattern in these arrivals. Financial data as well as perceived crowdedness in practices by physiotherapists shows lower arrival numbers during summer months and higher arrival numbers during the first months of the year and the months after the summer dip. Regarding daily patterns, the beginning of the week in general seems to see higher arrival numbers. To confirm these observations the number of client arrivals from the planning data is explored.

The arrival data is aggregated over all practices per year. It is important to take into account that practices are acquired and dropped over time. For this reason, the earlier introduced LFL principle should be used. Figure 4.2 presents the number of arrivals per year, only Figure 4.2c includes the LFL principle. The figures for the years 2017 and 2018 can be used to identify patterns but should not be used to compare the absolute number of arrivals to data of other years.



(a) 2017 (b) 2018

Figure 4.2: Monthly count of aggregated arrivals over all practices for separate years



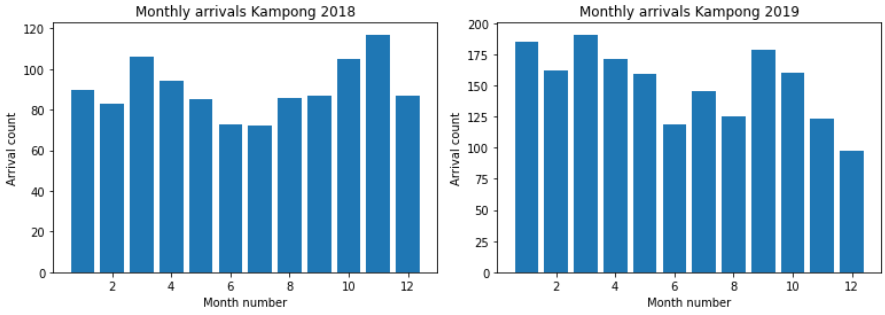
(c) 2019

Figure 4.2: Monthly count of aggregated arrivals over all practices for separate years

In general, the number of new client arrivals in January is significantly higher than the rest of the year. March, April, May, September, October, and November are average months, and a dip in February, July, August, and December can be observed. The dip in December and the subsequent peak in January can be explained by clients waiting for a new insurance coverage year. At the beginning of a calendar year, the number of covered physiotherapy sessions by insurance companies renews. The dip in the summer months July and August is easily explained by holidays taken by both clients and therapists.

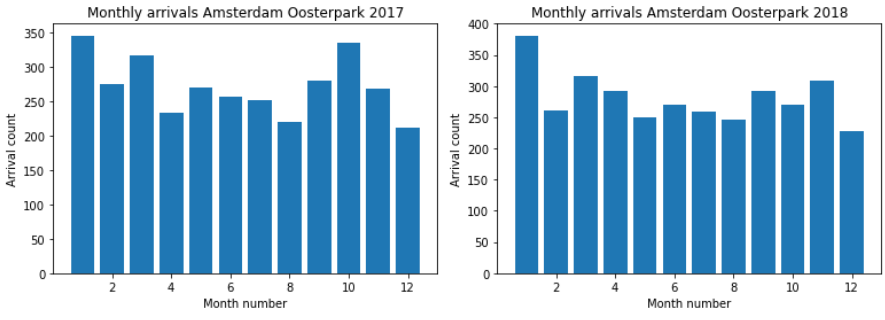
To further substantiate these observations the number of arrivals on a practice level is presented, using the earlier introduced use-case practices. Practice 1 has been fully operational since 2018, the monthly arrivals for this location are presented in Figure 4.3. The months with a relatively lower arrival count (June, July, August, and December) are again visible with exception of a peak in July 2019. The peak in January and the after-summer months are again visible, although the peak in January is less significant than in the overall data.

The overview of monthly intakes for the years 2017, 2018, and 2019 for practice 2 are presented in Figure 4.4. Similar patterns can be observed, relative lower arrival counts during the summer months and in December, notably higher intake in January and the months after the summer holidays. This concludes the importance to take monthly arrival patterns into account.



(a) 2018 (b) 2019

Figure 4.3: Monthly arrivals at practice 1 for separate years



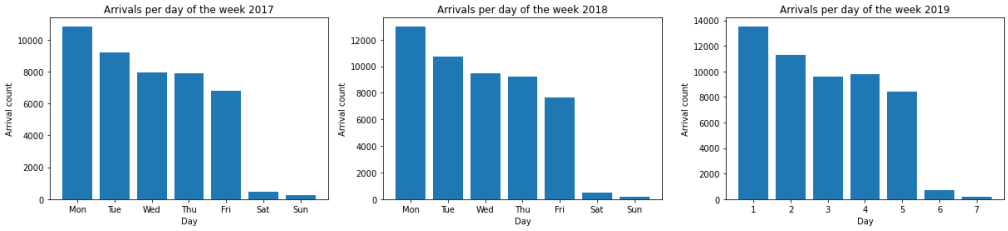
(a) 2017 (b) 2018

(c) 2019

Figure 4.4: Monthly arrivals at practice 2 for separate years

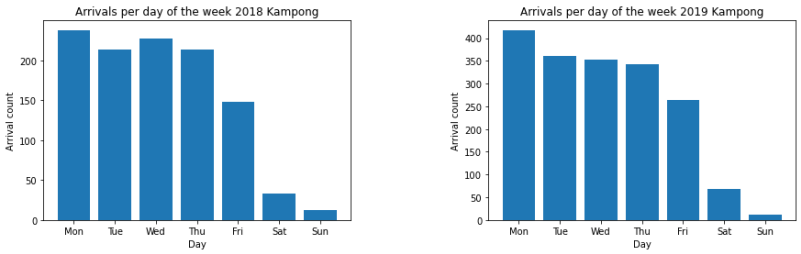
Next to monthly patterns and seasonality also daily patterns can be observed. Figure 4.5 shows extremely low arrival counts for weekend days generated by the few practices that are open during the weekends. Moreover, Monday and Tuesday receive significantly more arrivals and Friday notably less.

These patterns are again underlined by the arrivals on a practice level as presented in Figure 4.6 and Figure 4.7. Although some variations exist the general pattern of fewer arrivals on weekend days and Fridays and a more arrivals on Monday can be concluded.



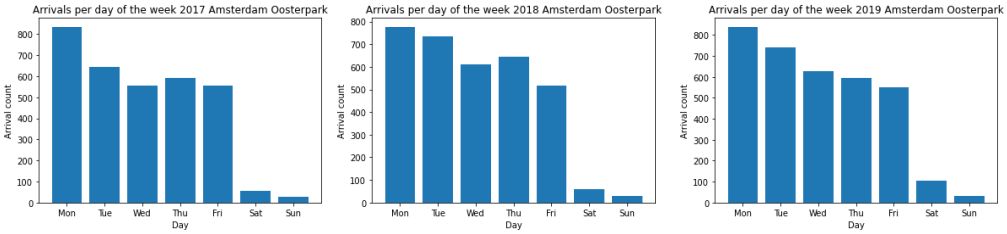
(a) 2017 (b) 2018 (c) 2019

Figure 4.5: Counts per weekday of aggregated arrivals over all practices for separate years



(a) 2018 (b) 2019

Figure 4.6: Arrivals per weekday at practice 1 for separate years



(a) 2017 (b) 2018 (c) 2019

Figure 4.7: Arrivals per weekday at practice 2 for separate year

The patterns and seasonality found in the arrival data indicate that the arrival process is a non-stationary process, i.e. the arrival rate is not independent of the time over which this rate is used. It is important to keep peak arrival moments as close to reality as possible as this will most accurately replicate peak moments in the planning process. To be able to keep the integrity of the arrival data, a non-homogeneous Poisson process is used to simulate client arrivals. Parameters are determined for every weekday of every month. Arrivals from 2019 (2020 excluded because of Covid-19 measures) are used to determine the arrival rates for the separate time intervals because this will most closely represent current arrivals. This will result in 84 different 'day of the month' arrival rates.

Splitting the arrival data into many different datasets according to the day of the month, results in a relatively small dataset to estimate the Poisson parameters. It is inaccurate to test whether each of these datasets follows a Poisson distribution because of the size of the dataset. A Poisson distribution is thus assumed on the basis that this is the most common way to model a non-homogeneuos arrival process.

4.2.2 Therapist information

This section will present the data regarding the specific therapist. This includes the different qualifications and therapist availability.

Therapist qualifications

The servers or care providers in this study are the physiotherapists. Physiotherapy knows a wide range of expertise and specialties. A specialty in this case is defined as a type of treatment for which a master's degree has been obtained and this is officially registered in the AGB-register.

On the other hand, expertise is defined as a type of complaint or treatment in which the skills or knowledge of these therapists exceeds the average.
From the data, it is not possible to track whether a historical treatment needed specific expertise. Therefore therapist expertise is out of scope. Therapists' specializations are directly linked to certain treatments because they correspond to a certain treatment type. For this range of treatment types a specialization is mandatory to be able to perform this particular treatment. These special treatments are:

- Edema
- Pelvis
- Psychosomatic
- Oncology
- Children
- Manual
- Geriatric

The AGB-register includes more specializations than the seven just mentioned. However, these treatments are not tracked as a separate treatment type in the data and are for this reason not distinguishable from general treatments. The present specializations at the two use-case practices are given in Table 4.4. We can conclude that the present number of specialized therapists can be scarce and their capacity should be managed with caution. Of all specializations, manual therapy is most closely related to general physiotherapy and thereby these treatment types can intertwine to a certain degree.

Specialization	**Practice 1**	**Practice 2**
Edema		1
Pelvis		1
Psychosomatic		
Oncology		
Children	1	
Manual	1	4
Geriatric		

Table 4.4: The number of specialized therapist per practice

Next to these specializations, therapists are split into three different qualifications based on their experience: junior, medior or senior. Besides experience, specializations and extra executed courses and masters are considered while defining the qualification of a therapist. The qualification per therapist for the use-case practices are known.

Therapist availability

Therapist availability in this study is defined as the time a therapist is available to perform treatments. This excludes any organizational hours like meetings, supervision of interns, etc. In the central planning environment Intramed, therapists define the slots available to perform treatments in their agenda. In this way, the planning team knows when treatments can be planned. Therapists themselves can overbook their agenda's when needed.

Intramed does not have the functionality to export this agenda availability. For a long time, this piece of information has therefore been unknown. Because of the importance of accurate

therapist availability data the organization started a project to internally gather and update this data. Because of these efforts, the therapist availability (in hours available to perform treatments) has been tracked from the first of July 2020 and an estimate of availability is made for the period before the first of July. This therapist availability is updated monthly by location managers in collaboration with the individual therapists. This process of keeping track of therapist availability is manual and prone to errors. The downfalls of this process will be further discussed in subsection 4.3.1.

4.2.3 Client treatment information

A treatment episode can consist of multiple treatment series each consisting of one or multiple individual treatments. A treatment episode can be split into multiple treatment series for a number of reasons. Different kinds of treatments need different indication codes for declaration administration. For instance, the indication code 010 indicates a pelvis treatment against urine continence for which the first nine treatments are covered by Dutch basic insurance. After these initial nine treatments, the indication code changes and a new treatment series within the same treatment episode needs to be initiated. Secondly, a treatment series can be closed after which the client returns with the same complaint, again a new treatment series within the same treatment episode needs to be created.

Theoretically, every treatment episode should start with an intake appointment and is closed after a certain number of treatments. The initial intake appointment is combined with the first treatment in a double time slot and from there on follow-up treatments are planned. However from gathered data there are a few alternative possibilities for the beginning of a treatment episode:

- A combined intake appointment and first treatment in a double time slot.
- One intake appointment in a single time slot.
- One treatment in a single time slot.

The latter of these three cases is an administrative error, as every episode should start with an intake appointment. This will thus be corrected by changing this treatment to an intake appointment. After each of these three options, the episode can be directly closed or follow-up treatments are needed to treat the complaint.

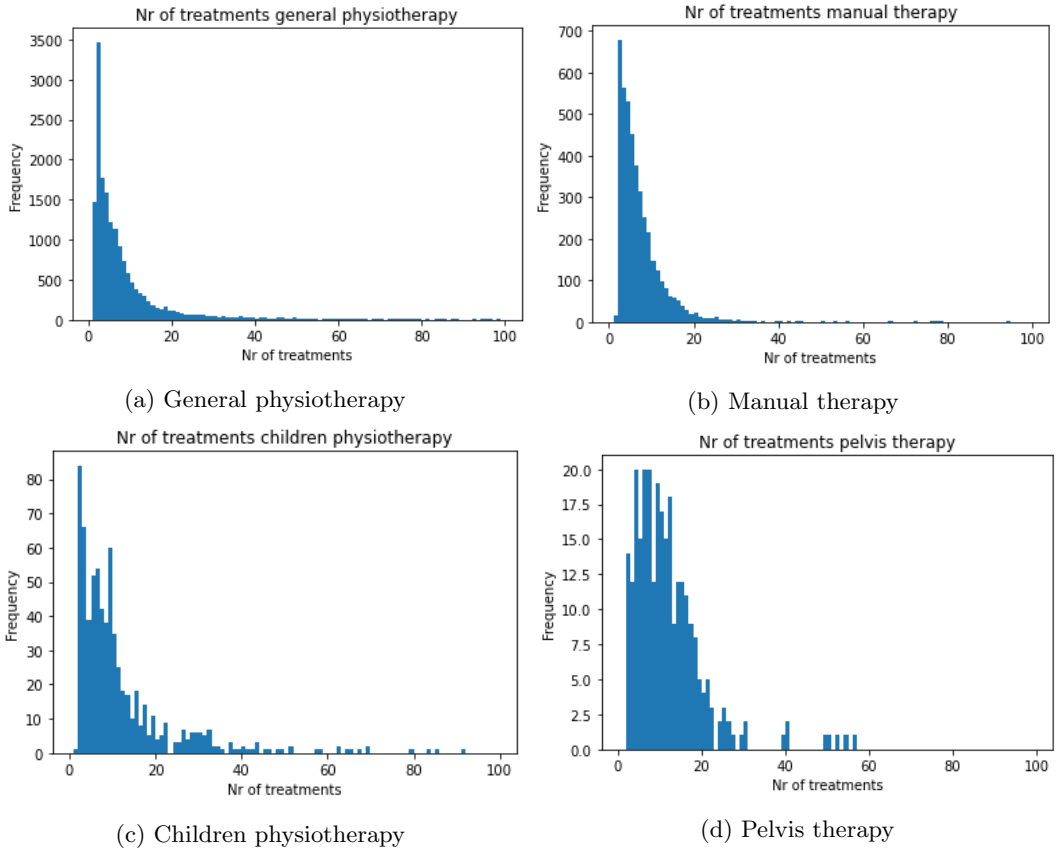
In general, a treatment episode only includes treatments of the same type although exceptions exist. Regarding the modeling of a treatment trajectory for simulation purposes, the number of treatments and the time between treatments need to be explored.

According to therapists in the field, it is important to keep the integrity of a treatment episode intact. The type of treatment, as well as the background of the complaint, has an effect on the number of treatments needed as well as the time in between these treatments. For instance, post-operative physiotherapy needs more frequent treatments shortly after the operation after which the intensity of treatments can be lowered. On the other hand, chronic complaints, in general, show a long-lasting treatment pattern with a fixed and stable time in between treatments. Other factors, like treatment type and age, could also be important to consider while modeling these variables. At first, the data will be explored splitting the data into the different types of treatments and age groups. The outcome of this exploration will decide if it is possible to fit a distribution to the historical data or if an empirical distribution needs to be used. The initial explanation of therapists about the setup of a treatment episode for different clients points towards the use of an empirical distribution.

Number of treatments in a treatment episode

The initial exploration of the number of treatments in a treatment episode includes two years of data from one cluster of practices. Only episodes that are started and closed within this period are considered. The dataset is reduced to one cluster to make the analysis more manageable regarding the run time of the program to perform this analysis. The total number of treatments analyzed within this cluster of practices is 227,812.

The histograms of the number of treatments are initially split into the four most commonly performed treatment types. When treatment types are mixed within a treatment episode the most common type is taken to assign the episode to a unique treatment type. The most common types are regular physiotherapy treatment (72.1%), manual treatment (17.8%), children physiotherapy (2.9%), and pelvis therapy (1.2%). The number of treatments for each of these treatment types is presented in Figure 4.8.



(a) General physiotherapy

(b) Manual therapy

(c) Children physiotherapy

(d) Pelvis therapy

Figure 4.8: Number of treatments in a treatment episode per treatment type

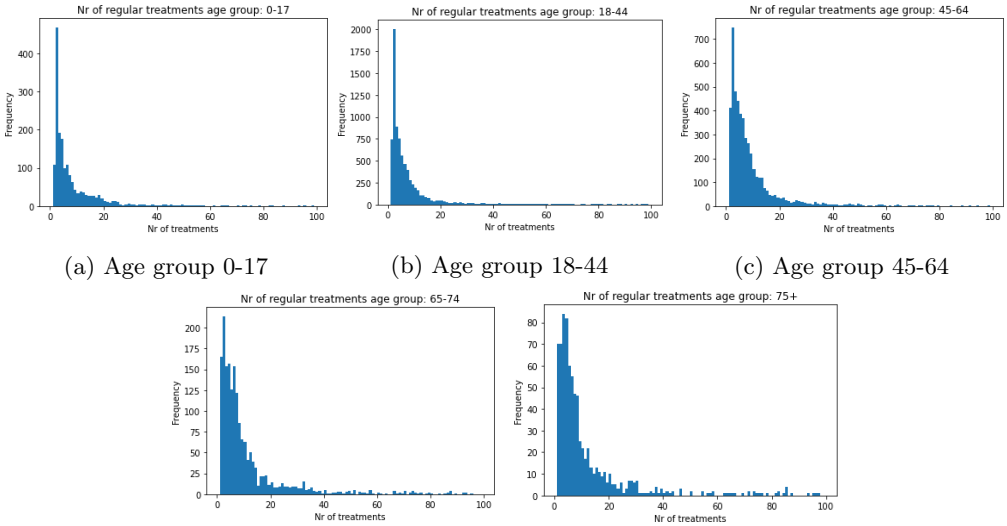
It is clear that all distributions are right-skewed with a long tail. For instance, the number of general physiotherapy treatments within a treatment episode reaches a maximum of 312 treatments. Outlier detection is needed to be able to fit any classical distribution to this data. However classical outlier detection methods like the interquartile range method (Barbato et al. (2011)) will eliminate roughly 9% of the data, while these data points are not necessarily invalid.

The general interquartile range method will exclude all data points outside certain limits. These limits are calculated using:

$$\text{Lower limit} : Q_1 - 1.5IQR$$
$$\text{Upper limit} : Q_3 + 1.5IQR$$

Q_1 and Q_3 indicating the first and third quartile of the data and IQR the interquartile range, defined as $Q_3 - Q_1$. Barbato et al. (2011) indicates that this method can be used up to a maximum of seven times the interquartile range in some cases. Still even the extreme number of treatments do not seem invalid. Therefore the decision has been made not to perform any outlier detection method.

The second split is made per age group. The figures and tests presented only include general physiotherapy treatments. The results for this treatment type with regard to the age of the client will be generalized for other treatment types. The counts of the number of treatments in a treatment episode per age group are presented in Figure 4.9. From these figures we can observe that treatment episodes seem to last longer for clients in older age groups, i.e. the median number of treatments within a treatment episode for these clients is higher.



(a) Age group 0-17 (b) Age group 18-44 (c) Age group 45-64

(d) Age group 65-74 (e) Age group 75+

Figure 4.9: Number of treatments in a treatment episode per age group

To statistically test whether the splits in treatment type and age group could be regrouped and thus modeled as one homogeneous set a Kruskal-Wallis (Kruskal and Wallis (1952)) test is performed. In this case, the Kruskal-Wallis test is selected because it does not need any assumptions of underlying distributions. Where on the contrary many similar tests assume normally distributed data (like the student t-test Student (1908)). The null hypothesis of the Kruskal-Wallis test is that all the population distribution functions are identical. The alternative hypothesis is that at least one of the populations tends to yield larger observations than at least one of the other populations. To perform this test the Python ScipyStats. Kruskal package is used. The output of the Python package includes a T-test statistic and p-value, the common

significance level of 0.05% is chosen to evaluate the outcomes. The results of the tests performed can be found in Appendix C. The conclusion of these tests on the distributions regarding different treatment types and age groups is that almost all of these subsets have different underlying distribution functions. In theory, only the age group 65-74 can be combined with the age group 75+.

With these analyses and conclusions as a basis, the decision is made to use empirical distributions for the setup of a treatment episode. In this way any important factors (treatment type, age group, complaint type etc.) will be taken into account, without mixing the possible effects of these factors on the length of a treatment episode.

Time between treatments

As mentioned before it is assumed that the time between treatments also depends on a number of factors. Some of these factors (post-operative treatment, muscle treatment, tendon treatments, etc.) can not be retrieved from the data. For this reason alone it is sensible and most accurate to use an empirical distribution for the time between treatments. Keeping the link between the number of treatments and time between treatments again helps to ensure that the integrity of the treatment episode is preserved and the possible factors influencing these variables are not mixed resulting in an illogical setup of treatment episodes. An example of the time in between treatments for general physiotherapy is given in Figure 4.10. Two patterns can be observed from this histogram. Firstly a right-skewed distribution with a long tail and secondly a cyclic pattern every seven days. This is in line with the expectation from therapists described at the beginning of subsection 4.2.3.

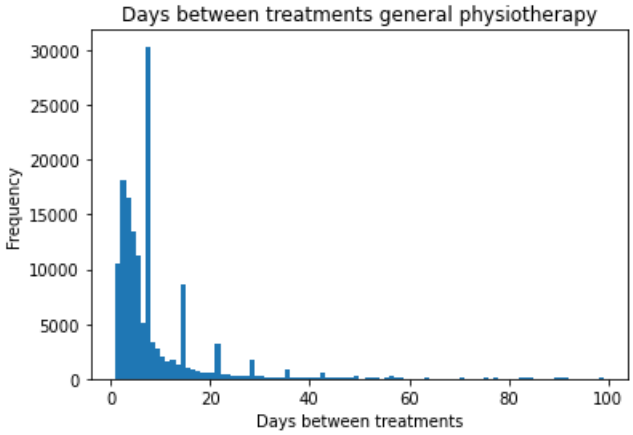


Figure 4.10: Number of days between treatments for general physiotherapy sessions

Treatment duration

Every treatment within a treatment episode has its standard predefined treatment duration. This predefined duration is assigned based on internal standards per treatment code. The vast majority of treatments have a predefined duration of 30 minutes. Deviations exist for home treatments, group treatments, and some specializations. In practice, a significant part of the practices uses a standard treatment time of 25 minutes instead of 30 minutes. This is not accounted for in the predefined treatment duration, which leads to inaccurate analysis on multiple

counts. The effects of this observation on the utilization analysis will be further discussed in subsection 4.3.1.

Besides the predefined duration, therapists are able to manually change the duration of the treatment. The reasoning behind an alteration of duration is mostly based on earlier experience with treatments of the same client. From a productivity perspective, it is important to know to what extend therapists change the treatment duration. Payments from health insurance providers are mostly per treatment, no matter the duration of the treatment. Manually changing the treatment duration can therefore change the productivity of a therapist.

In practice, the standard time therapists take per treatment varies per practice and even within practices per therapist. On a management level, assumptions are made on standard treatment duration on a cluster level however analyzing duration data on a therapist level shows major differences. Table 4.5 shows the relative usage of different treatment duration for general physiotherapy treatments at one practice. At this practice, a standard treatment duration of 25 minutes is assumed. As can be seen in the table 10 out of 18 total therapists actually schedule 25 minutes for these treatments, seven therapists use a 30-minute schedule and one therapist plans the majority of the treatments for 20 minutes. From a capacity and planning standpoint a 5-minute difference per treatment has big effects. On an eight-hour workday, a therapist that uses a 30-minute schedule instead of a 25-minute schedule will be able to treat 16.6% clients less on average.

	Treatment duration (minutes)											
	20	25	30	35	39	40	45	50	55	60	65	75
Therapist 1		**72,05%**	10,44%	0,82%		0,54%	1,27%	4,45%	0,18%	9,17%	0,54%	0,27%
Therapist 2			**100,00%**									
Therapist 3			**100,00%**									
Therapist 4		**90,30%**	5,69%	0,33%			0,33%	1,34%		2,01%		
Therapist 5		**85,71%**						14,29%				
Therapist 6		18,18%	**81,82%**									
Therapist 7		**74,35%**	8,38%	0,12%		0,12%	0,25%	11,10%	0,12%	5,43%		0,12%
Therapist 8		**100,00%**										
Therapist 9		15,11%	**81,35%**					0,32%		3,22%		
Therapist 10		**62,05%**	36,20%				0,23%			1,51%		
Therapist 11		35,90%	**58,67%**	2,45%	0,18%			1,05%		1,58%	0,18%	
Therapist 12	2,27%	**96,59%**						1,14%				
Therapist 13		**71,96%**	20,30%				0,37%	0,74%		6,64%		
Therapist 14		10,01%	**79,87%**				0,06%	0,23%		9,83%		
Therapist 15		4,17%	**91,67%**					4,17%				
Therapist 16		**100,00%**										
Therapist 17		**100,00%**										
Therapist 18	**56,25%**	39,58%	4,17%									

Table 4.5: Used treatment duration per therapist at Kampong for a general physiotherapy treatment

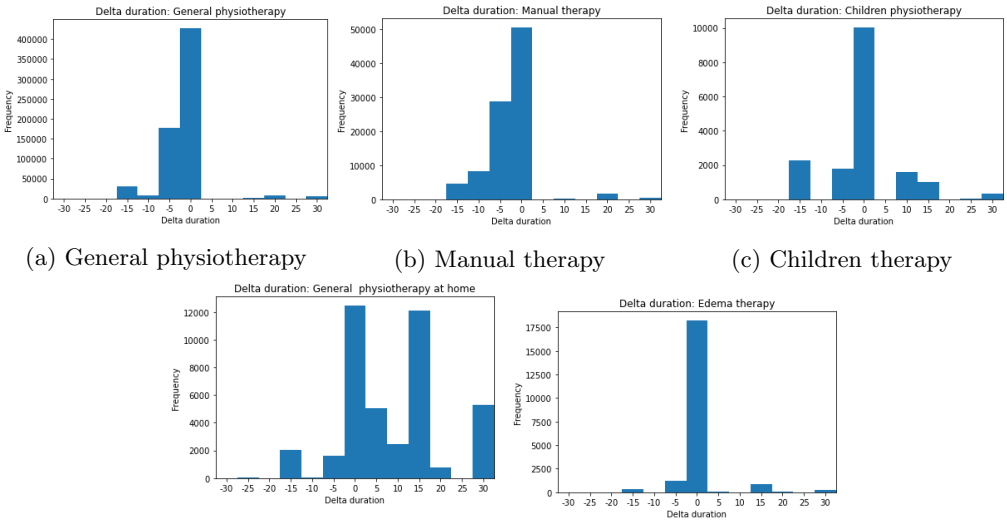
To further explore this deviation between the predefined- and actual treatment times this difference in presented in the histograms in Figure 4.11. The delta duration in these graphs are defined as:

$$\text{Delta duration} = \text{Actual treatment duration} - \text{Predefined treatment duration}$$

A frequently occurring deviation has been described earlier, the 25-minute schedule has not been embedded in the predefined treatment duration. This results in the peaks at -5 in almost every graph. Another striking observation can be made regarding manual therapy, in many cases, it seems to be possible to shorten the duration of these treatments. The opposite can

be concluded for general physiotherapy treatments at home. The predefined treatment duration for this treatment is 45 minutes, however many therapists seem to take more time. In many cases, this is caused by the travel time to go to-and return from a client from the practice. This travel time is partly included in the longer predefined treatment duration but turns out to be insufficient sometimes.

In general these histograms prove that in many cases there is a difference between the predetermined treatment duration and the actual treatment duration. It is important to take this into account throughout the remainder of the performed analysis.



(a) General physiotherapy (b) Manual therapy (c) Children therapy

(d) General physiotherapy at home (e) Edema therapy

Figure 4.11: Difference between predetermined- and actual duration per treatment type

4.3 Data analysis

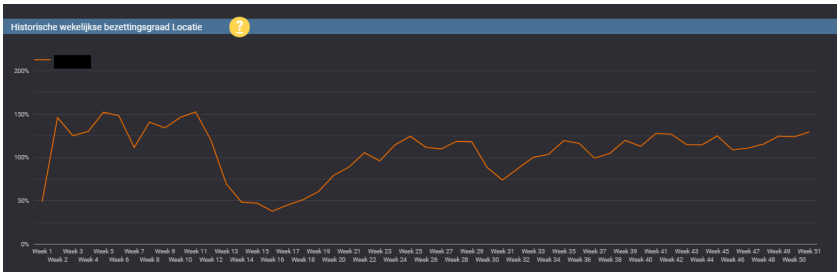
In this section, the analysis concerning utilization and standardized operations will be presented.

4.3.1 Therapist utilization

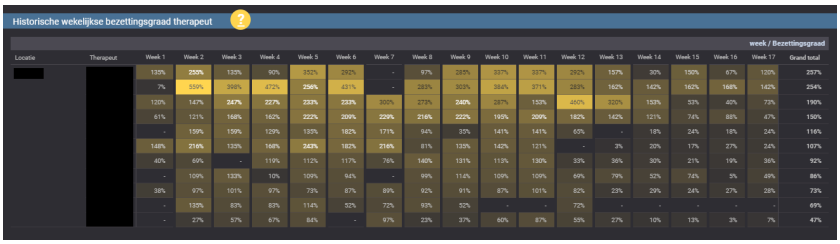
During the execution of this research, a focus group within FysioHolland has been working on a dashboard including therapist- and practice utilization. This dashboard includes two different data visualizations. First the weekly historical utilization per location and therapist (Figure 4.12) and secondly the daily utilization for the coming week. The utilization is calculated as follows:

$$\text{Utilization} = \frac{\text{Sum of predefined treatment duration per week}}{\text{Weekly available hours}}$$

The sum of the predefined treatment duration is directly taken from the planning system. The weekly available hours are gathered from the manually updated file of therapist availability as introduced and discussed in subsubsection 4.2.2.



(a) Historical weekly utilization for one practice



(b) Historical weekly utilization per therapist for one practice

Figure 4.12: Current dashboard of practice- and therapist utilization

This utilization calculation has three major drawbacks:

- **Group treatments**
  Currently the duration of group treatments is estimated based on the predefined treatment duration. Groups are divide in group sizes: 2-3, 3-4, 5-6, 7+. Each having a predefined duration of 30, 20, 15 and 12 minutes respectively per client. This leads to inaccuracies because the total duration of a group will never amount to the actual duration of the treatment. For example a group of 4 people have been treated in a treatment of one hour, based on the predefined duration this will now amount to 4 x 20 = 80 minutes, while the actual treatment only lasted 60 minutes.

- **Double booking**
  Booking two appointments in one time slot will result in inaccuracies because the worked hours will be overestimated. If two appointments are planned in a 30 minute time slot, the therapist will have worked 60 minutes based on the predefined treatment duration, while this therapist was actually occupied for just 30 minutes.

- **Difference predefined and actual treatment duration** When therapists manually change the duration of a treatment this is not taken into account in the current utilization analysis. The predefined duration will still be used although actually the treatment may have lasted shorter or longer.

All these drawbacks can be resolved by making two adjustments to the current analysis. Using the exact appointment time, the duration of the sum of treatments in one slot can be divided by the number of treatments in this slot to come to a net duration. In other words, when two or more appointments start at the same time by the same therapist this double booking needs to be taken into account. Secondly, using the actual duration of a treatment instead of the predefined duration will result in a more accurate utilization. To be able to execute these changes the export design has been altered to gather the exact starting times of appointments.

Figure 4.13 shows the difference between the current utilization dashboard and the analysis after the improvements for one practice. This figure displays the most recent utilization after closing down all physiotherapy practices due to the first lockdown in the Netherlands. A significant difference in utilization can be found for this practice. This method of obtaining an improved utilization analysis is robust and can be used for any practice.

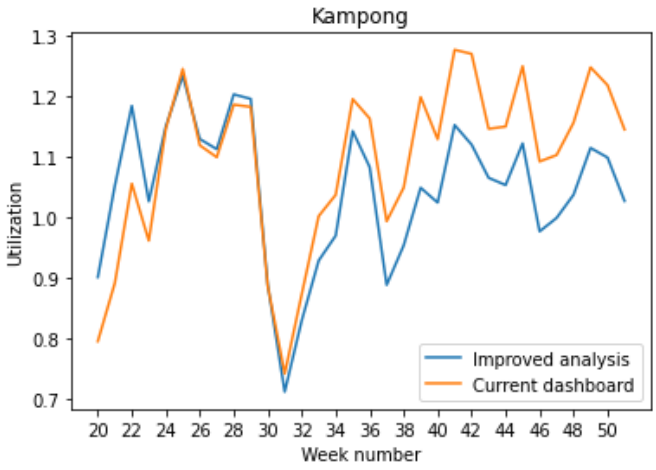
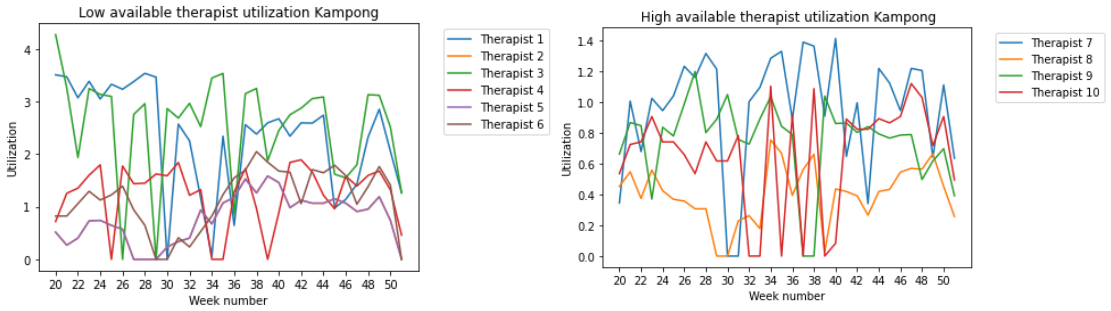


Figure 4.13: Difference in utilization between the current dashboard and the improved analysis for Kampong



(a) Low available therapists

(b) Medium to high available therapists

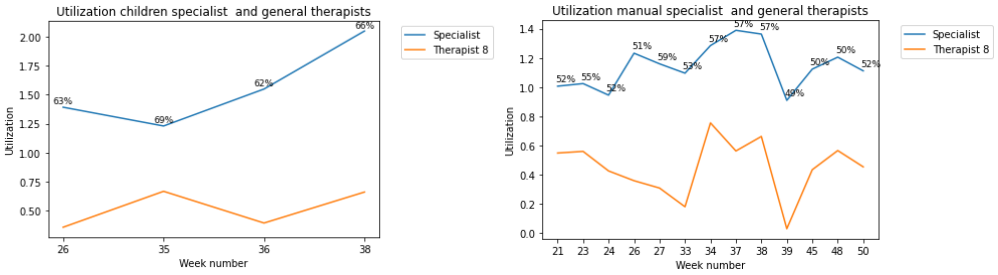
Figure 4.14: Utilization per week 2020 (after corona lockdown) per therapist split into groups according to availability

Another striking result is the level of the current utilization. For some months practices seem to be significantly over-utilized, indicated by a utilization of greater than 1. This situation is of course undesirable and can lead to unwanted therapist overtime or increased waiting times for clients. To get a detailed view on the utilization of a practice the individual utilization of the therapists can be further explored. The 10 therapists that have been active most recently will be used to represent the individual utilization in this practice. These therapists have been split up between therapists with low general availability (average weekly availability of fewer than eight hours) and medium to high availability (average weekly availability of more than eight hours)

in Figure 4.14. The utilization of low available therapists shows some questionable results. In general for all therapists over the entire course of the analysis, the utilization surpasses 1, with some extreme values higher than 3. This would indicate that during this week a therapist worked three times as much as its available hours. As mentioned before the accuracy of the therapist availability needs to be questioned at this point. The effect of this inaccurate availability data results in inaccurate utilization data. A process change in tracking and gathering daily therapist availability is needed to ensure that the analysis yields more accurate results.

4.3.2 Specialists utilization

This section will focus on the utilization of specialists. The capacity of specialists can be scarce, Table 4.4 showed that only a few specialists are available per practice. Whenever these therapists are operating close to maximum capacity, the ratio between the time spend on specialist treatments and general treatment can become important. There could be an abundance of capacity for general treatments while the capacity for a certain treatment type is already at its maximum. To show this practice 1 will again lead as an example. This practice has two specialists, one for children physiotherapy and one for manual therapy. Figure 5.4 highlights four weeks in which the children physiotherapist specialist is working at or close to the maximum capacity while spending a relatively large amount of time on general treatments. The percentages given in this figure indicates the time spend on the specialization relative to the total amount spent. Besides the utilization of the specialist, the figure presents a general therapist with spare capacity for general treatments. We can conclude that although the specialist has a utilization greater than 1, there is still a significant proportion of time spent on general treatments. Reassigning these general treatments to the therapist with lower utilization creates extra capacity for specialized treatments. An additional benefit is the fact that specialized treatments will generate more turnover and profit compared to general physiotherapy treatments.



(a) Children physiotherapy specialist

(b) Manual therapy specialist

Figure 4.15: Utilization of specialist and general therapist with relative time spend on specialist treatments

4.3.3 Standardized operations

From a managerial standpoint, the differences in operations within the organization result in unnecessary complexity. Standardizing operations could result in a more manageable practice overview for location managers, financial- and operational controllers, and planners. One easy to implement process change is the standardization of treatment duration on a practice level, meaning that within the same practice all therapists will work according to practice standards.

To define the standardized treatment duration per practice the most commonly used duration per treatment type will be defined.

The effects of this standardized treatment duration on the utilization are presented in Figure 4.16. Logically, the difference between analysis with and without the standardized treatment duration will depend on the level of deviation from this standard in the current situation. The practice in this example has a relatively big variation in treatment duration per therapist, resulting in a significant difference in utilization as well.

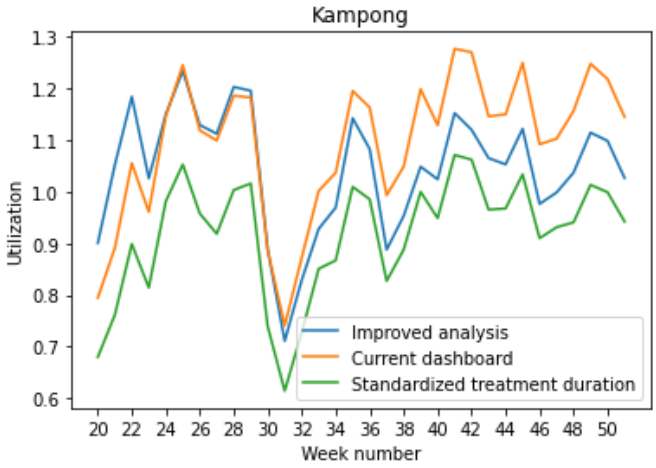


Figure 4.16: Difference in utilization between the current dashboard, the improved analysis and the improved analysis with standardized treatment duration for Kampong

4.4 Conclusion

In this chapter, the relevant data regarding capacity and utilization analysis has been introduced and explored. The exploration of this data is important to answer research question 1. Understanding and exploring data of supply (therapists) and demand (client) related data is needed to define the capacity of the organization, practices, and individual therapists. On the supply side, the different therapist qualifications with their relation to different treatment types have been explained. Also, the therapist availability and the issues regarding the gathering process of this data have been discussed upon.

Looking at the demand, the structure of treatment episodes has been researched. This includes the number of treatments within an episode, the time between treatments within an episode, and the treatment duration. The conclusion from this exploration is the wide variety in structure between different treatment episode on all these three factors. Possibly, but not limited to, effects of the type of treatment performed and the age of the client. Although these factors may influence the structure of the treatment episodes no accurate groupings of clients can be found in which the treatment episodes are comparable. The workload of the treatment episode of a client widely varies over the non-homogeneous group of clients.

The second part of research question 1 addresses the utilization of current resources. In this chapter, the current utilization analysis is discussed and three downfalls have been detected and resolved. Thereby leading to a more accurate utilization analysis. The effect of inaccurate

availability data on the utilization is discussed and this further underlines the importance of the data gathering process regarding therapist availability.

Also, the utilization of specialists has been more thoroughly analyzed. Leading to possibilities to free up specialist capacity by sharing general clients with less utilized therapists.

Research question 2 deals with the standardization of planning and appointment scheduling. Throughout this chapter, multiple operational differences between practices and individual therapists have been defined. First of all, there is a variety of ways in which therapists handle the intake- and first appointments. The preferred standard from a therapist and client point of view is to perform the intake and first appointment in a double block. This provides the first appointment scheduling standardization.

Secondly, therapists do not always use the predefined treatment duration. The treatment duration is manually altered thereby leading to different ways of working within practices. Standardizing the treatment duration on a practice level ensures uniformity in work within practices.

Lastly, administration regarding group treatments and double time slot bookings causes operational differences between therapists. Booking double time slots should not be possible and in practice, this has to be administrated as a group treatment. A uniform way of working needs to be established, practical insights on this process will be further discussed in chapter 6.

Chapter 5

Simulation study

In this section, the simulation study will be presented and discussed. At first, important modeling assumptions and decisions will be presented. Hereafter the results of the three different scenarios will be presented and discussed. The data from the two use-case practices introduced in chapter 4 is used throughout this simulation study.

5.1 Simulation modules

The simulation model consists of two different modules. First of all the arrival module in which client arrivals are generated. Subsequently, these arrivals are used as an input for the planning module. Both modules will be discussed in this section. These are the modules for the baseline scenario, whenever models change this will be described in the section of the concerned scenario.

5.1.1 Arrival module

The arrival module generates daily client arrivals. The input of these client arrivals consists of the arrival rates per day of the month. This random generated number initiates a list of a size consistent with the number of arrivals for this day. The type of treatment for the incoming clients is determined according to the historic ratio of treatment types from incoming clients. Consecutively the number of treatments and a list of the days in between these treatments are stored. The number of treatments and the days between the treatments are drawn randomly from the empirical data of treatment episodes from this practice for the same treatment type. Finally, the duration of the first treatment (intake + treatment) is determined according to practice standards for the particular treatment type. A typical daily outcome for this module is presented in Table 5.1.

Client nr.	Treatment episode nr.	Treatment code	Duration	Entry date	Intake	Treatments left	Days between treatments	Specialization
1	1	1000	50	01-01-2021	1	10	[7,3,7,4,7,7,7,14,7]	None
2	2	1200	50	01-01-2021	1	23	[7,7,7,14,7,7,7,14,...]	Manual
3	3	1864	50	01-01-2021	1	1	[]	None
4	4	1000	50	01-01-2021	1	4	[7,7,7]	None

Table 5.1: Typical daily output of the arrival module

5.1.2 Planning module

After the daily arrivals are generated the planning module gets triggered. This module will plan treatments for the new daily clients, execute treatments for the day and plan any follow-up treatments. On the first simulation run the input of treatments to be planned only consists of the output of the arrival module. First, the new clients will be planned. The assignment of a client to a therapist is based on the treatment type and utilization. Clients requiring a specialist will have a subset of viable therapists to be assigned to. The utilization of every therapist for the current week (week of the day of planning) and the following week will be determined. The therapist with the lowest average utilization over these two weeks will get assigned to the client. Once a client has been assigned to a therapist it will stay with the therapist for the remainder

of the treatment episode. This assignment rule may not be optimal but requires low effort and will be somewhat close to the current planning operation.

$$U_t = [\frac{W_{current}}{A} + \frac{W_{current+1}}{A}]\frac{1}{2} \tag{5.1}$$

After the assignment of a client to a therapist, the treatment is planned in the agenda. The first slot in which enough time is available for the duration of the treatment is chosen. This does not take the time of the day into account. The treatment duration is provided as a predefined input to the simulation according to historic practice standards as described in subsection 4.3.3. An intake appointment always consists of a double appointment, the first one is the intake and the second is the first treatment. If the treatment episode consists of only 1 treatment the treatment episode will be closed and the client will leave the system. If the episode consists of multiple treatments the follow-up treatment will be planned directly after the initial treatment is finished.

For both practices that act as a use-case for this simulation study there is one therapist with a specialization and limited availability. Intuitively the available time for these therapists is reserved for their specialisms. The therapist specializations and weekly availability per practice are presented in Appendix B.

Algorithm 1 Daily planning module

```
1: while List of treatments to be planned not empty do
2:     if New Client then
3:         Determine subset of viable therapist
4:         for Every therapist within subset do
5:             Calculate U_t
6:         end for
7:         Select therapist with minimum U_t
8:         Plan treatment on first available day
9:     else                                          ▷ Existing client
10:        Get preferred treatment date
11:        Plan treatment on first available day
12:    end if
13: end while
```

5.2 Model assumptions and decisions

There are some modeling decisions and assumptions which are important to emphasize and will clearly define the environment of the simulation. Whenever these assumptions or decisions were not previously discussed a short explanation and substantiation is given. The list below will provide an overview:

1. Data over 2019 is taken to find practice working standards when it comes to treatment duration
2. Treatments duration are always according to practice standards
3. Data over 2018 and 2019 are taken to define the structure of the treatment episodes
4. A treatment episode consists of only one kind of treatment. This treatment type is defined as the treatment type that is most commonly performed within an episode
5. Only treatment types that have a possibility of over 0.5% of occurring are taken into account

6. All treatment episodes generated will start with an intake and first treatment occurring in one appointment
7. Client to therapist assignment does not change during an episode
8. A treatment episode always starts with a double block consisting of an intake appointment and the first treatment
9. Clients are treated as soon as possible from the moment of first contact with the planning team
10. Therapist with less than four-hour availability are not taken into account
11. Only specialists registered in AGB-register are defined as a specialist
12. Therapist expertise is not taken into accounts. All therapists will be able to treat any client in need of general physiotherapy treatment
13. Only specialized treatment which from historic data undoubtedly can be defined as need for a specialist are taken into account

Decisions 1 and 2 involve the standardization of treatment duration. The data over 2019 is chosen to define these standards because this is the most recent and accurate data. Data gathered during 2020 might be influenced by the global pandemic. Decision 3 includes data for the years 2018 and 2019. In this instance, multiple years of data are needed to include longer treatment episodes in the simulation study. Assumption 4 is made in cooperation with data owners and a therapist, it ensures a more workable model. Changing treatment types throughout the treatment episode is a rare occurrence and should be registered as a new treatment episode. Decision 5 is included to eliminate extremely rare occurring treatment types and for the sake of simulation run-time. This principle has been used by multiple researchers presented in chapter 2. Decision 7 has been established early in this research in is assumed to be the most accurate representation of the current way of working. Decision 10 is applied because a therapist with such low availability will not work in a simulation environment which includes model decision 7.

The performance measures of interest for this simulation study are defined in the research questions and include therapist utilization and maximum waiting time. These performance measures will be presented on either practice or individual therapist level according to the different scenarios and goals of the presented results.

The target for the maximum waiting time per treatment is set to seven days throughout the entirety of this simulation study. In practice, the desired waiting time for a first treatment might be one day at some practice. However, these small waiting times are infeasible to reach in this simulation study due to two reasons. A significant level of flexibility by the planning team and therapists is required (planning overtime or sharing clients) to reach these extreme low waiting times. Due to the rigid rules of this simulation, this is not possible. Moreover, some therapists are only available for one day per week. Logically, the waiting time for clients assigned to this therapist will at least be seven days at any time.

5.3 Simulation warmup

To be able to accurately perform any statistical analysis on a simulation it is important to identify the type of simulation to be analyzed. Law et al. (2000) divides the type of simulation according to Figure 5.1. The simulation of this study will be identified as a nonterminating simulation with steady-state cycle parameters. There is no natural occurring event that will terminate the simulation. There are cyclic parameters involved including the arrival rate changing per month. It is however questionable to identify if the simulation will reach a steady state. Treatments in the system will on average leave within four weeks, however they can stay in the system for as

long as two years.

The simulation has a considerable warm-up period. The system starts empty, i.e. completely available therapists without any clients in the system. The system needs to warm-up to reach a 'steady-state'. The most often used technique to deal with this warm-up period is called initial data deletion (Law et al. (2000)). The observations generated during the initial warm-up period will be deleted and only the remainder of the observations will be used to analyze the system. To be able to estimate the warm-up period of the simulation a slight variation of the Welch procedure is used (Welch (1981) and Welch (1983)). The original Welch method uses a moving average, but using a moving average can be inconsistent in simulations with a high level of variability (Currie and Cheng (2016)). In this instance, a simple graphical representation procedure will be used instead of the moving average. It involves creating a minimum of five replications with a long run-time. For each replication, a plot of the number of treatments performed per week will be generated. These plots will be used to determine the length of the warmup period by estimating where the plot is reasonably smooth. Figure 5.2 is an example for one of these plots. For consecutive runs the number of treatments performed per week seems to stabilize at 20 weeks. To avoid mixing results of multiple years, a warmup period of 52 weeks i.e. one year will be used. In this manner, the initial data deletion method can be applied to the first year of data.

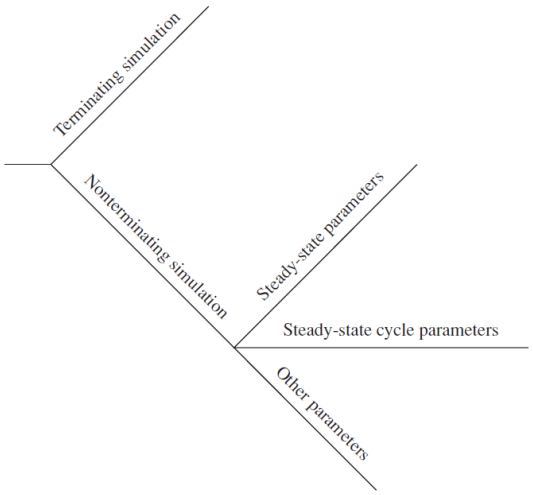


Figure 5.1: Types of simulations with regard to output analysis (Law et al. (2000))

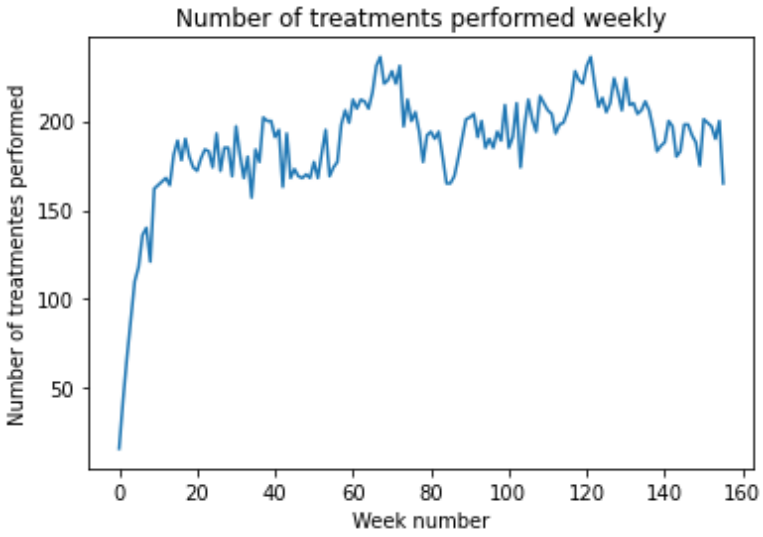


Figure 5.2: Weekly number of treatments performed

5.4 Simulation run-length

To be able to have sufficient confidence in the outcome of the simulation it is important to determine an appropriate run-length. Because of the significant warmup period and the goal of this simulation, the simulation will only be run once per scenario. The outcome is still reliable if the simulation is run for a sufficient amount of time. The minimum run-length of the simulation is bounded by the warmup period and the periodic variation of the input parameters. As indicated before the warmup period is defined to be 52 weeks and the simulation will include monthly and daily variation in client arrivals. It would thus make sense that the minimal run-length is two years (one year of warm-up and one year to account for model input variations). To determine the run-length the goal of the simulation is one of the deciding factors. The goal of this simulation study is to assess the feasibility of certain scenarios under different simulation setups. Whether a scenario is deemed feasible is defined by the waiting time staying below a level of seven days over the entire run-length. This will thus be the performance measure on which statistical analysis can be performed, thereby deciding a sufficient run-length. Chapter 8 in the book by Ross (1990) presents different ways of deciding when to stop a simulation. One of these methods is based on deciding an acceptable value d for the standard deviation of the estimator. The estimator can be any statistical variable regarding a performance measure or simulation outcome. In the case of this study, the simulation outcome of interest is a Bernoulli (0,1) value, defining whether the threshold value for the maximum waiting time is passed. For every generated day in the simulation, all appointments are checked on the waiting time. If one of the appointments during this day has a larger waiting time than seven, the outcome will be 1, otherwise the value for this day is 0:

$$X_i = \begin{cases} 1 & \text{with probability } p \\ 0 & \text{with probability } 1-p \end{cases} \tag{5.2}$$

Now the estimator of interest is $E[X_i] = p$, i.e. the probability that the maximum waiting time for a certain day will be surpassed. This estimator is calculated using the n generated

values per day $X_1, \ldots, X_n$:

$$\bar{X}_n = \sum_{i=1}^{n} \frac{X_i}{n} \tag{5.3}$$

At last, to be able to decide the run-length, an acceptable value for the standard deviation of the estimator needs to be decided. The estimator for the $\mathrm{Var}(X_i)$ is $\bar{X}_n(1 - \bar{X}_n)$.

The entire method is described in the following steps:

1. Choose an acceptable value d for the standard deviation of the estimator
2. Generate at least 100 data values
3. Continue to generate additional data values, stopping when you have generated k values and $[\overline{X}_k(1 - \overline{X}_k)/k]^{\frac{1}{2}} < d$.
4. The estimate of p is $\overline{X}_k$, the average of the k data values

Figure 5.3 shows the standard deviation of the estimator after the initial 100 days. Note that the values during the warmup period (20 weeks) are already deleted. Although the simulation warmup is extended to 52 weeks for the actual simulation results, for this method we only use a warmup period of 20 weeks. An initial data deletion of 52 weeks together with the initial 100 data generations would cause an unnecessarily long run-up to the actual statistical analysis. The value for the standard deviation of the estimator directly after the run-up is already small. After 348 days of simulation time the standard deviation drops strictly below 0.01, this level is assumed to be an acceptable level for the standard deviation of the estimator. Including the warmup period, the total run length to ensure the acceptable value for d will thus be 713 days. For simplicity purposes, the total run length is rounded to two calendar years.

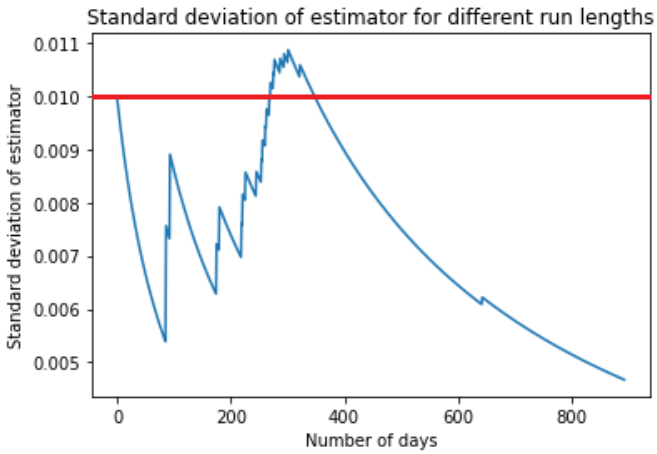


Figure 5.3: Standard deviation of the estimator for different run lengths

5.5 Model validation

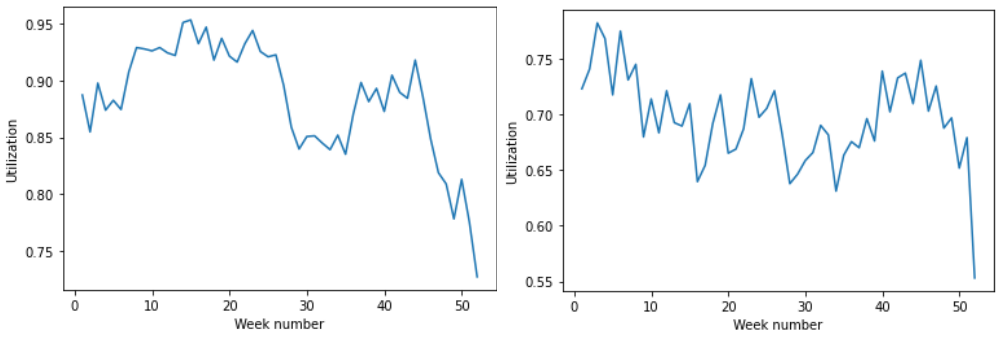
To built and keep confidence in modeling assumptions and outcomes, these factors have been repeatedly shared and discussed with multiple stakeholders in the company. However, the model includes multiple strategic scenarios and is built from multiple building blocks with a large

number of varieties. For example, the availability is taken from the latest data in 2020, the arrival rates have been fitted to a non-homogeneous distribution from the data from 2019 and the length of treatment episodes is taken from empirical distributions from data ranging as far back as 2018. This mix of input variables and modeling decisions makes it complex to formally validate the accuracy of this model, as for most outcomes there is no real-world data to compare it to. Instead of model outcomes, the number of intake appointments can be validated. Although the decision to generate client arrivals has been substantiated in subsection 4.2.1 it is still useful to test whether the generation of client arrival of the model is in line with the expected arrivals from the original data. The two-sample rank-sum test (also known as the Wilcoxon two-sample Wilcoxon (1946) or Mann-Whitney two-sample test Mann and Whitney (1947)) will be used to compare the real-world number of intakes compared to the intakes generated by the simulation model. The two-sample ranked sum test is chosen because it does not assume normally distributed data. The test will decide whether both data sets are drawn from the same distribution. In other words, whether the data from the simulation model is an accurate representation of the data from the real system. A p-value lower than 0.05 will reject the null-hypotheses of indistinct underlying distributions between the two sets. When the number of monthly intakes is tested for one entire run of the simulation against the real-world values **the p-value of the two-sample ranked sum test is 0.5** thereby confirming the null-hypotheses. Meaning that the number of monthly intakes from the simulation is an accurate representation of the real data.

5.6 Simulation results

5.6.1 Scenario 1: Baseline

This section will present the results of the baseline model. Figure 5.4a shows the practice utilization of this simulation scenario for use-case practice 1. The utilization of the entire practice is already close to the maximum. Under the assignment and planning rules of this scenario, it leads to the maximum waiting time of clients as presented in Table 5.2. For five therapists somewhere during the total simulation run the waiting time for a treatment exceeded the maximum of seven days. These therapists all have relatively low availability, earlier this was defined as a therapist with availability of fewer than eight hours a week. Assigning new clients based on utilization can cause a sudden increase in the number of clients assigned to a therapist without taking into account the effect of a therapist's schedule in the long run. At a certain point in time the utilization of a therapist might be low, but assigning a new client to this therapist with a treatment episode with high intensity (many treatments with a short time in between treatments) can weigh heavily on a therapist only available on one day in the week for a limited time. The intensity of a treatment episode is not known beforehand in this simulation study. These long term effects lead to excessive waiting times for treatments performed by these low available therapists.



(a) Practice 1

(b) Practice 2

Figure 5.4: Practice utilizations for scenario 1

Therapist	Maximum waiting time (days)
Therapist 1	**10**
Therapist 2	**10**
Therapist 3	4
Therapist 4	**10**
Therapist 5	7
Therapist 6	**9**
Therapist 7	**9**
Therapist 8	6
Therapist 9	7
Therapist 10	6

Table 5.2: Practice 1 maximum waiting time per therapist for scenario 1

In the same matter, the simulation outcomes for the second use-case practice are presented. There is a noticeable difference in utilization between these two practices. Figure 5.4b presents the practice utilization for the baseline scenario. The practice is running less close to maximum capacity. However, observing the maximum waiting time per therapist (Figure 5.4b), the same conclusion can be made compared to the first practice. All therapists except one comply with the maximum waiting time goal. Therapist 1 is the only one crossing the threshold, this therapist again is a therapist with relatively low availability.

The conclusion of the results from this initial scenario is that a more sophisticated assignment rule is needed to prevent overloading therapists. The number of clients within the portfolio of a therapist can be used as an additional rule. This additional rule will be further discussed in the next scenario.

Therapist	Maximum waiting time (days)	Therapist	Maximum waiting time (days)
Therapist 1	**9**	Therapist 11	2
Therapist 2	5	Therapist 12	3
Therapist 3	5	Therapist 13	2
Therapist 4	7	Therapist 14	2
Therapist 5	4	Therapist 15	4
Therapist 6	4	Therapist 16	3
Therapist 7	5	Therapist 17	4
Therapist 8	4	Therapist 18	3
Therapist 9	4	Therapist 19	4
Therapist 10	2	Therapist 20	4

Table 5.3: Practice 2 maximum waiting time per therapist for scenario 1

5.6.2 Scenario 2: Limit maximum number of clients in therapist agenda

The results from scenario 1 show a bottleneck in planning operations for therapists with low availability. A new client can have a significant impact when the availability is limited. For this reason, a maximum capacity in the form of a maximum number of clients within a therapist's agenda needs to be established.

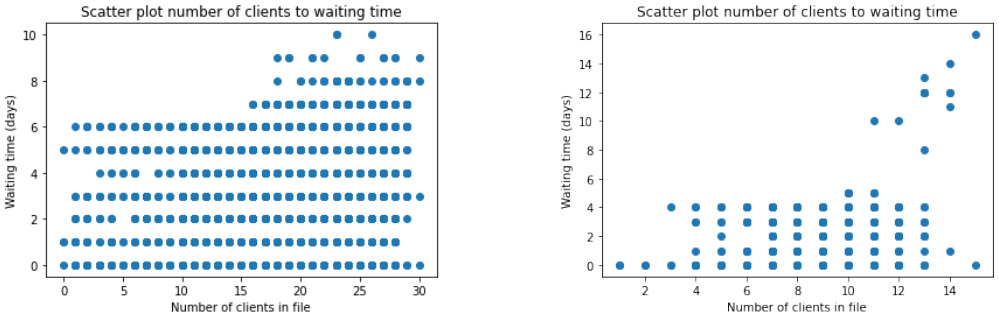
An initial insight into the workload of one client on the agenda of a therapist can be obtained analytically. Since there is a large variance in the number of treatments that a client requires and the time in between these treatments, this method will not result in a precise rule but it gives an intuitive first estimation. From chapter 4 we obtain an average episode length of ten treatments and an average time in between treatments of nine days for general physiotherapy treatment. As the initial intake and first treatment will be combined during the first appointment, the remainder of the episode includes eight treatments. Planning eight treatments with an average time of nine days between treatments leads to a treatment episode lasting 72 days. The standardized treatment duration concerning general physiotherapy treatment is 25 minutes and 30 minutes for practice 1 and 2 respectively. The therapist with the lowest availability at practice 1 has a weekly availability of 6.5 hours, at practice 2 this is a weekly availability of 8 hours. Using these parameters an initial estimate of the maximum number of clients in a therapist's portfolio would be:

$$\begin{aligned}
\text{Weekly therapist availability} &= 390 \text{ minutes} \\
\text{Treatment time} &= 25 \text{ minutes} \\
\text{Time between treatment} &= 9 \text{ days} \\
\text{Treatments in an episode} &= 10 \\
\text{Total episode length} &= 8 \times 9 = 72 \text{ days} \\
\text{Total episode workload} &= 250 \text{ minutes} \\
\text{Average weekly workload of one client} &= \frac{250}{72} \times 7 = 24.3 \text{ minutes} \\
\text{Maximum number of clients} &= \frac{390}{24.3} = 16.0
\end{aligned}$$

Based on this calculation the low available therapist at practice 1 with an availability of 6.5 hours per week could handle 16 clients in his portfolio. Using the same method a therapist at

practice 2 with a weekly availability of 8 hours can have a maximum of 16 clients in his portfolio as well. The therapist at practice 2 has a higher availability but the workload of a client at this practice is higher because of the 30-minute treatment duration, as opposed to the 25-minute treatment duration at practice 1.

The previously mentioned maximum number of clients are based on statistical averages of treatment episode information. The high variance in these variables and the variable influx of new clients to the practices over time might cause this method to be inaccurate in some cases. Another way of determining the maximum number of clients in a portfolio is to use the results of scenario 1. The waiting time per appointment and the number of clients in a portfolio are known at any point in time for the results of scenario 1. These results two variables are presented in two scatterplots, again showing the waiting time of every appointment against the number of clients in the portfolio of the concerned therapist at the time of planning the appointment (Figure 5.5). From these plots, we can determine the lowest number of clients in the portfolio at any time in the simulation where an appointment crossed the waiting line goals. Planning and therapist assignment problems in the baseline scenario only occur for therapists with an availability equal to or lower than eight hours. The scatter plots only include appointments planned for these low available therapists. A maximum waiting time of seven days is the initial target. For the first practice, the minimum amount of clients in the portfolio while not making the seven-day waiting time is 17 clients. In the second practice, the limit is already reached at 11 clients in the portfolio. The difference between the observations for the different practices can be explained by the large difference in practice size and thereby the arrivals of new clients. The second practice is a considerably larger practice handling more clients on a daily basis than the first practice. Whenever a low available therapist is temporarily under-utilized, their portfolio will fill up quicker in the larger-sized practice. The limit of the maximum number of clients in a portfolio should thus be lower in practice 2, to prevent a large number of new clients for therapists who are not able to satisfy the demand for the follow-up appointment of these clients.



(a) Practice 1

(b) Practice 2

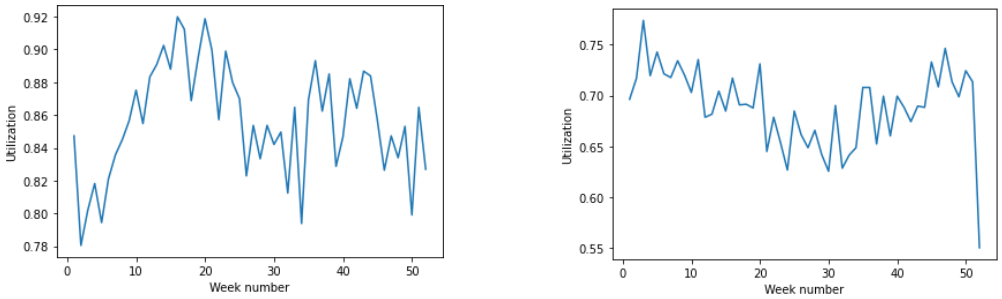
Figure 5.5: Scatterplot of number of clients in the file of a low available therapist against the waiting time

Comparing the outcomes of the analytical method to the method based on the results of scenario 1 gives some insights. For practice 1 both methods lead to the same rule of a maximum number of clients of 16. For practice 2 the analytical method implies a maximum number of clients of 16 and the method based on the simulation scenario one results in maximum 11 clients in the portfolio. As mentioned before the influx of new clients in practice 2 is significantly higher. The analytical method does not take the bigger arrival rates at practice 2 into account, which

could be a cause for the difference in outcomes between the two methods.

Implementing a rule of a maximum number of 16 clients for practice 1 and 11 clients for practice 2 in a portfolio of a low available therapist is easily implemented by adding one constraint to the client assignment rule. The new planning module will not only take utilization into account but has a second rule. This rule implies that a new client can never be assigned to a therapist with low availability whenever the maximum number of clients in the portfolio is already reached. The remainder of the simulation modules stays unchanged.

The outcomes of the simulation in this scenario are again presented in the form of the practice utilization and the maximum waiting time per therapist per practice. Figure 5.6 shows comparable levels of utilization to the baseline scenario for both practices. As expected, the maximum waiting time now never exceeds seven days for all therapists at both practices as can be concluded from the results in Table 5.4 and Table 5.5.



(a) Practice 1

(b) Practice 2

Figure 5.6: Practice utilization for scenario 2

Therapist	**Maximum waiting time (days)**
Therapist 1	6
Therapist 2	6
Therapist 3	4
Therapist 4	7
Therapist 5	5
Therapist 6	6
Therapist 7	7
Therapist 8	4
Therapist 9	6
Therapist 10	4

Table 5.4: Practice 1 maximum waiting time per therapist for scenario 2

Therapist	Maximum waiting time (days)	Therapist	Maximum waiting time (days)
Therapist 1	4	Therapist 11	2
Therapist 2	4	Therapist 12	3
Therapist 3	5	Therapist 13	2
Therapist 4	7	Therapist 14	2
Therapist 5	4	Therapist 15	4
Therapist 6	3	Therapist 16	7
Therapist 7	3	Therapist 17	4
Therapist 8	4	Therapist 18	3
Therapist 9	3	Therapist 19	4
Therapist 10	2	Therapist 20	4

Table 5.5: Practice 2 maximum waiting time per therapist for scenario 2

5.6.3 Scenario 3: Advanced client assignment strategy

The last scenario involves a new triage and client assignment strategy. Physiotherapy is evolving in many ways. Fees received by physiotherapist practices from health insurance instances are now fixed per treatment. This is slowly changing to a fixed fee per treatment episode. This new scenario is an incentive for physiotherapists to treat clients more effectively. A short and effective treatment episode will now yield more turnover, wherein the earlier scenario (counter intuitively) more treatments lead to more turnover.

A way of revolutionizing how physiotherapy is now organized within FysioHolland involves the now proposed new triage and client assignment strategy. Clients will always receive an intake and initial treatment by a senior therapist, after which the client gets reassigned to a medior or junior therapist. Senior therapists are assumed to be more accurate and faster in assessing the cause and most effective treatment for a complaint, thereby resulting in a more effective treatment plan and a higher intake capacity. Furthermore, medior and junior therapists can develop expertise in certain complaint types by creating a more homogeneous portfolio of clients with similar complaints. On a higher level, this process change will create clear treatment paths and a more streamlined way of working.

Implementing this new scenario does require some more advanced planning rules. First of all the capacity of senior therapists needs to be sufficient to satisfy the demand of new clients within an acceptable waiting time. The case in which incoming clients need to be rejected should be avoided at all times.

In the first practice used for this simulation, there are two senior therapists. These therapists are 15 and 39.5 hours available respectively. It should be ensured that in peak intake months the demand for intake appointments can be satisfied. A peak month in a simulation for this practice includes 190 incoming clients. Translated to demand in hours this would indicate a demand of 158.3 hours. Because senior therapist 1 has a rather limited availability all his time should be reserved for intake appointments. This results in a capacity of roughly 60 intake hours. If the available time for this therapist would be split into time for intake- and time for follow-up appointments this would result in yet another therapist with low availability. The proportion of time remaining for regular treatments would then be comparable to that of a low available therapist causing planning problems.

The remainder of the intake capacity has to be fulfilled by therapist 2. His total capacity is 158 hours, so $\frac{98.3}{158} \approx 62\%$ of its time should be reserved for intake appointments. The remainder of the time can be spent on general treatments. In this case, we are able to split the therapist agenda because the total available time is relatively large.

The maximum number of clients for low available therapists needs to be reconsidered as well. In this scenario the intake procedure is performed by designated therapists, thereby somewhat lowering the time needed for a treatment episode for the therapist that takes over. The method to define this new maximum is the same as described in scenario 2, resulting in a maximum number of clients of 24 for this practice.

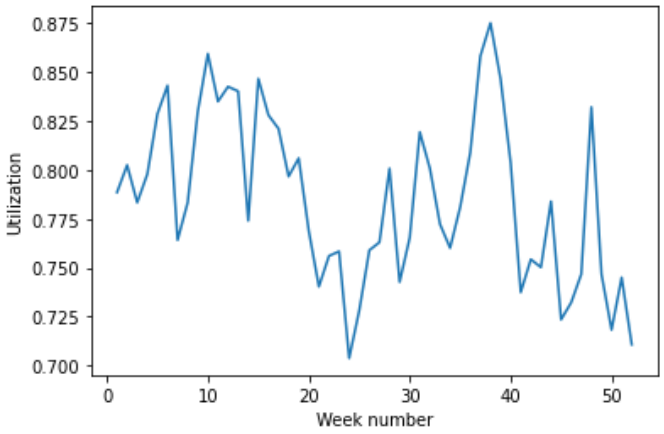


Figure 5.7: Practice 1 utilization for scenario 3

The practice utilization for this scenario is presented in Figure 5.7. The average utilization is significantly lower than in the previous two scenarios. This observation can be explained by the fact that the proportion of time spent on intake appointments is estimated from the demand in peak months. Naturally, this will result in spare capacity in months where the number of incoming new clients is lower. Due to demand uncertainty, we are unable to predict these fluctuations beforehand. In this scenario, it is very complex to fully utilize the capacity of senior therapists throughout the entire year. Table 5.6 underlines this statement, since therapists 2,3 and 10 are extremely under-utilized given the fact that the practice is running close to its maximum capacity. For therapists 2 and 3 this can be explained by the fact that there is a restriction on their portfolio size. This does however not have a major impact on the entire practice as it includes a limited number of available hours. Therapist 10 is the senior therapist with a split agenda for intake and follow-up appointments which is under-utilized because of previous imperfections of the planning rule for this scenario.

Therapist	Maximum access time (days)	Maximum waiting time (days)	Mean utilization
Therapist 1	-	7	84%
Therapist 2	-	6	68%
Therapist 3	6	6	62%
Therapist 4	-	7	87%
Therapist 5	**19**	**19**	96%
Therapist 6	-	7	83%
Therapist 7	-	7	76%
Therapist 8	**12**	-	88%
Therapist 9	-	**14**	97%
Therapist 10	2	1	63%

Table 5.6: Practice 1 maximum waiting time per therapist for scenario 3

The output with regard to maximum waiting times is split between access time and waiting time for this scenario. Access time indicates the days between the first contact of the client with the planning team and the first appointment. Waiting time is the time between the preferred and actual date of the follow-up appointments. Logically, access time can be only be observed for therapists with a specialization or senior therapists. One therapist does not have a maximum waiting time because all its time is reserved for intake appointments.

Table 5.6 shows that the unrestricted therapists 5 and 9 get overloaded with regard to waiting time. These therapists do not have any restrictions on portfolio size causing their appointment schedules to overflow. Access time also exceeds the limits for general clients as well as specialized intakes performed by therapist 5. Balancing capacity to either increase the capacity for intakes or capacity for follow-ups would result in even more skewed results.

The second practice poses a very different environment for this scenario. This practice is less reliable on one senior therapist, since there is enough availability of senior therapists to be able to define a number of designated therapists for intake appointments. To estimate the capacity needed to satisfy incoming clients the same procedure as the previous sector is performed. For practice 2 a peak intake month consists of 385 new clients, equal to a workload of 385 hours. A number of senior therapist have been arbitrarily selected to match this demand as close as possible. Therapists 2, 6, 12, and 19 will dedicate their entire agenda to new clients resulting in a capacity of 393.3 hours.

While for practice 1 we had to redefine the maximum number of clients in a therapist's portfolio, this is not necessary for practice 2. Because of the almost insignificant contribution of the two low available therapists to the total capacity, the number of maximum clients in a portfolio for these therapists remains unchanged in this scenario.

Figure 5.8 shows a similar practice utilization to the previous scenario's. The access- and waiting times for every therapist stay within boundaries for every therapist as can be concluded from Table 5.7.

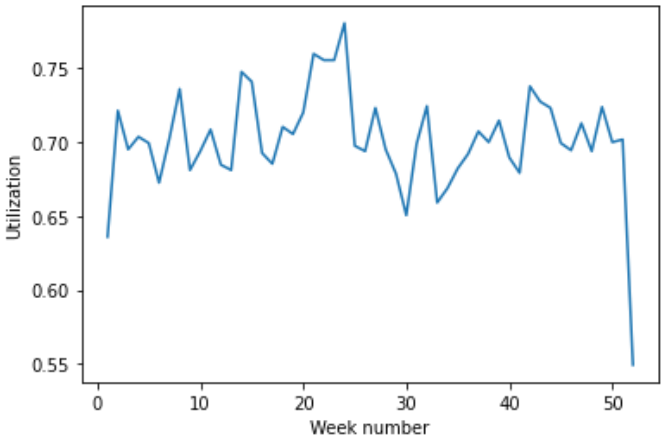


Figure 5.8: Practice 2 utilization for scenario 3

Therapist	Maximum access time (days)	Maximum waiting time (days)	Therapist	Maximum access time (days)	Maximum waiting time (days)
Therapist 1	-	5	Therapist 11	2	2
Therapist 2	5	-	Therapist 12	-	2
Therapist 3	-	5	Therapist 13	-	3
Therapist 4	-	4	Therapist 14	3	-
Therapist 5	-	4	Therapist 15	-	4
Therapist 6	4	-	Therapist 16	3	3
Therapist 7	-	3	Therapist 17	4	4
Therapist 8	5	4	Therapist 18	6	5
Therapist 9	-	4	Therapist 19	4	4
Therapist 10	-	2	Therapist 20	-	4

Table 5.7: Practice 2 maximum waiting time per therapist for scenario 3

5.7 Conclusion

This chapter presented the results of a simulation study as a goal to answer research question 3, thereby gaining insights into the behavior of the system under different appointment scheduling strategies.

Scenario 1, acting as a baseline scenario, shows that the introduction of a scheduling rule based on therapist utilization leads to a planning bottleneck for therapists with low availability. On multiple occasions, the waiting time for appointments at these therapists succeeds the goal of a maximum waiting time of seven days. Scenario 2 introduces a rule, defining a maximum number of clients at any time for therapists with low availability. This rule was introduced to overcome the long waiting times observed in scenario 1. The rule leads to a reduction in waiting times for therapists with low availability.

Scenario 3 introduces a new appointment scheduling strategy including a revised client assignment rule. For practice 1 this scenario is deemed infeasible because it leads to high waiting times for numerous therapists. This is caused by a scarcity of senior therapist capacity and the

high utilization of resources at this practice. For practice 2 the scenario is deemed feasible.

Lastly, it is important to emphasize the difference in results between the two use-case practices. The results of scenario 1 showed a significantly higher utilization for practice 1 compared to practice 2. For both practices, the same planning bottleneck at therapists with a low availability is observed. However, scenario 2 leads to a different rule for both practices. The maximum number of clients at practice 2 is significantly lower than at practice 1. The probable cause for this difference is the longer standardized treatment duration at practice 2 and the higher arrival rates at this practice. A higher arrival rate can lead to a more extreme influx of new clients in a therapist's portfolio, thereby causing longer waiting times.

The results of scenario 3 show a significant difference in the feasibility of this scenario for the two use-case practices. This difference in results is caused by two factors, differentiating the two practices. These factors are practice utilization and senior therapist availability. At practice 1 the senior therapist availability is scarce (2 therapists) and the practice is operating at high utilization. Leading to the situation where the agenda of the senior therapists need to be split in time fixed for intake appointments and time fixed for follow-up appointments. The senior therapist's time reserved for intake appointments is estimated based on peak arrival rates. This leads to possible under-utilization when there are fewer arrivals. As practice 1 is operating at a high utilization it can thereby not afford to have this idle capacity.

On the other hand, practice 2 has ample senior therapist availability and resources are less utilized. The abundance of senior therapists leads to a situation where the entirety of some dedicated therapists' agenda can be reserved for intake appointments. The idle time of these therapists in times of lower arrival rates has less impact on the waiting times because the practice has sufficient spare capacity.

Chapter 6

Qualitative verification

This section will present the results of the conducted interviews with employees of multiple practices. There are two goals for these interviews. Firstly, the current situation of operations regarding planning- and appointment scheduling of the interviewees and their concerned practices are discussed. These results will act as a verification of the current planning environment and can lead to practical insights and recommendations. Consecutively, multiple scenarios inspired by the results of this research will be discussed during the interviews. These scenarios include the introduction of the new client assignment rule introduced in scenario 3 of the simulation study of chapter 5 and the standardization of the treatment duration.

This chapter starts with an introduction of the included practices and interviewees. Hereafter the results of the interviews are presented divided into the current situation and the proposed changes in planning rules. The main results from the interviews are presented per topic in cursive statements, whereafter body to these statements are provided. Whenever opinions and differences between interviewees occur these will be explained and discussed as well. The questions asked and the global structure of the interviews can be found in Appendix A.

The interviews are conducted over employees working at four practices. One relatively large and very productive practice (practice 1), a medium-sized practice (practice 2), and two smaller sized suburban practice (practice 3 and 4). Within these practices, the roles of the interviewees are: one double function regional manager-senior therapist, two double functions location manager-therapist (one senior and one medior therapist), and two general therapists (one senior and one junior therapist). The operations of a therapists are generally known. The role of a regional manager includes keeping track of KPI's, different long term goals, and direct contact with higher management with regard to practices within their region. The general tasks of a location manager include facility work, personnel matters, and managing daily operations at the practice.

6.1 Current planning operations

The general planning operations include the way in which clients contact the practice and how clients are first assigned to therapists. These operations vary over the three practices included in these interviews. The difference between these practices and the effects of these differences are discussed in this section.

6.1.1 The planning team

Practice 1 has its own local planning team and only uses the central planning team as a backup whenever the local planning team is unreachable. This local planning team also provides planning services to other practices located in the same city. Practice 2 has a similar setup, although here the planning team is located at another practice in the same city. Practice 3 and 4 have one local planning employer but planning is mostly performed by therapists themselves.

The distance between the planning team and the practice has different effects on the accuracy and control of planning operations

In general the further the planning team is located from the actual practice the more problems

arise. Local knowledge of therapist expertise, specialisms, and preferred ways of working is important for accurate planning. Sometimes this knowledge lacks at the central service team. There is a central database in which relevant therapist information is stored, but this information is gathered and maintained manually. This is an intensive and far from foolproof process. These problems with centralized planning caused the shift towards local planning for some practices.

Distance from the planning team also causes worries for therapists with regards to filling their agendas. A full therapist agenda is important because it defines the therapist's income and it is their own responsibility. A remote planning team can give a therapist the perception of being less in control over the influx of clients. This leads to therapists finding clients within their personal circles and taking on planning operations themselves.

6.1.2 Treatment trajectories

The way in which treatment trajectories are designed varies per practice. This treatment trajectory includes the initial assignment from a client to a therapist and the design of the remainder of the treatment episode.

Junior therapists will treat any complaint which is not too complex. Over time most therapists will specialize by either finishing a master's degree (specializations mentioned throughout this study) or focus on certain parts of the body (expertise). The first assignment of a client to a therapist is mostly based on the expertise/specialism that fits the complaint best. The design of the remainder of the treatment episode varies per practice and individual therapists. Practice 1 uses clusters of therapists according to similar expertise and specializations. In some of these clusters, clients can receive treatment from multiple therapists within this cluster. Other therapists prefer a more personalized treatment plan in which one therapist treats one client. In some instances, therapists will start a shared treatment plan. A client is shared between two therapists most of the time including one senior therapist and one medior or junior therapist who work in close collaboration.

Practice 2 is smaller in size and thus has less opportunity to work in these expertise clusters. To some extend the shared senior-medior/junior treatment plan is still executed. Again it is emphasized that this requires close collaboration between therapists and a similar way of working. Practices 3 and 4 handle a more strict client-therapist assignment. With some exceptions clients get treated by the same therapist throughout their treatment episode.

Client sharing between therapists can be a tool to save scarce capacity, although the therapist's preferred way of working must be taken into account

These different treatment trajectories each have their different pros and cons. It is important to form a good client-therapist relationship. Some therapists feel like this is where their edge is and thereby prefer a fixed client-therapist assignment. Treatments sometimes involve winning trust and finding mental causes of physical problems, which will be more difficult to resolve if clients are shared between multiple therapists. On the other hand, when therapists do work with a shared treatment plan between senior and junior therapists this is perceived as positive and they indicate that this setup could be used more. Indications are given that the complexity is hidden in communication and common ways of working. Having one clear therapist acting as the owner of the client file and defining the treatment plan helps in this process. Using client sharing also enables possibilities to save scarce resources in moments of extreme high utilization. Time from senior therapists or specialists can be saved by shifting other treatments to the medior/junior therapist that they are working together with. Another advantage of this system is a

quicker knowledge transfer between experienced and less experienced therapists because of this close collaboration.

6.2 Proposed planning changes

6.2.1 New client assignment rule

At first the client assignment rule of scenario 3 of the simulation study is discussed. This rule is a first effort to enable client sharing between senior and junior therapists as mentioned in the previous section. However, in this case, only seniors can perform intake appointments and the remainder of the episodes are performed by either junior or medior therapists. The proposition of this scenario leads to different responses.

The influx of new clients at the concerned practice is important for the feasibility of the new client assignment rule

Firstly the introduction of this rule would enable and stimulate sharing clients and defining clear treatment plans. To some extent this process has been started in practice 1 and 2. The major difference between these practices is the influx of clients leading to different responses to the new rule. Practice 1 has a very large influx of clients, the capacity of senior therapists is possibly not sufficient to treat all new clients in a timely manner. This raises doubts about the feasibility of the new rule. At practice 2 the influx is lower. Therapists can sometimes be worried about filling their agenda. Fixing senior therapists to intakes and giving clients away afterward can take away a guaranteed amount of work for a longer time. In other words, influx would need to suffice to fill senior therapists' agendas for seniors to be willing to pass clients on in most cases.

Performing intakes is an important part of the learning process of junior and medior therapists

Other comments regarding the new assignment rule indicated a disadvantage of taking away intakes for junior and medior therapists. Performing an intake can be an important learning moment for less experienced therapists. Taking away this opportunity might stagnate the personal development of therapists.

Work satisfaction of senior therapists needs to be taken into account

From the perspective of a senior therapist only executing intake appointments can be one-sided. Some of the satisfaction comes from treating clients from beginning to end on a complex problem. However, they indicate that working together in close collaboration with other therapists on a client would still give them this satisfaction.

6.2.2 Changing treatment duration

The remainder of this section will discuss the used treatment duration and the possible effects of changing the treatment duration. These insights are valuable while implementing possible organization wide process standardization.

The importance of personal attention to specific clients is an important factor while looking at the possibility to shorten the treatment duration

In general, therapists either work with a 30- or 25-minute block schedule. The preferences regarding treatment duration vary per therapist. Some indicate that for the time purely spend on the treatment a 25-minute treatment would be sufficient. Others say that it would not be possible to give the personal attention that some of the clients require.

Shortening the treatment duration might lead to increased work pressure, the time for administration is an important factor when it comes to work pressure

The time for administration and finishing a client's file is an important factor in the decision of the duration of a treatment. The administration should be performed during the treatment, whenever this is not the case the therapist has to finish this administration in their own time. Most therapists are able to perform their administrative tasks within 30 minutes. Shortening this to 25 minutes would significantly increase work pressure and sometimes leads to missing or faulty administration.

A 25-minute agenda will lead to a less clear overview of appointments during the day

A 30-minute agenda leads to a very clear overview of the agenda. Appointments start and end every half hour. Switching to a 25-minute agenda will create a less clear agenda with regard to the starting time of treatments. This is not a major problem, but it is indicated by multiple therapists as an undesirable side-effect.

Shorter treatment duration for practice clients is possible, but in the current situation these clients lead to administrative errors

A difference in the manner in which treatments are performed is also important to note when it comes to treatment duration. So-called practice clients are mostly treated in a gym, performing exercises, partly under the supervision of a therapist. Other clients need hands-on treatment in a treatment room. In the gym, it is possible to attend to multiple clients in a block sharing the attention of the therapist between the different clients. For these clients, it is in theory possible to shorten treatment duration. They can make use of the gym for a longer time and a therapist attends to them for a fixed time. For treatments within a treatment room, there is less margin for changes in treatment duration. A downside of treating multiple clients at the same time in a gym is the fact that this is administratively impossible. These double bookings need to be administrated as a group treatment, whereas the mentioned example is not a group treatment. Therapists make up administrative workarounds, which can lead to invalid administration and subsequent data analysis.

Chapter 7

Conclusions and recommendations

This section presents the main findings of this study. These findings will be presented in threefold, according to the three research questions. After the findings, some practical recommendations are proposed and the limitations and future research will be presented and discussed.

7.1 Conclusions

This section will present the main conclusion regarding each of the three research questions. Chapter 4 provides the answers to the initial two research questions, while Chapter 5 answers research question 3. These results are underlined and complemented by the results obtained from the interviews in Chapter 6.

1. *What is the current capacity and utilization of the therapists and practices?*

Naturally, there is no unambiguous definition of the capacity of an entire organization. The capacity is dependent on therapist availability, specializations, treatment duration, the number of treatments in a treatment episode, and the time between these treatments. These construct have been explored in chapter 4. Firstly, the availability of the therapists and moreover the inaccuracy of this information has been discussed. The difference between the specializations and expertise of therapists have been defined. Specialists were identified during this research however expertise and the exact way in which the expertise defines a therapist remain unknown from a data standpoint. Also within practice differences in treatment duration have been detected, thereby identifying another difference in capacity between different therapists. The wide variety of build-ups of different treatment episodes were explored and presented. The conclusion can be drawn that the arriving clients can not be seen as one homogeneous group of clients. There are many differences in episode lengths as well as time in between treatments. An effort has been made to group clients with similar characterizations, but no client information was found to make accurate groupings.

Looking at the current utilization analysis, a number of inaccuracies have been specified and corrected. Two easily implementable changes were proposed to achieve this improved analysis. The new utilization analysis also leads to the conclusion of the inaccurate therapist availability data which should be an important aim for the company to improve as soon as possible. Significant differences in utilization between therapists with low- and high availability are pointed out. Lastly, the utilization of specialists is split in time spent on their specialization compared to time spent on general physiotherapy treatments. This analysis leads to the conclusion that spare capacity for general physiotherapy could be used to free up the scarce time of specialists.

2. *What is the effect of introducing a traditional and standardized appointment scheduling system on therapist capacity and utilization?*

The operational variety between different therapists and practices concluded from the first research question lead to the need for more standardization. First of all, this standardization can be used to define input variables and a standardized process for the third research question. Secondly, a uniform way of working could help the manageability of the organization. //

The differences in appointment scheduling between different therapists and practices include treatment duration, intakes, and the trajectory of the client throughout his treatments. The differences in treatment duration have been discussed and the effects of standardizing the treatment duration on the practice utilization have been presented. These effects naturally depend on the level of variety at the concerned practice. In general, this is the difference between the 30-minute and 25-minute schedule at which different therapists operate.

There are few variants in which intakes are handled currently. However, from therapist opinion and historic data, there is one preferred way of handling intakes. The initial appointment from a client should include an intake and direct first treatment. Clients expect to receive some kind of treatment on their first visit, only an intake would not be sufficient according to most therapists. This thus includes two appointments in the planning system, which should be administrated accordingly. Experienced senior therapists could be able to handle both the requirement of an intake and the first treatment in one appointment, but for the sake of uniformity, this is not deemed feasible. Applying this as a general planning rule does have some effect on the capacity and utilization of therapists. In periods of high demand, forcing a double appointment for the client's first visit could lead to long waiting times, because of the scarcity of free double slots.

The trajectory of a client throughout the treatment episode varies per practice. The majority of the clients stay with their assigned therapist, except when a specialist is needed or when other complaints occur for which other therapists are more experienced. Exceptions exist at some practices, where client sharing is applied to a certain degree. This principle is applied either in the form of a collaboration between fixed couples of senior and junior/medior therapists or in a group of therapists with the same expertise. These ways of working are not applied to a great extend yet.

3. *What are the effects of different appointment scheduling strategies on the capacity and utilization of therapists while ensuring acceptable waiting times for clients?*

This research question uses the results from the previous research questions as a basis to design the simulation study of chapter 5. This simulation study provided the results regarding the effects of different appointment scheduling strategies. First of all this simulation study resembles a much more rigid environment than the real-world. Scenario 1 showed that the proposed appointment scheduling rule leads to a bottleneck for low available therapists. An additional rule, defining the maximum number of clients in a portfolio for a low available therapist proved to overcome this bottleneck. Although this rule leads to suboptimal utilization of low available therapists it does not have a major impact on the practice utilization as a whole.

Introducing the client assignment rule where new clients get assigned to senior therapists lead to interesting insights comparing the two use-case practices. In the case of a practice with spare capacity (relative low utilization) and sufficient senior therapist capacity, the new rule is feasible and could be the first incentive towards more resource- and thereby client sharing.

In the case of a practice operating at high utilization, the rule is less desirable. To be able to ensure ample capacity for the intakes of new clients, senior therapists need to reserve time for intake appointments. The time reserved is based on peak arrival rates, therefore leading to suboptimal utilization of senior therapists in times of fewer client arrivals. This will cause extra pressure on the agenda of the remaining therapists, possibly causing excessive waiting times.

Chapter 6 lead to insights on the practical application of this rule. Therapists indicate that a full agenda is important because in most cases this will define their income. Also under this new rule, every therapist should be able to fill the agenda without being forced to give up clients. Therapists would like to stay engaged in the remainder of the treatment of new clients

to prevent repetitive work, possibly leading to less work satisfaction. Lastly, junior and medior therapist involvement in intakes is pointed out as an important step in the learning process of less-experienced therapists.

7.2 Recommendations

This section proposes practical recommendations based on the results of this study and the conclusions drawn from these results. The first five recommendations are directly linked to the conclusion of the research questions, recommendations 6 and 7 are based on the remaining findings throughout this study.

1. Improve the therapist availability data by retrieving the availability directly from the planning system
2. Apply the proposed improvements regarding the utilization analysis
3. Detect possibilities for resource sharing when specialized capacity is scarce
4. Consider the proposed operational- and planning standardization regarding treatment duration and intakes
5. Pilots for the implementation of the new client assignment rule should be launched at low utilized practices with sufficient senior therapist capacity

The accuracy of the therapist availability has been mentioned multiple times throughout this study. In cooperation with the supplier of the planning system, the availability should be directly retrievable from the therapist agenda in the planning system. This new data source would provide accurate data and enable time-specific analysis on therapist work and availability. For example, the detection of therapist overtime in times of high utilization. If this new data source is not created, at least the availability of low available therapists should be checked periodically to prevent inaccuracies in analysis using this data.

The proposed improvements for the utilization analysis include using the exact treatment duration as opposed to the predefined treatment duration and use the exact appointment time to correct for double bookings and group treatments. These implementations will lead to a more accurate utilization analysis. Also, the utilization analysis regarding specialists can be split between time spent on specialization and time spent on general physiotherapy. The results showed that in times of scarce specialized capacity there are opportunities to free up capacity by sharing the workload of general physiotherapy clients. Some specialists spend a considerable amount of their time on non-specialist treatments while already working at extremely high utilization.

Treatment duration and the matter in which intakes are performed can be standardized at a practice or organizational level. It is important to consider the long-term strategy of the organization. If the strategy is to centralize the management of the organization as much as possible, the proposed process uniformity is much needed. If the strategy shifts to more local management, variety in operations can be allowed to a certain degree. Lastly, changing treatment duration, and thereby the therapist's schedule, should be done with caution. It can have effects on the perceived work pressure and it may counteract with the preferred way of working of some therapists.

The new client assignment rule needs practical testing. It is advised that pilots are launched at practices with spare capacity and sufficient availability of senior therapists. From the results of the simulation study it is concluded that problems will arise if these requirements are not satisfied.

6. Create a retrievable database of therapist expertise and specializations
7. Enable administrative double bookings for practice clients

Up-to-date and accurate information on therapist expertise will improve planning operations. The availability of this data can improve the match between clients and therapists. Also, a more detailed capacity and utilization analysis can be executed matching the specific expertise of a therapist to the complaint type of a client. This will also enable the possibility to study the possibility of client sharing between therapists with similar expertise.

From historical data, a significant amount of double bookings (multiple clients in one appointment block) have been detected. Normally this should be planned as a group session. From the result of the therapist interviews, these turned out to be practice clients who get partial attention in the gym during a longer appointment block. From an administrative standpoint, this manner of booking appointments is not possible. Therapists use workarounds to plan these kinds of treatments, leading to inaccurate data analysis. A way of planning multiple practice clients within one block, without it being a group session, should become available.

7.3 Limitations

There are some limitations to this research, which are important to point out. The accuracy of therapist availability data has been mentioned multiple times throughout this study. This limitation leads to the necessity of extreme caution when concluding anything from analysis using availability data (thus including utilization analysis).

The operational variety throughout the organization also posed a limitation for this research. The analyses performed in chapter 4 are generalizable and robust. However, this simulation study performed in chapter 5 required a vast amount of manual data transformations to come to a workable model.

From a strategic standpoint, the qualification of therapists (senior/medior/junior) will become increasingly important. There has not been a clear definition of these qualifications available throughout the study and the assignment of these qualifications seems to largely rely on the opinion of location managers. Especially for the results of the simulation study a change in qualification can have a big impact on the results.

The performance measure regarding waiting time used in the simulation study is based on assumed preferred treatment dates from clients. There are no actual recording of the preferred treatment date of clients. These waiting times could thus not accurately represent real-world waiting times. To be able to track client waiting times in the future, preferred client treatment dates need to be recorded.

7.4 Future research

The most interesting topic for future research is the exploration of client sharing between therapists. To be able to utilize capacity optimally this topic of future research could lead to interesting insights and recommendations. Highly productive practices can be used as an example for planning and appointment scheduling suggestions. In particular, the use of similar therapist expertise to share clients between these therapists could be an interesting angle for future research.

However, to be able to perform such a study, data needs to be available on therapist expertise. Also, the necessary expertise for a certain treatment should be known to be able to couple clients to therapists according to the client complaint and therapist expertise.

Furthermore, the effect of different mixes of resources could be studied. Throughout this research, the resources qualifications (specializations and experience) are fixed based on the real-world scenario. Varying the resource qualification could lead to interesting insights into the effects of these variations. A possible variations in these resource qualification could be the ratio between available senior and medior/junior hours.

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Appendix A

Interview structure and questions

- Introduction
  - General introduction from both sides
  - What is your exact role and experience within FysioHolland?
- Planning
  - Could you describe the current planning process for your practice?
  - How do you deal with your specialism/expertise when it comes to planning?
  - Are you content with the current planning operations?
  - What are common problems occurring regarding to planning currently?
  - Do you have any suggestions for improvement?
- Treatment trajectories
  - Can you describe the current way of assigning a new client to a therapist at your practice?
  - What does the remainder of a treatment episode for this client look like?
  - Do you use a fixed client-therapist assignment? If so why? If not so, what does this assignment look like?
  - Have you ever thought about changing the way clients get assigned to therapists?

    Picture the following scenario:
    Seniors predominantly perform intakes after which remainder of treatments are performed by junior and medior therapists. This to ensure accurate intake and evaluation of complaint and define more clear treatment paths.

  - Would this be a feasible scenario in your eyes?
  - What would be the positive and negative effect on introducing this rule?
- Treatment duration
  - Is there a treatment duration standard within your practice? If so what is this standard?
  - Are you content with this current standard or would something else be preferred?
  - What would be the difference for you as a therapist working a 30 minute schedule or a 25 minute schedule?

Appendix B

Overview therapists in simulation study

B.1 Use-case practice 1

Therapist	Weekly availability (hours)	Specialization	Experience qualification
Therapist 1	7.5	-	Medior
Therapis 2	7.5	-	Junior
Therapist 3	8	Children physiotherapy	Medior
Therapist 4	6.5	-	Junior
Therapist 5	21	Manual therapy	Medior
Therapist 6	7.5	-	Junior
Therapist 7	7.5	-	Medior
Therapist 8	15	-	Senior
Therapist 9	15	-	Medior
Therapist 10	39	-	Senior

Table B.1: Overview of therapits, available hours, specializations and therapist qualifications for use-case practice 1 of the simultion study

B.2 Use-case practice 2

Therapist	Weekly availability (hours)	Specialization	Experience qualification
Therapist 1	8		Medior
Therapis 2	8		Senior
Therapist 3	16.5		Junior
Therapist 4	21		Junior
Therapist 5	15.5		Medior
Therapist 6	17		Senior
Therapist 7	21		Junior
Therapist 8	10	Pelvis therapy	Senior
Therapist 9	19.5		Medior
Therapist 10	37		Medior
Therapist 11	27	Manual therapy	Senior
Therapist 12	23.5		Medior
Therapist 13	24.5		Medior
Therapist 14	40		Senior
Therapist 15	22.5		Medior
Therapist 16	25.5	Manual therapy	Medior
Therapist 17	24	Manual therapy Edema therapy	Senior
Therapist 18	18.25		Senior
Therapist 19	15.5	Manual therapy	Senior
Therapist 20	15.75		Junior

Table B.2: Overview of therapits, available hours, specializations and therapist qualifications for use-case practice 2 of the simultion study

Appendix C

Results Kruskal-Wallis tests

Datasets tested	**p-value**
General physiotherapy vs manual therapy	0.000
General physiotherapy vs children physiotherapy	0.000
General physiotherapy vs pelvis therapy	0.000
Manual therapy vs children physiohterapy	0.000
Manual therapy vs pelvis therapy	0.000
Children physiotherapy vs pelvis therapy	0.000
Age group 0-17 vs age group 18-44	0.000
Age group 0-17 vs age group 45-64	0.000
Age group 0-17 vs age group 65-74	0.000
Age group 0-17 vs age group 75+	0.000
Age group 18-44 vs age group 45-64	0.000
Age group 18-44 vs age group 65-74	0.000
Age group 18-44 vs age group 75+	0.000
Age group 45-64 vs age group 65-74	0.000
Age group 45-64 vs age group 75+	0.000
Age group 65-74 vs age group 75+	0.288

Table C.1: Results of the Kruskal-Wallis test for the number of treatments in a treatment episode over different client- and treatment characteristics