Optimisation of elective care patient allocation over multiple locations based on patient preferences

A case study for Franciscus Gasthuis & Vlietland

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franciscus Vlietland

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A case study for Franciscus Gasthuis & Vlietland

By

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In partial fulfilment of the requirements for the degree of

Master of Science
in Transport, Infrastructure & Logistics

at the Delft University of Technology,
to be defended in public on March 6, 2020.

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Cover:
Geographical representation of all Franciscus locations.
@ Franciscus Gasthuis & Vlietland

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Preface

Before you lies the report that contains my MSc. Thesis research. This research concludes six and a half years as a student at the Delft University of Technology. Last year, I have spent working on this thesis to fulfil the last requirement for the degree of Master of Science in Transport, Infrastructure and Logistics. I have experienced this period as an intensive, but educational process. Determining the exact problem for a hospital and subsequently designing a suitable scientific model for possible improvements turned out to be a more challenging task than initially expected. The last year, I have learned a lot on both scientific and personal level. I want to thank the people that have supported me throughout the process, I could not have succeeded without them.

First of all, I would like to thank Franciscus Gasthuis & Vlietland for granting me the opportunity to carry out this thesis research for them. Especially, Suzanne Korthorst, she provided me with all the tools, data and contacts that I needed to make the most of this project. Besides, she always made time for me, for advice and questions on certain matters. Furthermore, she provided me with a nice working place when I needed it. I have spent many hours in the Flextuin!

I also want to thank my supervisors from Delft University of Technology. Lorí Tavasszy, Marcel Ludema and Mark Duinkerken provided me with useful insight and guidance, when needed. Thank you for all the fruitful meetings, the critical feedback and positive boosts whenever I questioned my own ability to conduct this research.

Moreover, I would like to thank Rebel Group for hiring me to carry out this research as my thesis. The first 6 months of my thesis, they provided me with the working environment I needed to make the most of this study. I would like to thank Joris Snijders and Marrit van Baalen specifically. As my supervisors, they supported me in the best way possible, each with their own expertise. Marrit provided me with all the ins and outs of the healthcare sector and I have had very fruitful meetings with Joris that contributed to the design of my model.

Last but definitely not least, I would like to thank my friends and family. To start with my brother, Niels. He has pulled me through the (never ending) last phase of my thesis. Without his realistic, but motivational pep talks and thorough feedback, I would not have succeeded. A special thanks for the all nighter in the last week! Furthermore, A big thank you to my boyfriend Renaldo, for always being there for me and comforting me in difficult and emotional situations. Thank you for your patients, support and believe in me, especially whenever I doubted myself. I would also like to thank my parents for always being available to support me during this whole process, you kept me realistic and motivated. Lastly, I would like to thank my (former) roommates, as they always where the ones that had to cope with my grumpiness, stress and complaints. A special thanks to Daan for the feedback on my whole thesis!

This thesis concludes my time in Delft. I have had a great time as a student at the Delft University of Technology, it has given me great opportunities. For example, I have spend a quarter in Cuba and participated in several committees. I have enjoyed every bit of it! Now I am ready to close this chapter of my life and I am very excited for the first steps in my professional career. Enjoy!

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Abstract

With the implementation of the “Zorgverzekeringswet” in 2006, the healthcare system has changed over the years from a supply-driven system to a more demand-driven system. Service for patients have become increasingly important for healthcare providers, for example hospitals. Due to this change, hospitals experience more pressure to find the perfect balance between the components of the Triangle of Health Care: accessible, cost-friendly and high quality care. In order to improve the accessibility of care for patients, care parties have set up an initiative: “the right care in the right place”(JZOJP). This initiative is setup with the aim to shift the perspective of healthcare providers from their interests and what they have to offer, to what people need from them to live independently as long as possible. Furthermore, transmural care and concentration and decentralisation are also developments to improve the accessibility of care for patients.

One way hospitals can contribute to these initiatives and developments is by setting up external outpatient clinics (EOCs). These clinics are located on the edge of their care areas or between hospital locations. These EOCs are set up to provide care closer the homes of patient and to attract patients living on the edge of care area. However, nowadays hospital are more focussed on the service for patients and less on competition with other hospitals.

Franciscus Gasthuis & Vlietland is a hospital group in the area of Rotterdam. Franciscus has seven locations: Franciscus Gasthuis, Franciscus Vlietland, EOC Berkel, EOC Maassluis, EOC Hoogvliet Haven polikliniek and het Oogziekenhuis, Rotterdam. The performance of the EOC locations have not yet been researched in detail before. However, after a first analysis of the patient flow it was concluded that the patient flow for Maassluis and Hoogvliet were decreasing. Also, Franciscus believes that the locations are not optimally used due to empty rooms during opening hours and lack of work for employees at the locations. With focus on the service for patients, the increasing pressure on the main locations and the vacancy of rooms at EOCs, Franciscus aims to use the EOC locations more efficient.

To aim of this research is to find possible measures that improve the performance the EOCs of Franciscus to increase the service for patients. Therefore, a Linear Programming model is designed that seeks for the optimal allocation of patients over multiple locations by optimising the service for patients. Service for patients is defined by factors that influence the decision-making of the hospital location choice for a patient. the following main research question was formulated:

How can the performance of external outpatient clinics of Franciscus Gasthuis & Vlietland be improved to increase the service for patients?

To be able to answer the research question, the service for patients is defined and the current performance of the EOCs are determined and quantified. Therefore, the following steps have been executed:

A literature study is carried out on the Dutch Healthcare system. To get an overview of the hospital sector in the Netherlands and the role of the EOCs within the sector and Franciscus. Subsequently, a literature review is conducted on decision-making factors for hospital locations for patients. The factors that are used in the decision-making process are: travel time (time to travel from origin to destination) and waiting time (time between scheduling an appointment and the moment of the appointment). These two factors represent the service for patients in this study.

Subsequently, a current state analysis is performed with focus on three components: stakeholders, customer journey and data. With this current state analysis bottlenecks for the current performance of EOCs have been determined. Subsequently, the lack of performance and service for patients are quantified. This is done based on observations, interviews, data-analysis and KPIs. Bottlenecks that are found are:

- The schedules of EOCs are based on planning of specialists, unaware of the demand of patient on a location.
- Lack of communication between main locations and EOCs and little awareness of EOCs at the main locations. This causes unnecessary extra time to schedule rooms and resources and inefficient use of the EOC locations due to late cancellations.
- Chaotic appointment system. Every location makes appointments for that location or one of the EOCs without considering the origin of the patient. This causes inconvenience for the patients.
- Long waiting times for patients. The waiting times often exceeds the Treeknorm of 28 days. Due to long waiting times patient choose other locations or even other hospitals.

The effects of the bottlenecks are quantified based on performance indicators and KPIs. In concluding, there is a mismatch in supply of consultation hours and demand of patients at the Franciscus locations. This causes a lack of performance for EOCs and affects the service for patients.

Based on the outcomes of the current state analysis, a LP model is designed with focus on the service of patients. The LP model minimise the inconvenience costs for appointments for all appointments for all locations. Inconvenience costs are defined by the relative travel time and waiting time for an appointment. The appointments are assigned to a location considering the capacity constraints of locations, the capacity of specialties on a location and the utilisation of a specialty on a location. This model is designed to seek a match between demand and supply for each involved location. The model is applied for Franciscus. A base model is simulated and allocates the appointments over the Franciscus locations. Subsequently, an ideal situation is simulated (situation without any waiting time or capacity constraints). Scenarios are setup to analyse the effect of two measures on the service for patients. the dataset of the scenarios are created based on the comparison between the base model and the ideal situation.

The main result concluded from the application of the designed model is that a shift in consultation hours towards the EOC locations would improve the performance of EOCs. Subsequently, the improvement performance of the EOC causes an increase in service for patients, since the average travel time per patient is decreased. Furthermore, this measure leads to less consultation hours the main location, therefore the pressure on the main locations is decreased. Besides, the average costs per consult, regardless of the location, is decreased. Nevertheless, the implementation of this measure can only be achieved by the cooperation of several stakeholders. Changes in the organisation of Franciscus are necessary to achieve an increase in service for patients.
A second measure that can improve the performance of EOCs is the investment of Radiology equipment at the EOC Maassluis. This measure does not necessarily increase the service for patients as defined by the KPIs, however it does improve the accessibility for patients and therefore the service for patients. This investment increases the attractiveness for patients and for specialists, as a complete diagnosis can now be carried out at once on the same location.

The model designed in this study is the first version of a model that allocates elective care patients over multiple locations including multiple specialties. Therefore, the model is not applied or reviewed by other researchers. Considering the results of this study, some recommendations for future research are:

- Usage of different modelling methods. Models that include waiting time as dynamic variable that changes over time;
- Inclusion of other constraints in the LP model than only capacity constraints;
- Extend the definition of service for patients. Exploration of other factors that define the service for patients.

Subsequently, recommendations are provided for Franciscus with regard to tackling the bottlenecks. Some of these recommendations are:

- One general appointment system. This could either by one central system or a system wherein every outpatient clinic schedules her own appointments;
- Further research into causes of waiting time. Before waiting times can be tackled, it is necessary to obtain insight in the causes of waiting time.

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List of Abbreviations and Acronyms

Abbreviation/Acronyms	Nederlands	English
3Bs	Berkel, Bergschenhoek, Bleiswijk	Berkel, Bergschenhoek, Bleiswijk
AMC	Amsterdams Medisch Centrum	Amsterdam Medical Centre
CBS	Centraal Bureau voor de Statistiek	Statistics Netherlands
CEC	Capaciteits Expertise Centrum	Centre for Capacity Expertise
DTC	Diagnose Behandeling Combinatie	Diagnosis Treatment Combination
ECG	Elektrocardiogram	Electrocardiography
ED	Spoedeisende Hulp	Emergency Department
EHR	Elektronisch Patiëntendossier	Electronic Health Record
ENT	Keel, Neus, en Oor	Ear, Nose and Throat
EOC	Buitenpolikliniek	External Outpatient Clinic
GP	Huisarts	General Practitioner
ICM	Integraal Capaciteits Management	Integral Capacity Management
JZOJP	Juiste Zorg Op de Juiste Plek	Right Care at the Right Place
KPI	Kritieke Prestatie Factoren	Key Performance Indicators
LP	Lineair Programmeren	Linear Programming
NVvH	De Nederlandse Vereniging voor Heelkunde	Dutch Surgery Organisation
RIVM	Rijksinstituut voor Volksgezondheid en Milieu	National Institute for Public Health and the Environment
Vumc	Vrije Universiteit Medisch Centrum	Open University Medical Centre
VWS	Volkgezondheid, Welzijn en Sport	Health, Welfare and Sport
WLZ	Wet Langdurige Zorg	Long-Term Care Act
WMO	Wet Maatschappelijke Ondersteuning	Social Support Act
ZKN	Zelfstandige Klinieken Nederland	Independent Clinics in the Netherlands
ZVW	Zorgverzekeringswet	Health Insurance Act

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1. Introduction

1.1. Situation

With the implementation of the “Zorgverzekeringswet” (ZVW) in 2006, the Dutch healthcare system officially changed from a public controlled system to a system that is based on privately regulated negotiations (Nederlandse Vereniging van Ziekenhuizen, 2016). This law ensures a sufficient basic healthcare insurance for every Dutch citizen whereby the insurance companies and healthcare providers are responsible for the execution of this law. The ZVW creates a regulated market mechanism with competition between the different insurance companies and providers. This should keep healthcare affordable for the Dutch citizens (Ministerie van VWS, 2016). Moreover, this law causes the healthcare system to change from a supply-driven to a more demand-driven system and the service for patients becomes increasingly important for healthcare organisations, such as hospitals. (Nederlandse Vereniging van Ziekenhuizen, 2016).

Nowadays, hospitals have to set private goals besides the usual public goals to be able to keep up with other hospitals in their care area. Therefore, hospitals have become more patient-oriented (Putters, 2001). Patients become more demanding and the standard service in hospitals changes to a more patient-specific service (Nederlandse Vereniging van Ziekenhuizen, 2016). Thence, hospitals experience an increasing pressure on access, cost and quality of healthcare, also referred to as the Triangle of Health Care. The decrease or increase of one the components results in changes for one or both other components. Hospitals are constantly seeking for the optimum balance between the three components (Goes, Edwardson, Rayamajhee, Hollis, & Hunter, 2019; Nancy, 2015).

The term access in the Healthcare Triangle has a double meaning. On the one hand, access is intended as healthcare that is available for everyone, regardless of how rich, poor, young or old. On the other hand, access is intended in a geographical way: healthcare must be within the reach of patients. Accessibility is becoming increasingly important for patient, as patients prefer hospital locations closer to their homes. This, for example, can be explained by the aging population of the Netherlands (Alle Cijfers, 2019; Ministerie van VWS, 2016).

In context of making healthcare more accessible, care parties have set up an initiative: The right care in the right place (JZOJP) (Taskforce Zorg op de Juiste Plek, 2018). This initiative is led by the Ministry of Health, Welfare and Sport. It aims to shift the perspective of healthcare providers, from their interests and what they have to offer, to what people need from them to live independently as long as possible (Taskforce Zorg op de Juiste Plek, 2018). One of the means to achieve this goal is transmural care. Transmural care is care supplied by multiple healthcare providers to fulfil the needs of a patient in an optimum way. This concept is further explain in Section 2.2 (Medical Groep, 2019; Stichting Transmurale Zorg, 2019).

One of the ways hospitals can contribute to this initiative is by setting up external outpatient clinics (EOCs). These clinics are located between hospital locations or on the edge of the hospitals’ care areas (Sonneveld & Heida, 2014). EOCs make it possible for patients to receive care closer to their homes, which is an advantage for patients. Patients can visit an EOC for their polyclinical appointments instead of the hospital at a location further away (Sonneveld & Heida, 2014). Besides, EOCs also benefit the hospital, because they enlarge the care area of the hospital. This increases the patient flow, which causes increasing turnover for this hospital (Runia, 2017;

Sonneveld & Heida, 2014). Therefore, the number of EOCs has grown from 61 in 2009 to 134 in 2018 (Rijksoverheid, 2018).

1.2. Research Problem

Franciscus Gasthuis & Vlietland (Franciscus) is a hospital group in the area of Rotterdam and plays a prominent role in the province Zuid-Holland. Besides her main locations in Rotterdam and Schiedam, Franciscus has three EOCs located in Berkel, Hoogvliet and Maassluis. Furthermore, Franciscus has several polyclinics in de Haven polikliniek and an polyclinic Oogziekenhuis Rotterdam (Franciscus Gasthuis & Vlietland, 2019).

The hospital acknowledges the fact that patients need healthcare closer to their homes. At the same time, the hospital wants to fulfil her part in the transmural care initiative. Additionally, Franciscus saw the opportunity to attract more patients by expanding her care area. Therefore, she has set up these three EOCs (Korthorst S. , 2019). Figure 1.1 shows the care area of Franciscus including her locations and all hospitals within this area. Oogziekenhuis Rotterdam is not included as it is not an official Franciscus location.

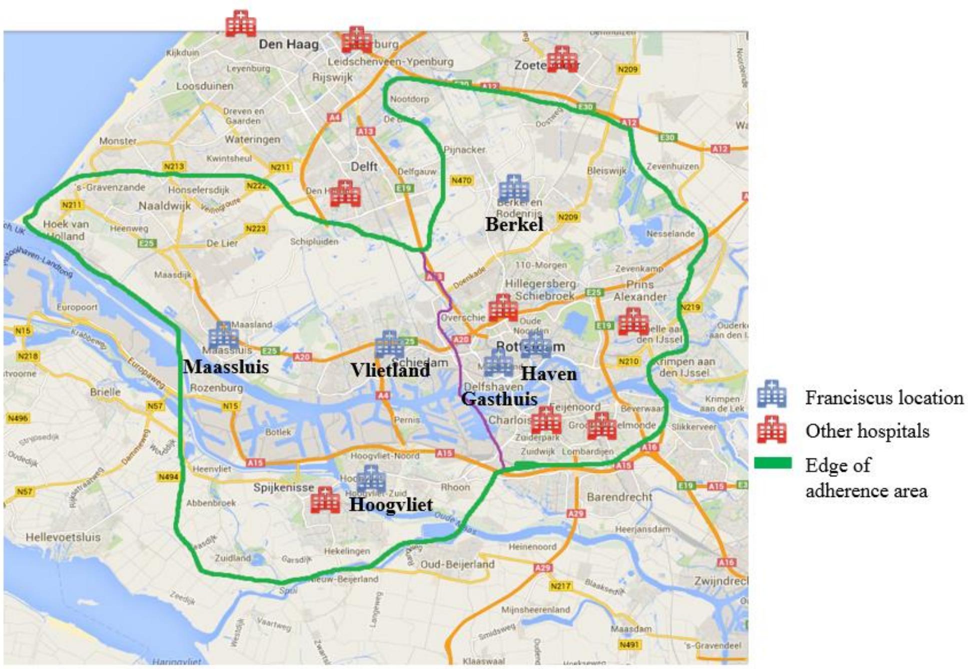

Figure 1.1 Care area of Franciscus Gasthuis & Vlietland

Since the opening of the EOCs, their performance has not been researched in detail yet. However, in the first months of 2019 an analysis was carried out on patient flow of each clinic. It appeared that the patient flow in 2018 decreased in comparison to 2017 for the locations Hoogvliet and Maassluis (Korthorst & Stelt, 2019). Furthermore, Franciscus noticed that the external outpatient clinics are not used optimally (Korthorst S. , 2019). For example, there are multiple empty rooms during opening hours and there is a lack of work for employees during their shifts. In 2018, the maximum occupancy rate (% time of consultation hour used in comparison to the total time of consultation hours) of Hoogvliet has been 70%, and for Maassluis and Berkel the occupancy rate was 80% (Korthorst & Stelt, 2019). Besides, there is an increasing pressure on the main locations of Franciscus, due to the increasing number of patients. Therefore, waiting lists are extending, causing a negative effect on the quality of service for patients (Korthorst S. , 2019).

With focus on the service for patients, the increasing pressure on the main locations and the vacancy of rooms at EOCs, Franciscus feels that the EOCs can be used more efficiently. This could lead to less waiting time for patients. Nevertheless, because the demand and supply of EOCs have not been evaluated before. For this reason, Franciscus has trouble finding possibilities to improve the utilisation of EOCs.

By analysing the current state of the EOCs of Franciscus, the current performance of EOCs can be measured and the current level of service for patients can be determined. Bottlenecks can be identified that influence the performance of the EOCs. Subsequently, an optimisation model can be designed to optimise the allocation of patients over all locations, based on the patients preferences. The results of this model show whether the service of patients can be increased by rescheduling the planning of specialties over multiple locations and by improving the performance of EOC locations.

Planning optimisation in the hospital environment is a well-known topic in science (Benneyan, et al, 2012; Hulshof & al., 2011). Research is carried out on strategical, tactical and operational levels. Theoretical frameworks are developed to define problem areas with planning and control of hospitals or specific departments (van Houdenhoven, Wullink, Hans, & Kazemier, 2007). Furthermore, research is carried out on new planning methods to improve the waiting times for patients (Yih & Min, 2009). Besides, multiple studies address the topic of optimisation of hospital planning. In literature, multiple optimisation model are developed for one department specifically, mostly to minimise the processing or waiting times for patients during an appointment (Jalali, Ahmadi-Javid, & Klassen, 2016; Strahl, 2015). Nevertheless, these are focused on one location or a single department only. Moreover, several optimisation models exist which help finding the best locations for new hospital facilities (Azadeh, Baghersad, Farahani, & Zarrin, 2015; Smith et al, 2018). However, none of these models involve patient scheduling for bot multiple existing locations of a hospital organisation and multiple specialties that are offered at these locations. Therefore, this research serves as a first exploration on how the planning of multiple specialties can be optimised while focusing on multiple locations of a hospital. The outcomes of this research can encourage other researchers into further research of hospital planning over multiple locations.

Moreover, this research contributes in societal terms as healthcare is a social good. It contributes to the Dutch governments initiative JZOJP. This is because the model is designed to find a better allocation of appointments and to come up with an advice on how to make more efficient use of hospital locations. This thesis seeks to find ways to improve the performance of locations by focusing on the service for patients, including waiting time and travel time. Furthermore, by increasing the efficiency of the existing hospitals locations, more patient can be treated while using the same resources. This can support the growth of patient flow in hospitals without extra investments. Subsequently, benefits the annual healthcare expenditures of the government.

1.3. Research objective

The main purpose of this thesis is to find measures to improve the performance of the EOCs to increase the service for patients. This is achieved by designing a model that seeks the optimal allocation of appointments over multiple hospital locations based on patient preferences. The aim of this study is to meet the preference of patients as much as possible to achieve the highest level of service for patients. The preferences of patients are defined by factors that influence the location choice of a patient and are determined in Section 2.5

The research problem and the research objective has been converted into the following main research question:

How can the performance of external outpatient clinics of Franciscus Gasthuis & Vlietland be improved to increase the service for patients?

The main research question is supported by four sub-questions:

1. What role do external outpatient clinics play within the Dutch healthcare system and Franciscus and how do they contribute to the service for patients?

To answer this sub-question, a literature study is carried with focus on the Dutch Healthcare system. The healthcare system is explained, the recent developments are reviewed and the functioning of EOCs is elaborated. A thorough study of the field provides a good overview of the role of EOC within the current healthcare system. Subsequently, a background study is performed to elaborate the Franciscus organisation and to determine the role of EOCs within this organisation.

2. Which factors influence the decision for patients in the care area of Franciscus when choosing the location to receive elective care?

Previous literature research is reviewed to identify factors that influence the decision-making of hospital location choice for patients. The following three databases are used in this research: Google Scholar, Scopus and Science direct. Based on this review, the important factors that influence the decision-making process of patients are determined.

3. What are the bottlenecks that create inefficient use of the external outpatient clinics of Franciscus?

To find the bottlenecks that cause inefficiency in the use of EOCs, a current state analysis is carried out. The analysis is executed by means of three components: stakeholders, process and data. Different methods are used for each component.
Firstly, a stakeholder analysis is done to determine the key players within this study. Key players are stakeholders that should be taken into account in search for measures to improve the performance of EOCs. Interviews are held with stakeholders to gather insight in the problem and to determine their perspectives on the EOCs.

Secondly, the process is described by the customer journey at EOCs. The journey is explained by means of a visualised representation. Subsequently, waste that is found during this journey is elaborated. Waste is the unnecessary use of resources and time.
Lastly, a data analysis is performed to gather statistical information about the current use of EOCs and the behaviour of specialties on the EOCs. Key Performance Indicators (KPIs), that are determined by means of a literature study in Section 2.7, are calculated to measure the current performance of the EOC locations and the service for patients.

4. What possible measures can increase the performance of the external outpatient clinics of Franciscus Gasthuis & Vlietland and what is the effect of these measures?

Based on the results of the literature study and the findings in the current state analysis, an optimisation model is designed. A linear programming model is used that minimises the total inconvenience costs for appointments of patients, to maximise the service for patients. These costs are defined by the factors that are determined to answer sub-question 2, travel time and waiting time. Additionally, the outcomes of the current state analysis are used as base for the model.
Subsequently, the designed model is applied for Franciscus. First a base model is run based on actual data. These outcomes are compared with the outcomes of a run of the ideal model, this represents a situation without any waiting time and constraints. Based on this comparison scenarios are set up with measures that could improve the service for patients. The scenarios are run in the model and the results are presented by the KPIs that are determined in Section 2.7. With the model outcomes and the calculated KPIs for each scenario can be determined what measure would increase the performance of EOCs. Furthermore, it can also be concluded what effect a certain measure has on Franciscus and its service for their patients.

1.4. Scope

The scope of this research is to find potential measures to improve the performance of the EOCs of Franciscus to increase the service for patients. This is carried out by means of an optimisation model that is created during this research. This model is designed for every hospital that seeks to find the optimal allocation of patients over multiple locations by optimising the service for patients. The service for patients is defined by factors that influence the location choice of a patient. Quality of care is assumed to be equal for every location, so is not taken into account for the model set-up. Furthermore, the model only focusses on the locations of one hospital organisation. Therefore, patients only visits the hospital that it is referred to.

Additionally, this study focusses on the EOCs of Franciscus specifically. Therefore, only specialties that can offer consultation hours at these locations are taken into account. Consultation hours are held twice per day, in the morning and afternoon, and have an average duration of three and a half hours. Consultation hours are mostly scheduled with three types of appointments; first consults, repeat consults and phone consults. It differs per specialty whether specialists also do small surgeries or tests during a consultation hour. However, this is not common at EOCs, they only make up for a small percentage of the total consultation hours. Besides, they are often executed by doctor’s assistant in specialised rooms. Therefore, these surgeries and tests are neglected in this study. This research concentrates on the polyclincial appointments, therefore only elective and chronical care patients are taken into account. In Section 2.1 the types of patients are explained.

Additionally, Franciscus originally had seven locations;

- Two main locations: Gasthuis & Vlietland;
- Three EOCs in Berkel, Maassluis and Hoogvliet;
- Oogziekenhuis;
- The Haven polikliniek.

However, due to the decreasing patient flow and increasing location costs, Franciscus has decided to close the EOC in Hoogvliet as of November 2019. Due to this development EOC Hoogvliet is excluded from the search to improvements. Nevertheless, the location is taken into account in the current state analysis, because the location was still in use in 2018. The data analysis of the current state is executed over the year 2018, because this is the most recent completed year, since this research was conducted in 2019. However, a more recent month is used for the application of the LP model. This is because the model is applied for a single month. Therefore, a more recent month is used for more actual data.

The application of the designed model for Franciscus is taken into account as explorative study, because the model has never been applied before. Based on the outcomes of the model an advice can be given on measured that could help to improve the performance of their EOCs.

1.5. Structure of the report

This thesis is divided in five phases, this is presented in Figure 1.2. Each phase is executed by one or more chapter, the methodologies that are used for the chapters are presented in the lower right bottom. Furthermore, per phase is given what question is answered at the end of that phase. The black arrows present the order of the phases and the grey arrows denote the relationship between the phase.

The exploratory phase is elaborated in chapter 1 and 2, in this phase a theoretical base is provided for the rest of the report. In chapter 2 theoretical background and relevance of this research is discussed by means of a literature study. In the analytic phase the current state of the EOCs of Franciscus is analysed. Several methods are used to determine the bottlenecks that cause a lack of performance of the EOCs for Franciscus and service for patients. The KPIs that are determined in the exploratory phase are used to measure the current performances. In the design phase, an planning optimisation model is developed. This is achieved based on the theoretical base and the information gathered in the analytical phase. The optimisation model is used in the following phase, the implementation phase. In this phase, the model is applied for Franciscus, scenarios are set up and run in the model. Results are presented on hand of the KPIs that are determined in the exploratory phase. Lastly, the model and the report are discussed in the concluding phase. Based on the results of the implementation phase conclusions and future research recommendations are presented in the concluding phase.

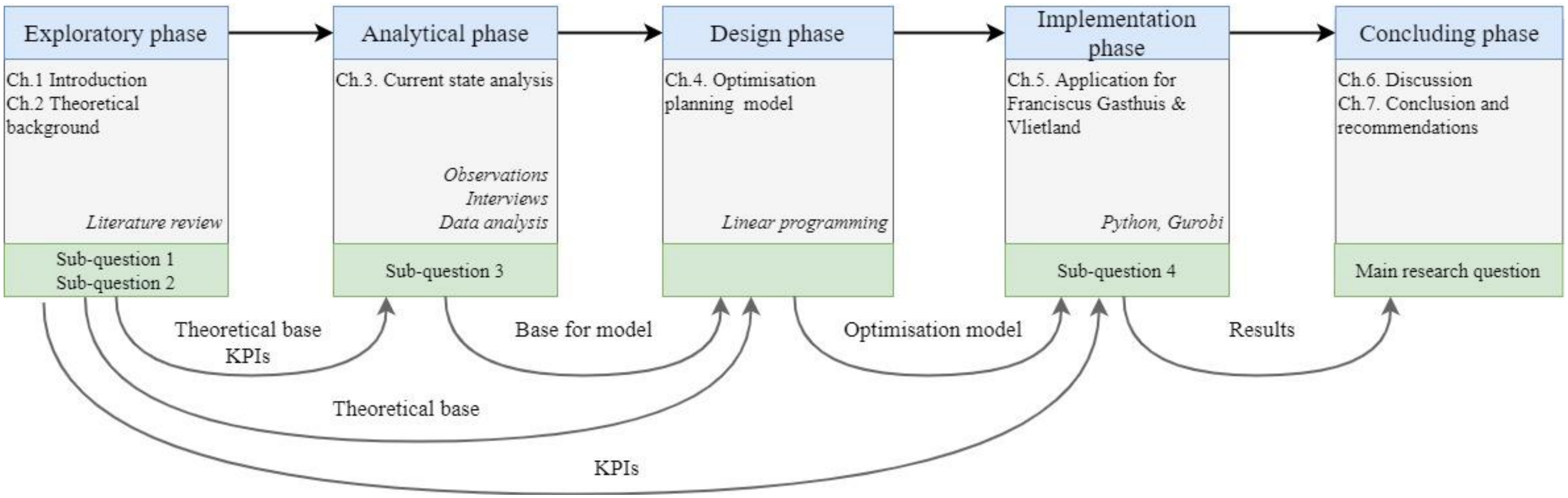

Figure 1.2 flow diagram of this report

2. Theoretical background

Chapter 2 is part of the exploratory phase, see Figure 2.1. This chapter elaborates on the background of the Dutch healthcare system and the role of EOCs within this system. Furthermore, background information of Franciscus and her EOCs is provided. With this information, the answer is provided for the first sub-question of this research. Subsequently, a literature review is carried out on the factors that influence the decision-making process for location choice of patients. A literature review is carried out on existing models and methods for hospital scheduling. Lastly, KPIs are determined that are used in the analytical phase in chapter 3 and the implementation phase in chapter 5.

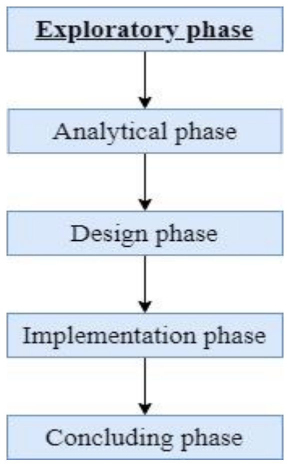

Figure 2.1 Exploratory phase of this study

2.1. Dutch healthcare system

The Dutch Healthcare system is merely regulated by four laws: the ZVW, Long-Term Care Act (WLZ), de Social Support Act (WMO) and The Youth Act. With these laws the government attempts to improve the quality of healthcare, to keep healthcare accessible and affordable during aging of people and to improve the integral approach (Zo Werkt de Zorg, 2018). This healthcare system aims to guarantee the following international principals (VWS, 2016):

- High quality of healthcare;
- Care needs to be accessible for everyone;
- Affordable care via a mandatory and accessible healthcare insurance.

Due to the implementation of the ZWV, all Dutch citizens are obligated to have a healthcare insurance. A monthly fee is paid to a health insurance company and this fee is used to cover basic healthcare costs. The expenditures for the healthcare sector for 2018 have been calculated at 100 billion euros, specialist medical care is accountable for 25% of these expenditures. The majority (83%) of these expenses is financed by healthcare insurances ZVW and WMO (Ministerie van Sociale Zaken en Werkgelegenheid, 2019). An elaborated explanation of the ZVW, WLZ, WMO and The Youth Act can be found in Appendix A.

2.1.1. Organisation of healthcare

The healthcare system in the Netherlands is a large and complex system. Therefore, several classifications are made in order to clarify this system. The most used classification divides healthcare into three levels. Each level has its own characteristics and rules (Breukel, 2019):

- Primary healthcare is care that is provided when a person consciously asks for care. For example, a person who calls a general practitioner (GP) for an appointment. GPs are an example of primary healthcare providers. Care providers on this level are providers with general knowledge. In other words they know the basic of many health problems.
- Secondary healthcare is only provided if a person has received a referral from a primary healthcare provider, in case one decides that more specialised care is needed. This level involves specialised healthcare, the care provider is specialised in a specific category of healthcare. General hospitals are part of secondary healthcare.
- Tertiary healthcare is comparable to secondary healthcare, however it contains more specialised and complex healthcare. Academic hospitals and highly specialised hospitals are categorised in tertiary healthcare. Patients receive this level of care after being referred by the specialists in secondary healthcare.

Besides these three levels, there is the, so-called, "nuldelijns" (level-0) healthcare. This includes preventive care for people with a high risk of becoming ill, such as elderly. An example of nuldelijns healthcare is breast examination that is provided for women at a high risk age for breast cancer. Furthermore, nuldelijns healthcare also includes care provided by non-professionals who make care possible at the home of a patient. This is preferably provided by parents, children, neighbours and friends. However, this can also be provided by volunteers and support groups (Gijsen, Post, & Verheij, 2019).

2.2. The hospital sector

Hospitals are providers of secondary and tertiary healthcare, so patients can only receive hospital care if they have a referral from a primary or secondary healthcare provider. The kind of care a patient needs can be classified into three types (Gaakeer, et al, 2014; van de Kassteele, et al, 2017):

- Acute care is care in cases of emergency. In other words, the patient is unexpectedly in need of direct care (e.g bone fracture, heart diseases, poisoning);
- Chronical care covers patients with a disease lasting longer than three months, for example Alzheimer or Cancer;
- Plannable or elective care includes all non-emergency care that can be planned beforehand (van de Kassteele et al, 2017).

Patients can receive these types of care in different types of hospitals (Statline, 2019):

- General hospitals are hospitals for diagnosis, treatments and nursery of all kinds of specialties. These hospitals do not focus on a specific population or specialty;
- Highly specialised hospitals are hospitals providing highly specialised care at some specialties and provide generalised care for other specialties;
- Academic hospitals are hospitals focused on patients in need of very specialised care, for example due to rare symptoms. These hospitals also conduct scientific research and provide education;
- Categorical hospitals are hospitals focused on a specific population or physical illnesses (CBS, 2019; STZ ziekenhuizen, 2019).

Table 2.1 shows the current number of facilities per category in the Netherlands. The numbers are based on the online list of hospitals of CBS (2019). However, this dataset contains information from 2018. Therefore, the fusion between academic hospitals AMC and VUmc is not yet included (Vermeulen, 2019). For this reason, the data has been modified and adjusted in the table above, there are now seven academic hospitals instead of eight. In total, there are 84 public hospital institutions in the Netherlands. Several of these institutions have multiple locations, these extra locations are mostly EOCs. In 2018, there were 134 EOCs in total. Additionally, there are also a large amount of private healthcare centres. The private healthcare sector is not very well-documented, however the Independent Clinics Netherlands (ZKN) has registered 358 private healthcare centres locations in 2018 (Giesbers, 2019; ZKN, 2018). The focus of this research lies on the performance of EOCs and their contribution to the service for patients. The private centres do not use EOCs, therefore private healthcare centres are out of scope for this research.

Table 2.1. Number of hospitals in the Netherlands (CBS, 2019)

Type of hospital	Quantity
General Hospital	33
Highly Specialised Hospital	26
Academic Hospital	7
Categorical Hospital	18
Total	84

2.2.1. Hospitals vs. Healthcare insurance companies

The ZVW that was implemented in 2006 has led to negotiations between healthcare insurance companies and hospitals. As mentioned in Section 2.1, the government has implemented the ZVW with aim to benefit quality, accessibility and costs of healthcare. According to the government, this is accomplished by a regulated competitive system. Insurance companies consider the quality, volume and price of medical specialised healthcare during the negotiations. Based on these components, insurance companies purchase efficiently from healthcare providers. Thence, insurance companies have also been given a directing role besides their financing role (Halbersma, van Manen, & Sauter, 2012; Ruwaard, Douven, Struijs, & Polder, 2014).

Before the ZVW was implemented, hospitals only knew budget financing. This means that hospitals received a certain budget from the government based on the expected expenses. However, this changed in 2012 towards a combination of budget financing and performance financing (NVZ a, 2019). Financing of hospital care is split in two segments: A-segment and B-segment. Around 30% of hospital care is covered by A-segment, which is financed by budget financing. This kind of care is mostly acute care and the maximum costs are annually determined by the Dutch Healthcare Authority (NVZ a, 2019). The B-segment covers the other 70% of hospital care containing plannable, non-emergency care. The prices of these treatments are determined by negotiations between healthcare insurance companies and the board of a hospital. The contribution of B-segment in the total financing of hospitals has grown from 34% in 2009 to 70% in 2012 (NVZ a, 2019; Ruwaard, Douven, Struijs, & Polder, 2014).

Hospital budget has become more dependent on performance and results, since the B-segment has grown to 70%. High quality care for a reasonable price has become the main purpose for hospitals, because this strengthens the position of a hospital during negotiations with insurance companies. The implementation of the ZVW provides insurance companies with the opportunity to select hospitals for collaboration. As a result, an insurance company does not have contracts with all hospitals. Therefore, the choice of a patient for a hospital is influenced by his or hers insurance company. This generates competition between hospitals, because the patient flow of a hospital is partly dependent on the contracts with insurance companies. (Ruwaard, Douven, Struijs, & Polder, 2014; Ministerie van VWS, 2016)

Hospitals vs. primary healthcare providers

Besides healthcare insurance companies, primary healthcare providers have an important role in the patient flow of hospitals. Providers refer their patients to a hospital if one is not able to provide the needed treatment and further specialised healthcare is necessary (Breukel, 2019). The provider decides, in collaboration with the patient, to which hospital the patient will be referred. Therefore, a good reputation and a good relationship with these providers are of high importance for hospitals. Nowadays, patient are digitally referred via a platform named ZorgDomein. This platform connects patient, primary and secondary healthcare providers with each other. A clear overview of all secondary healthcare providers is presented. Moreover, the waiting time for the desired treatment is displayed for each provider. Waiting time is the time between the moment of referral and the first available moment for an appointment. This gives the primary providers and their patients the possibility to choose the best option, which creates more freedom for the patient. (ZorgDomein, 2019). Based on the preference of the patient and the available information, a secondary healthcare provider is chosen. With this in mind, short waiting times are becoming increasingly important for hospitals, because short waiting lists make the hospital more attractive for primary providers and their patients.

2.2.2. Recent developments

Financial developments

As mentioned in Section 2.1, the total annual expenditures for healthcare in 2018 have been calculated at 100 billion euros. According to RIVM (VTV, 2018), it is likely to increase with an average of 2,9% per year to 174 billion euros in 2040, which is twice as much as in 2015. Hospital care is a large share in the total cost, since approximately 31% of these expenditures is spend by hospital care. The increasing costs can partly be explained by demographic changes. Care cost of aging elderly are increasing, due to the growth of people in need of chronical care and with multiple diseases. Aging is responsible for one third of the increasing expenditures, the other two third can be explained by factors as the implementation of medical technology (VTV, 2018; Volksgezondheidenzorg.info, 2019).

Consequently, the increasing expenditures cause an increasing pressure of healthcare insurance companies on healthcare providers to become more efficient. Moreover, hospitals struggle to stay financially healthy, according to the benchmark between hospitals executed by BDO (2018). In 2018, 14 hospitals were on the verge of bankruptcy, of which two were closed at the end of the year. 9 of these 14 hospitals already struggled to avoid bankruptcy in 2017.

Personnel and capacity problems

Another development that puts pressure on hospitals, is the shortage of staff. The number of vacancies has doubled in the last four years and reached a peak in 2018 (BDO, 2018; Vermeeren, 2019). This shortage has effect on the quality of healthcare for patients. Patients are confronted with long waiting times and employees have less time and attention for patients during their treatment (van Ommen, zijderveld, & Schout, 2017). Due to shortage of personnel, hospitals are forced to cancel planned surgeries and schedule less surgeries (Van den Brink, Herderschee, & Vleugels, 2018).

A consequence of these problems is extending waiting times for both diagnosis (polyclinical appointments) and treatments (clinical appointments) (Mediquest, 2019). Consequently, the so called Treeknorm is exceeded more often. The Treeknorm is the maximum acceptable number of days for a patient to wait before her or she receives the requested care. This norm is set by the healthcare providers and insurance companies for all hospitals in the Netherlands. The Treeknorm standard for polyclinical appointments is 28 days (Zorg en zekerheid, 2019).

Concentration and decentralisation

Dynamics are changing within the hospital sector, a mentioned in Section 1.1. Highly complex care is concentrated in more specialised hospitals and elective, chronic and acute care is spread out across local hospitals and (external outpatient) clinics, to offer care closer to the patient (NVZ b, 2010). The concentration of complex care is originated from the belief that the quality of care increases if treatments are executed more often. Furthermore, costs can be lowered due to scale effects caused by more efficient use of staff and resources (NVZ, 2019).

The Dutch surgery organisation (NVvH) has set minimum volume standards for these highly complex treatments (see Section 2.1). This implies that hospitals need to perform a certain treatment a minimal number of times per year to be allowed to offer this treatment to patients (Ruwaard, Douven, Struijs, & Polder, 2014). Healthcare insurance companies adopted these minimal volumes as requirement in their contracts with hospitals (NVvH, 2016). This causes a serious problem for smaller hospitals, because they are not able to reach these volume standards.

Therefore, they are forced to stop performing these operations or treatments. Thence, there are doubts whether volume standards are the right way to maintain quality. According to Mesman (2017), the quality of care also depends on process and structure indicators. Kiers (2017) argues that the effectiveness of offered cannot be measured by volumes.

Nevertheless, hospitals can spread their acute and elective care among several locations as these types of care are often offered in high volumes. This is a strategical choice of hospitals (NVvH, 2016). Multiple smaller locations increases the possibility to cooperate with other healthcare providers, such as GPs, pharmacies and other primary providers. This development contributes to the transmural care initiative. Transmural is defined as care provided by multiple healthcare providers of both primary and secondary healthcare (Stichting Transmurale Zorg, 2019). Through this collaboration between different providers, the focus lies on the care that is needed by a patient, regardless of the level of healthcare. The care a patient receives is based on agreements of collaboration, tuning and directions of the involved providers (Medical Groep, 2019). The aim of this initiative is to achieve more efficiency, higher quality and continuity of care and care aligned with the need of a patient (Zuster Jansen, 2019). Transmural care participates on the achievement of the following goals (Stichting Transmurale Zorg, 2019):

- Decreasing waiting times for patients by up and down scaling, patients will be seen at the right location;
- More effective and efficient transmission between healthcare providers. This leads to less mistakes in medical and medicine information;
- Transparent information towards the patients, which generates more control for patients.

The right care at the right place

The aim of all parties within the healthcare sector is to guarantee quality, accessibility and affordability of healthcare (see Section 2.1). One of the initiatives to achieve this is ‘The right care of the right place’ (ZOJP). This initiative focuses on daily functioning of people. KPMG (2018) defines ZOJP as follows:

- Includes sensible (appropriate) care;
- Accessible care for everyone in need without exceeding the Treeknorm;
- Creating the same or even better quality of healthcare based on the results of care and support at both clinical level and patient experience;
- Care at the lowest possible integrated costs.

The initiative includes multiple ways of reallocation. The word “substitution” is often used, which specifically means the shift of healthcare from secondary to primary care. Sometimes this also includes task reallocation, structural reallocation of tasks between different professions. Furthermore, concentration of healthcare is seen as part of the right care at the right place, but forced by volume standards.

2.3. External outpatient clinics

EOCs are located at the edge of an care area of a hospital or between two hospitals of the same hospital organisation (Sonneveld & Heida, 2014). At EOCs, patients can be seen for polyclinical appointments, such as a first consult with a specialist or a consult to check up after surgery. In 2018, the Netherlands counted 134 EOCs (Gijsen, Post, & Verheij, 2019). EOCs are set up to benefit strategy and goals of that hospital. Therefore, the design of each EOC differs and hospitals can decide which specialties and which care is offered at that EOC. In general, EOCs are set up so patients can receive care close to their homes. Additionally, these location are created by hospitals in order to compete with other hospitals in the area. Thence, by setting up an EOC they can attract people living at the edge of their care area (Sonneveld & Heida, 2014).

The vision on EOCs differs among Dutch hospitals. Some hospitals have multiple EOCs (Franciscus and Ziekenhuisgroep Twente) where others have none. Nevertheless, according to Sonneveld & Heida (2014) the use of EOCs increases the total turnover. It therefore seems to be a good strategy if a hospital aims for growth. The allocation of EOCs can be divided into four categories:

1. Between two locations of the same hospital organisation.
2. Between the hospital and another hospital, but closer to their own hospital.
3. Between the hospital and another hospital, but closer to the other hospital.
4. Beyond the other hospital. Another hospital is located between the EOC and the hospital.

Category two is the most common strategy in the Netherlands. EOCs are set up to offer patients a location closer to their homes, so they do not have to travel too far. This improves the attractiveness for patients to choose that hospital over others. EOCs of category three aim to attract patients that live closer to another hospital. This category results in extending the care area of a hospital. The application of category one and four is limited in the Netherlands (Sonneveld & Heida, 2014).

The EOCs of Franciscus are located closer to their own hospital, which is in line with category two. EOC Berkel is set up to serve people living in the Berkel, Bergschenhoek and Bleiswijk, the so called 3Bs. However, it also intends to attract people from Delft and several towns between Delft and Pijnacker. With this EOC Franciscus strengthens her position in relation to Reinier de Graaf Hospital in Delft (Franciscus Gasthuis & Vlietland, 2019).
EOC Maassluis is set up for patients in Maassluis and Westland. In this area there are few hospitals, so patients had to drive relatively far to receive care. By establishing the EOC Maassluis the travel time for patients is reduced (Franciscus Gasthuis & Vlietland, 2019).
EOC Hoogvliet is established due to bankruptcy of the Ruwaard van Putten hospital. Franciscus seized the opportunity to attract patients that used to go to that hospital by setting up an EOC. Meanwhile, MC Spijkenisse has taken over Ruwaard van Putten hospital and the patient flow of EOC Hoogvliet severely decreased in the last several years. Consequently, Franciscus has decided to close this EOC in November 2019, because the location was not beneficial anymore (Franciscus Gasthuis & Vlietland, 2019).

Initially, EOCs were set up by hospitals for competitive purposes. However this has changed over the years. In 2012 the “hoofdlijnenakkoord” of the government stated that the growth of hospitals had to be limited (Federatie Medisch Specialisten, 2011). Therefore, hospitals are reconsidering their EOCs. EOCs still have an added value for the municipalities EOCs are located in, but cannot be used for competitive reasons anymore. EOCs are often in close contact with first healthcare providers and are located rather far from the hospital location. Therefore, closing an EOC could have bad influence on the image of a hospital towards patients and primary healthcare providers. This would decrease the service for patients and could a decrease in patient flow (Fluent, 2017).

2.4. Franciscus Gasthuis & Vlietland

Franciscus is a hospital group located in Rotterdam and surrounded areas. She is founded in 2015 by the merge of Sint Franciscus Gasthuis and Vlietland Hospital. Both hospitals have a long history as Franciscus Gasthuis was founded in 1892 and Vlietland Hospital in 1808. Franciscus Gasthuis & Vlietland has setup a strategical plan for 2018-2023. Her mission is to provide healthcare for and by people. The patient comes first and she wants to exceed the expectation of quality and service. The motto of Franciscus is: Care for generations (Franciscus Gasthuis & Vlietland, 2019).

In order to achieve this ambition, Franciscus has developed four pillars (Franciscus, 2019):

- Franciscus provides valuable care, where educations, scientific research and innovation to add an important contribution to this care;
- Franciscus is big enough to deliver high-quality healthcare and small enough to give personal attention;
- Franciscus enjoys the collaboration with network partners, such as GPs and midwives;
- Franciscus invests in colleagues, because people like to be employed at Franciscus and improve care every day for her patients.

These pillars are supported by seven strategical choices (Franciscus, 2019):

1. To deliver continuously high-quality care for patients and to stimulate the patient's own directions;
2. To deliver both basic care on a daily basis, as well as top clinical care.
3. To focus on specific kinds of healthcare in which she wants to be distinctive.
4. To collaborate with partners if it will lead to better care for the patient.
5. To collaborate with her employees to make a difference in the organisation of Franciscus.
6. To be an innovative organisation with sustainable business operations.
7. To realise an appropriate governance together.

The EOCs of Franciscus already existed before the merge of the two hospitals. The EOC located in Berkel is originally founded by Sint Franciscus Gasthuis and the EOCs Maassluis and Hoogvliet belong to of Vlietland Hospital. Before merging, consultation hours in Berkel were held by specialists of Gasthuis and consultation hours in Maassluis and Hoogvliet by specialists of Vlietland. This separation can still be noticed sometimes, due to preferences of specialists for one of the EOC locations. However, this preference now merely depends on travel time for a specialist, as Berkel is closer to Gasthuis and Maassluis is closer to Vlietland. (Franciscus Gasthuis & Vlietland, 2019).

As mentioned in 2.3, EOC Berkel is founded to provide inhabitants of Lansingerland (3Bs) specialised medical care closer to their homes. Also, there is a GP practise, pharmacy and physiotherapist practise in the same building, which makes it very easy for patients to contact or visit the EOC after being referred.

EOC Maassluis exists nearly 40 years and receives patients from Maassluis and Westland. Franciscus Maassluis is the only hospital related facility in this region. This location also has a good partnership with the GP practises in Maassluis and has loyal referrers from Maassluis, Maasland and Maasdijk.

Hoogvliet is the newest EOC and has only existed for eight years. This location had two rooms and an examination room and was therefore a rather small location. However, in contrast to EOC Maassluis this location had the resources to practise Radiology and do ECGs.

Furthermore, since the reorganisation of Havenziekenhuis, Franciscus has taken responsibility for four specialties. Together with five other hospitals, Franciscus ensures continuity of care and employment at the Havenziekenhuis, (now called Haven Polikliniek). The specialties that Franciscus is responsible for are: Cardiology, Pulmonary Medicine, Urology and ENT.
Lastly, Franciscus has an outpatient clinic at Oogziekenhuis in Rotterdam. Here, she receives patients for several specific illnesses, for example diabetes and vascular diseases. Franciscus has a contract with Oogziekenhuis Rotterdam for the specialty internal medicine, which is offered for three days a week at this location (Korthorst & Stelt, 2019).

2.5. Hospital choice by patients

The aim of this study is to find measures that improve the performance of EOCs, to increase the service for patients. The focus is on scheduling of patients over different locations, because it is assumed that a better distribution of patients over the available locations will lead to higher performance of the EOC locations and better service for patients. Therefore, this literature review is performed to determine the factors that influence the choice of a hospital location by patients.

A lot of research has already been carried out on the decision-making process of patients when choosing a hospital. Research is executed in a wide range of countries all over the world. During this research, three databases are used, being Scopus, Google Scholar and Science Direct. Only articles published in English and Dutch were taken into account. The literature study is done based on different keywords that are relevant for this research, according to the researcher. The keywords and the number of hits per database are presented in Table 2.2.

Table 2.2 Key words used and number of hits per database

Keywords	Scopus	Google Scholar	Science direct
"Hospital" AND "Choice behaviour" AND "Outpatient"	136	265	133
"Hospital" AND "Choice behaviour" AND "Outpatient patient"	6	0	1
"Hospital" AND "Choice behaviour" AND "Outpatient" AND "Netherlands"	2	88	31
"Hospital" AND "Choice" AND "Elective Care"	7	2,020	151
"Hospital" AND "Choice behaviour" AND "Elective Patients"	1	35	4
"Hospital" AND "Choice behaviour" AND "Elective Care"	2	35	2

According to the literature review by means of the key words, mainly three types of research can be distinguished.

1. Research to whether patients choose their hospitals individually and the effect of this freedom of choice on hospitals (Birk, Gut, & Henriksen, 2011; Cruppé & Geraedts, 2017; Ringard & Hagen, 2011);
2. Research to the influence of one or multiple factors on the hospital choice of patients (Siciliani, 2005; Moscelli & al., 2016; Sivey, 2012).
3. Research to factors that influence the decision-making process of hospital choice for patients (Birk & Henriksen, 2012; Smith et al, 2018)

Category three is most relevant for this study, but literature of categories one and two are also taken into account during the review. In Table 2.3, an overview of factors that influence hospital choice for patients is presented.

Table 2.3 Search results decision-making factors

Factor	Results
Travel time	- Probability of the decision to bypass the nearest hospital for orthopaedics and neurosurgery based on waiting time and extra travel time (Varkevisser & Geest, 2006). - Determination of the importance of travel time, waiting time and quality in relation to patient characteristics for non-emergency hip replacement (Beukers, Kemp, & Marco, 2014). - Empirical research on hospital choice in UK. Short distance is the most common reason to choose a hospital, waiting time and quality are also considered as important factor (Birk & Henriksen, 2012) - Distance to hospital is one of the main factors that influence hospital choice in UK, considering among others factors as number of beds, waiting time patient safety (Smith, Currie, Chaiwuttisak, & Kyprianou, 2018) - Questionnaire study outpatient' choice of hospital. Location close to their home most important factor. GPs recommendations is second most important factor and short waiting time the third most important (Birk, Gut, & Henriksen, 2011). - Important criteria for hospital choice are personal experience of a hospital, recommendations from relatives and primary providers and distance from home (Cruppé & Geraedts, 2017).
Waiting time	- Effects of travel time and waiting time on hospital choice considering patients with cataract operations (Sivey, 2012). - Probability of the decision to bypass the nearest hospital for orthopaedics and neurosurgery based on waiting time and extra travel time (Varkevisser & Geest, 2006). - Determination of the importance of travel time, waiting time and quality considering patient characteristics for non-emergency hip replacement (Beukers, Kemp, & Marco, 2014). - Empirical research on hospital choice in UK, short distance most common reason, waiting time and quality are also considered as important factor (Birk & Henriksen, 2012). - Distance one of the main influence for hospital choice in urban/rural area in UK, considering among others number of beds, waiting time patient safety (Smith, Currie, Chaiwuttisak, & Kyprianou, 2018) - Questionnaire study outpatient' choice of hospital. Location close to their home most important factor. GPs recommendations is second most important factor and short waiting time the third most important (Birk, Gut, & Henriksen, 2011).
Quality of service	- Determination of the importance of travel time, waiting time and quality considering patient characteristics for non-emergency hip replacement (Beukers, Kemp, & Marco, 2014). - Empirical research on hospital choice in UK, short distance most common reason, waiting time and quality are also considered as important factors (Birk & Henriksen, 2012)
Availability of facilities	- Patient choice modelling. Availability of facilities is also an valuable factor, besides waiting and travel time. This includes car parking spaces, food and accommodation. (Smith H. , et al, 2018)

Factor	Results
Influence of GP	- Patients are advised by their GP. The GP makes a pre-selection for the patient (Beckert, 2017). - Patients use a mix of information sources. Recommendations of family members and friends and references of the general practitioner are the most important sources (Wiedenhöfer & Keppler, 2014). - Questionnaire study outpatient' choice of hospital. Location close to their home most important factor. GPs recommendations is second most important factor and short waiting time the third most important (Birk, Gut, & Henriksen, 2011). - Important criteria for hospital choice are personal experience of a hospital, recommendations from relatives and primary providers and distance from home (Cruppé & Geraedts, 2017).
Recommendations of family and friends	- Patients use a mix of information sources. Recommendations fo family members and friends and references of the general practitioner are the most important (Wiedenhöfer & Keppler, 2014). - Important criteria for hospital choice are personal experience of a hospital, recommendations from relatives and primary providers and distance from home (Cruppé & Geraedts, 2017).

As can be seen in the table above, there are multiple factors that influence the choice for a hospital. All factors are determined as important in at least one research of category three. The factors travel time and waiting time are the most common factors and are often used in research of category two. Furthermore, from the literature review can be concluded that GP have significant influence on the hospital choice of patients. As explained in Section 2.2, GPs are the primary healthcare providers that refer patients to a hospital. Without referral, a patient cannot receive specialised care of hospitals.
Furthermore, quality of service and recommendations of family and friends also turn out to be important for patients. Quality of service includes for example, the quality of care and the behaviour of personnel. Moreover, availability of facilities also influences the choice of hospital. However, this factor appear to be relevant for clinical patients. Besides, this study is focussed on outpatient clinics and food en accommodation are not provided for these patients. Considering these circumstances, the availability of facilities is not taken into account as factor for hospital choice.

This thesis focuses on patients with a polyclinical appointment that all visit the same hospital organisation. Therefore, not all factors are taken into account. Because one and the same hospital organisation is considered, the quality of care is assumed equal for every location, as mentioned in the scope description (see Section 1.4). Consequently, quality of care is excluded from this research. The same accounts for the factors influence of GPs and the recommendations of friends and family. Concluding, the factors that are established that influence the location choice for patients of one and the same hospital organisation, are:

- Waiting time (time between moment an appointments is made and the moment of the appointment);
- Travel time (time to travel from patients' origin to hospital location).

2.6. Patient planning optimisation

International literature for patient planning or patient allocation is merely focussed on the Emergency Department (ED) or surgery facilities. Patient scheduling is for these departments more complex than for polyclinics of specialties, because the schedule includes patients with different priorities (acute and elective care). Therefore, Min & Yi (2009) have researched a scheduling problem of patient with different priorities. Azadeh et al (2014) designed a mathematical model to minimise total waiting time for patients in laboratories of the emergency department, while considering patient conditions.

Outpatient appointment scheduling problems have gained more attention over the last years. Reason for this development can be found in the rapidly increasing healthcare expenditures, the increasing demand for healthcare services and patients' expectation of service quality (Jalali, Ahmadi-Javid, & Klassen, 2016). This can also be experienced in the Netherlands, where demand for care is growing and the expenditures for healthcare have passed 100 billion euros a year (Ministerie van Sociale Zaken en Werkgelegenheid, 2019). Notable is that research to outpatient clinics is a popular subject among Dutch theses for bachelor, master and PHD degrees. The depth of these researches differs per paper, some have only analysed the current situation and defined the bottlenecks (Reitsema, 2017; Eijndhoven, 2011). Others designed models or new systems to seek improvement (Sambeek, 2018; Andries & Van Gheluwe-Ghillymyn, 2015). For example, Rouppe van der Voort (2014) has carried out research on working without waiting list at outpatient clinics. Nevertheless, these theses focus on one or more outpatient clinics within a hospital, EOCs are not considered.

In the Netherlands, EOCs are a well-known concept. There are nowadays more EOCs than hospitals (Gijsen, Post, & Verheij, 2019). Although popularity of EOCs is growing, research on EOCs is still limited, as can be seen in Table 2.4. Most research that is carried out on outpatient clinics focusses on one specific department of a hospital and therefore only involves patients that visit that department (Froehle & Magazine, 2013; Ólafsson & Wright, 2006). This study focuses on scheduling patients of multiple specialties over several locations, to improve the performance of EOCs to increase the service for patients. Therefore, a model needs to be designed that is able to schedule polyclinical appointments for multiple specialties at multiple locations of one hospital organisation.

A literature review is carried with focus on planning optimisation models for outpatient departments concerning elective patients, to determine what is already known and what methods can be used to design a model. For this review, the same three databases are used as in Section 2.5: Scopus, Google Scholar and Science Direct. Only articles published in English and Dutch are taken into account. Table 2.4 present the keywords that are used in the search and the number of results per combination of keywords.

Table 2.4 Keywords used and hits per database

Keywords	Scopus	Google Scholar	Science direct
“Patient” AND “Planning” AND “Optimisation”	5.154	37.200	11.793
“Elective patient” AND “Planning” AND “Optimisation”	106	222	51
“Elective patient” AND “Scheduling” AND “Outpatient”	35	190	48
“Outpatient patient” AND “Planning” AND “Optimisation”	74	5	14
“Elective patient” AND “Planning” AND “Optimisation” AND “Outpatient”	7	108	32
“Elective patient” AND “Scheduling” AND “Optimisation” AND “Outpatient”	0	63	28
“Outpatient” AND “patient” AND “scheduling” AND “optimisation methods”	31	36	23
“External outpatient clinics”	0	12	5

The results of the search database gave a limited number of papers. The relevance of these papers were evaluated based on judgement of the title of the paper, the abstract and the conclusion. It can be concluded that there is no such thing as the perfect method for patient scheduling optimisation. In the literature several methods are used and each method has it shortcomings. The table below gives an interpretation of the most used methods for patient scheduling (Table 2.5).

As mentioned before, most research focuses on patient scheduling at emergency department or for surgeries. Furthermore, research is either focused on reducing waiting time for patients during consultation hours or on how to schedule patients within a certain capacity. In the literature waiting times is divided in two categories:

1. Waiting time during consultation hours (the moment of arrival until the moment of their appointment)
2. Waiting time between the moment of making an appointment until the day of the appointment.

Category 2 is taken into account for this research, since this waiting time is a factor that influence the choice of location for patients (see Section 2.5).

The model of Azadeh, Baghersad, Farahani & Zarrin (2015) has similarities with the model that is designed in this study. They designed a model to optimise the distribution of appointments over multiple locations. The objective of this model is: “To minimise the total waiting time of patients in the emergency department laboratories” (Azadeh, Baghersad, Farahani, & Zarrin, 2015). This model concerns multiple laboratories where different samples can be taken with different processing times. The similarities are: multiple locations (laboratories), different specialties (tests) and different types of appointments (processing times). However, a major difference between the model of Azadeh, Baghersad, Farahani & Zarrin (2015) and the model designed in this study, is that their model focuses on waiting times of category one. The model that is designed in this study focuses on waiting of category two. Hence, this results in different constraints and objective function.

Table 2.5 Search results for optimisation methods

Method	Results
(Discrete event) simulation	- Measures outpatient Orthopaedic clinic performance (Baril, Gascon, & Cartier, 2014). - Analysis of waiting times of category 1 in an ENT outpatient clinic (Andries & Van Gheluwe-Ghillymyn, 2015) - Analyses performance of the general surgery department and aid capacity planning decisions (Berkel & Blake, 2007) - Allocation of outpatient department facilities (Kritchanchai & Hoeur, 2018) Focus on the optimal location for an facility.
Queuing network optimisation	- Analysing and improving waiting times for Neurology (Reitsema, 2017) - Capacity allocation optimisation for multiple specialties and multiple types of patients (Deglise-Hawkinson, Helm, Huschka, Kaufman, & Van Oyen, 2018)
Linear programming	- Capacity allocation optimisation for multiple specialties and multiple types of patients (Deglise-Hawkinson, Helm, Huschka, Kaufman, & Van Oyen, 2018) - Tactical resource allocation and admission of elective patient. Multiple resources and multiple patient groups (Hulshof & al., 2011) - Evaluation of scenarios for surgery planning for cardiothoracic surgery on tactical and strategic level. Including the mix of patients. (Vissers, Adan, & Bekkers, 2005) - Maximise the level of patient satisfaction, by effective scheduling of laboratories, emergency rooms and patients in clinic (Azadeh, Hosseinabadi Farahani, Torabzadeh, & Baghersad, 2014) - Minimise total waiting time for patients in the emergency department laboratories based on the severe conditions of the patient (Azadeh, Baghersad, Farahani, & Zarrin, 2015)
Stochastic optimisation	- Scheduling of patients with different priorities for elective surgery at surgical facility with limited capacity (Yih & Min, 2009). - Optimisation of surgery schedule of elective patients. Uncertain surgery durations and availability of downstream resources are considered (Min & Yih, 2010). - Comparison of optimisation methods for elective surgery planning given a capacity for operating rooms for emergency and elective surgery (Lamiri, Grimaud, & Xie, 2009)
Monte Carlo simulation	- Comparison of optimisation methods for elective surgery planning given a capacity for operating rooms for emergency and elective surgery (Lamiri, Grimaud, & Xie, 2009)
Appointment scheduling optimisation	- Reduction of large waiting times at outpatient clinic of Oululu hospital (Strahl, 2015) - Minimising the hospital explicit and implicit cost and maximise patients satisfaction (Lee, Ng, & Cheng, 2018)

Based on the literature review, the most common methods for scheduling problems in hospitals are discrete event simulation and linear programming (LP). Each research focuses on a different aspect of this study. Discrete event simulation is mainly used in research that evaluate the performances of a department or hospital. LP is also used for allocation of patients and resources. The model that is designed in this study focuses on multiple decision-making factors leading to a complex objective function. The model considers multiple locations to allocate patients of multiple specialties. Therefore, the model has to cope with a large database when the model is implemented for Franciscus. Both models are capable for the design of such a model (Caro & Möller, 2016; Analytics Vidhya, 2017). However, discrete event simulation is initially designed for industrial systems, with actual physical structures. On the contrary, Linear Programming is often used in scheduling or planning of people. Furthermore, Linear Programming is a very suitable method to perform sensitivity analysis with, as LP is rather quick solver. Sensitivity analysis are used to analyse the sensitivity of models towards parameter fluctuation. The model that is designed in this study contain multiple estimated parameters, therefore sensitivity analysis is necessary. The biggest advantage of discrete even simulation in comparison to LP is that it can involve non-linear variables and constraints (Caro & Möller, 2016; Analytics Vidhya, 2017).

Considering the models in previous research, the comparison of properties of the methods and the research problem and objective of this study, LP appear to be the most suitable method for the design of the model.

2.7. Key Performance Indicators

Hospitals measure and evaluate their performances to evaluate their current state of performance and the determine what need to be improved to increase their performance (Grigoroudis, Orfanoudaki, & Zopounidis, 2012). If a hospital does not measure its current performance, it cannot optimise its performance, because it does not have complete knowledge of the bottlenecks (Harvey & al., 2016).

A common method to measure performances of hospitals is with Key Performance Indicators (KPIs) (Lugtenberg & Westert, 2007). KPIs could be either quantitative or qualitative indicators and can benefit healthcare practice in many ways (Amor & Ghannouchi, 2017). They can help to increase development and management of hospitals (Lloyd, et al., 2017). KPIs are often used in healthcare or hospitals in general (Rahimi & al., 2018; Rahman, Tumpa, Ali, & Paul, 2018). Furthermore, KPIs are also used for specific departments. For example, the performance of emergency departments (Amor & Ghannouchi, 2017; Núñez, Neriz, Mateo, Ramis, & Ramaprasad, 2018).

Therefore, KPIs are also an useful method to measure current performance of EOCs in this study. Moreover, KPIs can be used to see how the reallocation of patients influences the performance of the EOCs. Besides, KPIs are also used to measure the quality of service for patients in hospitals (Nijkamp, 2004). The outcomes of the KPIs could create the opportunity for the manager of EOCs to start a conversation with key players that influence the performance of EOC locations (Berler, Pavlopoulos, & Koutsouris, 2005). These key players are stakeholders with power and interest in EOCs, this is further elaborated in Section 3.2. The KPIs can also be used to compare the current state of performance with performance of scenarios in which measures are implemented, to evaluate the effects of these measures.

As mentioned in Section 1.3, the objective of this thesis is to find measures that improve the performance of EOCs of Franciscus to increase the service for patients. Therefore, the KPIs that are used for this study measure the service for patients. These KPIs are determined from a literature review of research that focus on the patient satisfaction (Amor & Ghannouchi, 2017; Núñez, Neriz, Mateo, Ramis, & Ramaprasad, 2018; Khalifa & Khalid, 2015). Moreover, the KPIs are chosen with focus on the Franciscus situation and the factors determined in Section 2.5. In this study, the following KPIs are used:

- Average travel time per patient;
- Average waiting time per patient;
- Average cost per consult.

The main focus of this study is on the service for patients. However, the aim is to increase this service by improving the performance of the EOCs. Therefore, it is useful to also measure the latter with indicators. These indicators create the opportunity to analyse the effect of suggested measures on performance of EOCs in comparison to the current state of the EOCs. The following indicators that are used (Khalifa & Khalid, 2015; Bamford & Chatziaslan, 2009; Rahimi & al., 2018):

- Patient flow per location;
- Supply per location;
- Utilisation rate of EOCs.

2.8. Conclusion

In this chapter, the explorative phase is carried out. In this phase, answers are provided for the first two sub-questions, which is done by means of a literature study. It should be noted that the articles and journals included in this literature study are based on the researcher's judgement.

Sections 2.1, 2.2 and 2.3 provide an answer for the first sub-question:

What role do external outpatient clinics play within the Dutch healthcare system and Franciscus and how do they contribute to the service for patients?

EOCs provide healthcare on secondary and tertiary healthcare level. Hence, these clinics are set up by hospitals to provide specialised healthcare closer to the patient. Initially, EOCs were used to attract more patients and to extend the hospitals care areas. Due to the "hoofdlijnenakkoord" of the government in 2012, the growth of the hospitals has been decelerated. Nowadays, EOCs are merely used to provide service for the patients. The clinics contribute to the current developments in healthcare as the initiative of "the right care at the right place". Furthermore, EOCs help to improve transmural care, as they often have close contact with primary healthcare providers as GPs and physiotherapists. For this reason, EOCs play an important role improving service for patients by making healthcare accessible for everyone.

Franciscus has set up EOCs to provide healthcare closer to patients' homes. Moreover, due to closure of another hospital an opportunity was seized to increase patient flow at Franciscus. Furthermore, the EOCs are used to release pressure from the main locations: Gasthuis and Vlietland.

The second sub-question is answered by Section 2.5, the question is as follows:

Which factors influence the decision for patients in the care area of Franciscus when choosing the location to receive elective care?

A literature review is carried to determine factors that influence hospital choice for elective care patients. From the review can be concluded that multiple factors influence the decision-making process of patients. These factors are:

- Travel time to hospital;
- Waiting time between scheduling of appointment and the moment of the appointment;
- Quality of care for patients;
- Availability of facilities;
- Influence of GPs;
- Recommendations of family and friends.

However, not all factors are taken into account for this study. This is due to the focus of this study on one hospital organisation. Therefore, it is assumed that the quality of care is equal for every location. Furthermore, the availability of facilities is only relevant for clinical patients, this study focus on policlinical patients. Lastly, the influence of GPs and the recommendations of family and friends are not taken into account, because the patients considered in this study go to one and the same hospital. Therefore, the factors that influence the decision for patient of Franciscus when choosing a location are: The travel time to a hospital location and the waiting time between the moment that an appointment is scheduled and the moment of the appointment.

This exploratory phase provide background information on the existence of EOCs. Furthermore, in this phase a theoretical base is created for the current state analysis and the design of the model. For example, KPIs are determined to measure service for patients and the performance of EOCs in Chapters 3 and 5. Subsequently, a literature review is conducted to previous research on planning optimisation of models to determine what has already been designed and what methods are used to design the model. This information is used for the design phase in Chapter 4.

3. Current state analysis

In this chapter the analytical phase is carried out, see Figure 3.1. In this phase, the current state of Franciscus is analysed. As mentioned in Section 1.2, since the establishment of her EOCs, Franciscus has not yet analysed the performance of EOCs in detail. Nevertheless, she expects that there is a lack of performance. Therefore, the current performance of her EOCs and service for patients are measured by the KPIs and indicators established in the exploratory phase. Furthermore, bottlenecks are determined that cause lack of performance of the EOCs. With this analysis, the answer is provided for sub-question 3. The knowledge obtained in this chapter is used for the design of the planning optimisation model in the design phase.

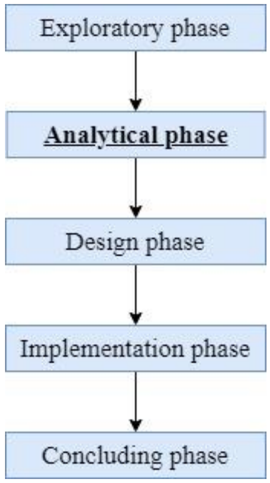

Figure 3.1 Analytical phase of this study

In this analysis, three main components are discussed: the stakeholders, the process and the data. First, a short introduction is given to explain the current situation of the EOCs, then the stakeholders are discussed. Subsequently, the process is explained by means of the customer journey for a patient that visits an EOC and waste is determined. Lastly, a data analysis is performed. With data obtained in this analysis, KPIs are calculated for the current situation.

3.1. Introduction

In general, all EOCs are organised in the same way. Firstly, consultation hours are planned per specialty and this planning is based on the availability of the medical specialists. The planning is put in the EHR (Electronic Health Record) of the hospital, named HIX. Secondly, the coordinator checks the planning of each specialty in HIX. Based on this planning, the coordinator schedules the rooms and supporting staff, like doctor's assistants and service desk employees, for the EOC location. Thirdly, the consultation hours are filled with appointments.

As mentioned in Section 1.4, patients visit EOCs for first and repeat consults. Furthermore, phone consults are also carried out at these locations. Besides these consults during consultation hours, patients can also visit an EOC for other hospital related activities, such as blood samples or X-rays. A prescheduled appointments is not required for these activities. Therefore, patients can visit the clinic without an appointment and are treated directly. Blood samples can be given at the EOCs Berkel and Maassluis and X-rays can be taken at Berkel and Hoogvliet (Korthorst & Stelt, 2019).

Even though the EOCs are organised in the same way, there are some organisational differences between them. One of these differences is the way appointments are scheduled for patients. For EOCs Maassluis and Hoogvliet, appointments for almost every specialty (except for general surgery) are scheduled by the central coordinated call centre. This centre is located at Franciscus Vlietland and makes appointments for Vlietland, Maassluis and Hoogvliet. For appointments at EOC Berkel, patients need to call the outpatient clinic of the concerned specialty at Franciscus Gasthuis. The call centre in Vlietland is not allowed to make appointments for Berkel and Gasthuis. The same accounts for the outpatient clinics in Gasthuis, they only schedule appointments for Gasthuis and Berkel, not for Vlietland, Maassluis or Hoogvliet.

Another difference is found in the way supporting staff is arranged. In Maassluis, each specialty has an doctor's assistant, however in Berkel and Hoogvliet only the specialties with preparatory procedures are assisted by a doctor's assistant. This difference can be explained by the lack of space of the EOCs Berkel and Hoogvliet. In Maassluis there are enough rooms for doctor's assistants, where there are barely rooms for doctor's assistants at Berkel and Hoogvliet.

3.2. Stakeholders

As the healthcare sector is a complex system with multiple involved parties, a stakeholder analysis is performed. The following definition is used for stakeholder:

"Any person, social entity or organisation able to act on or expert influence on a decision"

Enserink, et al., 2010

Appendix B, all involved stakeholders are described. Subsequently, these stakeholders are placed in a power-interest grid. This grid is created to gain understanding of the involvement and influence of stakeholders on the EOCs This stakeholder analysis determines relevant stakeholders that should be considered in the decision-making process of the performance of the EOCs. Lastly, interviews are held with several of these stakeholders, to gather information about their attitude to the EOCs.

3.2.1. Power-interest grid

The power-interest grid is set up in consult with the manager of Transmural care. Power is defined by: The influence a stakeholder has on decisions related to the performance of EOC. Interest is defined by: The interest a stakeholder has in good performance of EOCs. This grid categorises stakeholders in four groups: crowd, subjects, context setters and key players. Per group, the power and interests of the stakeholders are explained. The power-interest grid is presented in Figure 3.2.

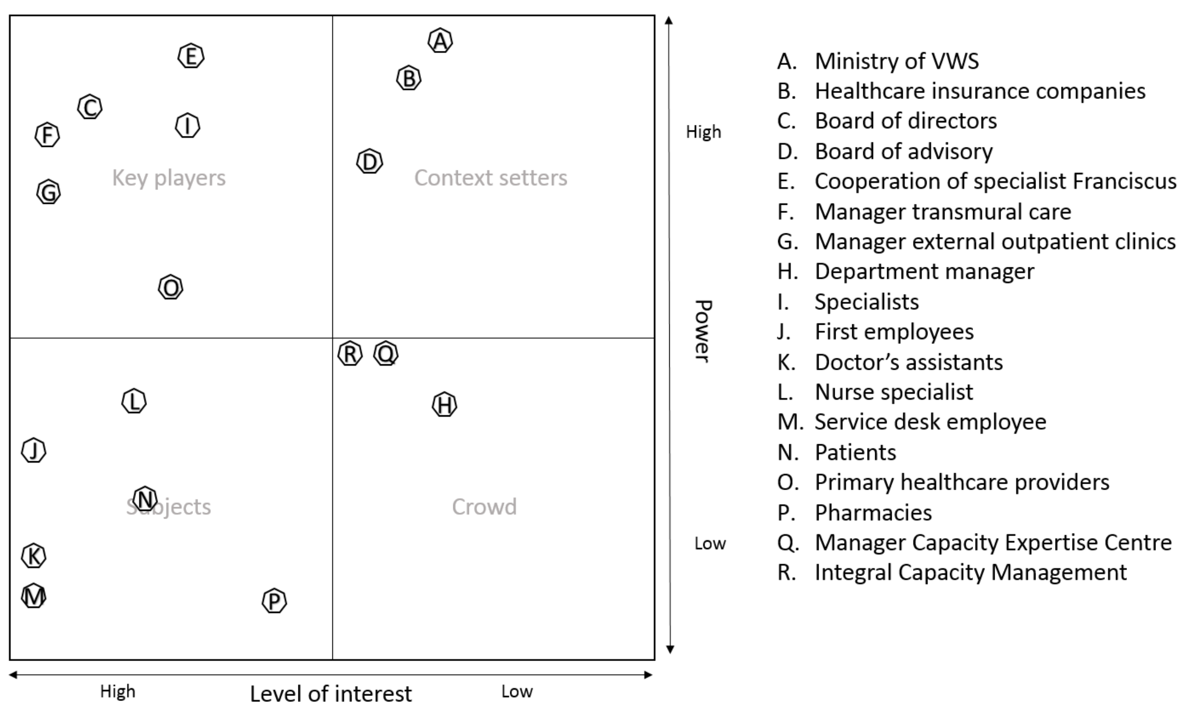

Figure 3.2 Power-interest grid of involved stakeholders

The crowd

This group involves stakeholders with low interest and low authority concerning the EOCs. The crowd is represented in right bottom, see Figure 3.2. The manager Capacity Expertise Centre (CEC), The Integral Capacity Management (ICM) and department managers do not have much power and little interest in the EOCs. The manager CEC and ICM only advice the Manager transmural care and board of directors about the use of capacity of EOCs. However, the EOCs are not a priority for these departments at this moment, therefore they have little interest. The department managers are mainly focussed on their own outpatient clinics at the main locations Gasthuis and Vlietland.

The subjects

These are stakeholders with a lot of interest but little power (lower left quadrant in Figure 3.2). They would benefit from better performance of the EOCs, but are dependent on others. If the performance of the EOC increases, there is more work for the first employees, doctor's assistants, nurse specialists and service desk employees. With better performance of the EOC the service for patients increases, for example a decrease in waiting time. Lastly, pharmacies would receive more customers due to the increasing number of patients.

The context setters

This group of stakeholders has little interest, but significant power considering the EOCs. These stakeholders are mostly external parties, like the Ministry of VWS and the insurance companies. These stakeholders do not actively participate to make the EOCs more efficient, but have influence on the decision-making for the performance of the EOCs. The EOCs have to function conform the laws and rules of the government. Furthermore, patients mostly choose hospitals that are included in their insurance, therefore the insurance companies have power over Franciscus. Lastly, the board of advisory checks the board of directors and can have influence on the decisions that are made by the board regarding the EOCs. Since the board of advisory has an advisory role, their interest lies in all the issues the board of directors addresses.

The key players

These are the most important stakeholders and are presented in the upper right quadrant in Figure 3.2. These parties are actively involved in the organisation of the EOCs and have influence on decisions considering the performance of EOCs. Moreover, they have influence on the decisions that are made based on the outcomes of this study. The key players are: Manager transmural care and EOCs, Manager EOCs, Board of directors, cooperation of specialists Franciscus, specialists and primary healthcare providers.

The manager transmural care and EOCs decides what will be done to improve the performance of the EOCs and creates the implementation plan together with the manager of the EOCs. The manager EOC is responsible for the execution of this implementation plan. Furthermore, the board of directors has more power and needs to grant permission for these plans. The board also has a higher interest, because better performance of the EOCs could increase the patient flow at these locations. This could cause an decrease of pressure on the main location. The cooperation of specialists Franciscus have the highest power at Franciscus. The board of this cooperation meets with the board of directors of Franciscus to decide on the organisation of specialists for the hospital. Subsequently, the specialist also have much power, since they schedule the location and time of their consultation hours themselves. The implementation of the EOC locations are based on the availability of the specialists. Furthermore, specialists have interest in this project because the changes can influence their schedules. Lastly, the primary healthcare providers have power because they decide, in consultation with their patients, where the patient is referred to. There is a great chance that patients go to the referred hospital, therefore the primary healthcare provides have a lot of influence. Besides, they have interest in EOCs because these locations provide secondary healthcare near their practises, this is convenient for both providers and patients.

3.2.2. Interviews

To gather insight in the attitude towards EOCs, several stakeholders are interviewed. These is done by structured or semi-structured interviews. The stakeholders that are interviewed are the following:

- Manager Transmural Care and EOCs
- Manager EOCs
- Specialists
- Call centre coordinator
- Doctor's assistants and laboratories at Berkel and Maassluis
- Service desk employee at Maassluis
- Manager CEC.
- First employee EOC Berkel
- Department manager

The questions asked to the specialists and first employee are represented in Appendix C, as well as several questions that are asked to the coordinator of the call centre. Furthermore, some interviews are elaborated in Appendix C. Based on the conversations with multiple stakeholders the following conclusion have been drawn:

- The policlinics at the main locations consider the EOCs as less relevant than the main locations. The doctor's assistants often do not know how the EOCs are really organised and patients are mostly scheduled at the main locations. Furthermore, there is a lack of communication between policlinics at the main locations and the EOCs. For example, communication regarding specialist schedules and cancellations.
- Overall, specialists have a positive opinion regarding the EOCs. They like to have consultation hours once or several times a week, due to the informal and relaxed atmosphere at the EOC locations. Nevertheless, the main locations have priority and consultation hours are cancelled at the EOCs in case the presence of the specialist is required at the main location. Reasons for cancellation are for example, less availability of specialists during holidays or suddenly available time at the operation rooms, because surgery has priority over consultation hours. Specialists officially have to cancel six weeks in advance, but sometimes cancellation is done only a few weeks in advantage.
- The appointment system does not perform perfectly. Appointments can be made via the call centre in Vlietland, via polyclinics of specialty in Gasthuis or via the EOCs. The call centre in Vlietland experiences trouble in communication with the polyclinics at Gasthuis, since their call is not always answered. Also, at Vlietland the call centre is not allowed to make appointments for every specialty. Due to this restriction at the call centre, patients have to call the outpatient clinic for appointments instead of the call centre. This causes difficulties, since patients are not always aware of this restriction and contact the call centre for an appointment. Then, the employees at the call centre have to disappoint patients and refer to the specific outpatient clinic of that specialty, which causes a lack of service for patients. Furthermore, the call centre system is not optimally used, because patients are not scheduled based on their origins and the call centre does not consider every Franciscus location when scheduling an appointment.

3.3. Customer Journey

The customer journey of patients visiting an EOC is visualised to determine bottlenecks. This journey represents all activities that are carried out by the hospital and the patient when a patient visits an EOC. All registrations and proceedings are considered. The journey is divided in four phase, the total process is displayed in Appendix D. At first, the steps are explained. Subsequently, the waste that is encountered during the journey, is defined.

1. Referral and scheduling an appointment. As shown in Figure 3.3, the journey starts when a patient with a health complaint visits a primary healthcare provider, generally the GP. If a GP decides specialised medical care is needed, the patient gets referred to the hospital. This reference letter is written and printed on paper or is send digitally via ZorgDomein. The next step in the journey depends on the way a patient is referred. In case the patient has a printed reference letter, one needs to call Franciscus to schedule an appointment. If the referral is send via ZorgDomein, the patient receives a call from Franciscus to schedule an appointment. After the first appointment is scheduled, a care path is opened for that patient. This is called a DTC (diagnosis treatment combination). In a DTC all activities (for example diagnosis, treatments and check-ups) of a patient are documented. These DTCs are closed when the patient is finished with the treatment and costs are declared at insurance companies (Zorgwijzer, 2019).

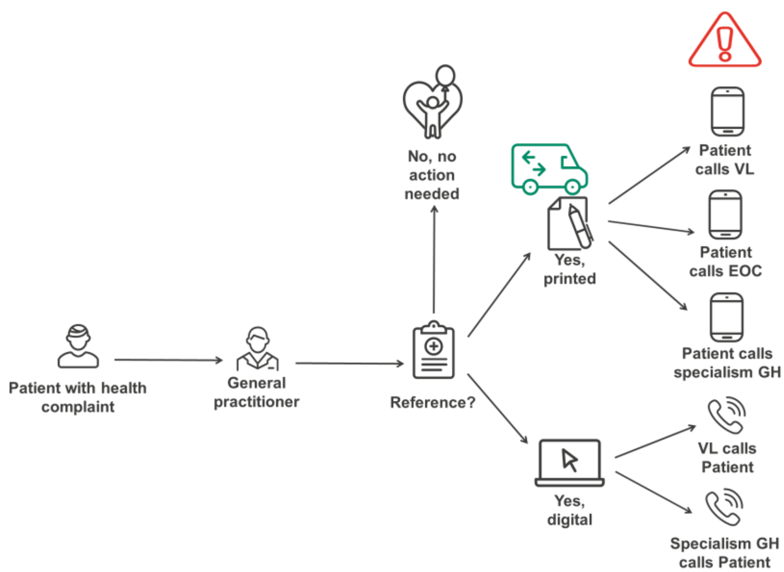

Figure 3.3 Referral and appointment scheduling

2. Pre-appointment phase (Figure 3.4). If a patient calls or gets called by Franciscus. an appointment is scheduled and the patient waits till the day of the scheduled appointment. In the time between an appointment is scheduled and the appointment itself, the schedule of consultation hours can change. This is, for example, caused by cancellation of that consultation hour. Then, the appointment needs to be rescheduled. However, it sometimes occurs that a patient is not informed about these changes beforehand, which results in the presence of a patient at the EOC at the wrong date and time. In this case, the appointment still needs to be rescheduled and the patient leaves the EOC without receiving any care. If there are no adjustments, the patients travels to the agreed Franciscus location for the appointment on the day of the appointment.

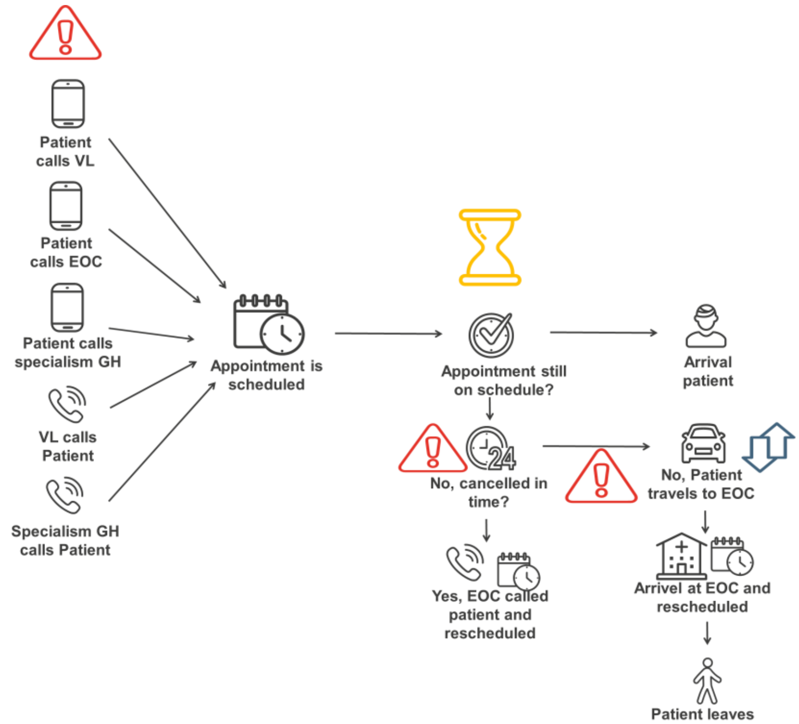

Figure 3.4 Pre-appointment phase

3. The arrival phase (Figure 3.5). After arriving at the location, the patient has to check-in at the desk and is announced in the system. In case the patient has been to Franciscus before, the patients' information is known and only name and birth data are checked. If the patient has not been to Franciscus before, all information in the system is checked and added where necessary. Afterwards, the patient is checked in. When a patient is visiting the EOC without a reference letter or no appointment, one is sent away. Then, it is possible for that patient to schedule an appointment for another day in case the person has a reference letter.

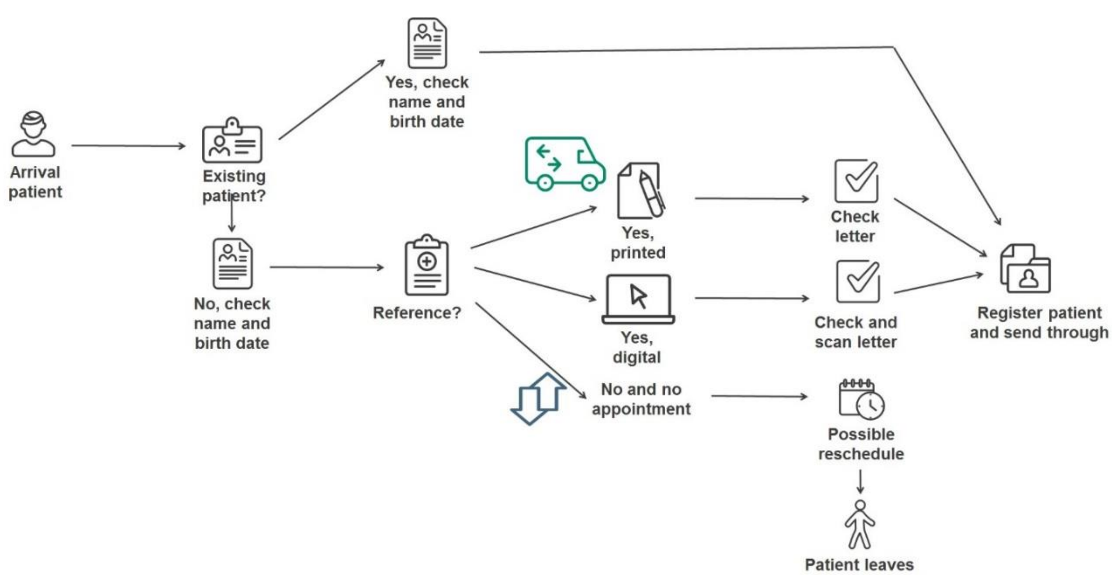

Figure 3.5 Arrival phase

4. The appointment phase (Figure 3.6). When the patient is checked in, the patient is seated in the waiting room, where it waits until the specialist or nurse doctor's assistant calls for the patient. The patient then receives the required care and is send back to the service desk if a follow up is needed. Otherwise, the patient just leaves the location.

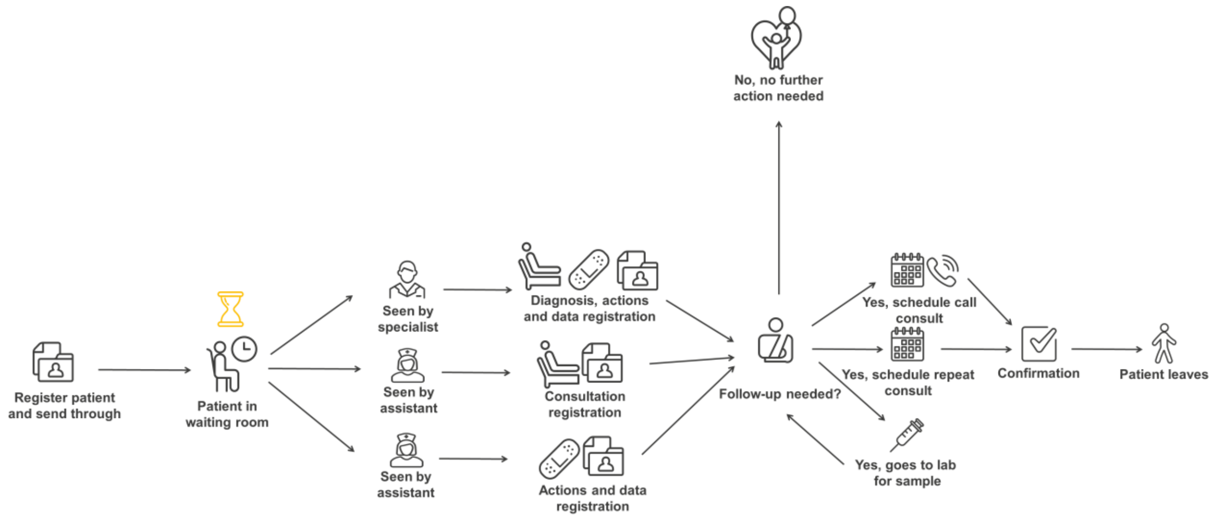

Figure 3.6 The appointment phase

3.3.1. Waste

To define the bottlenecks, several types of waste are determined: Defects, transportation, motion and waiting time. Defects are all errors in products or services, transportation is unnecessary movements of products, motion is unnecessary movement of people and waiting time is every moment of stagnation. The places where waste occurs in the customer journey are displayed with symbols, as can be seen in the figures above. The determined waste is explained in the following paragraphs.

3.3.1.1. Defect

The biggest defect is caused by the appointment system (see Figure 3.4). There are five ways to make an appointment, which depends on the location preference of the patient and the way of referral. In case the letter is printed, the patient has to call the hospital. When a patient prefers to go to Vlietland, Maassluis or Hoogvliet, the call centre of Vlietland has to be called. The call centre is only allowed to make appointments for these three locations. As a consequence, a patient that prefers to go to Gasthuis or Berkel needs to contact the polyclinic of the concerning specialty. This is due to the fact that each specialty makes its own appointments. A third option is to call an EOC location, in case the patient wants to go to Maassluis, Berkel or Hoogvliet.

If a patient is referred digitally, Franciscus receives this referral directly. After receiving the reference letter, Franciscus is obligated to wait a few days. This gives the patient the opportunity to call him or herself for an appointment. If this does not happen, Franciscus calls the patient. The digital referral includes a specific Franciscus location. If the location is Vlietland, Maassluis or Hoogvliet, the call centre of Vlietland contacts the patient. In case the letter refers to Gasthuis or Berkel, the doctor's assistant of the specialty contacts the patient. Inconvenience is caused in the service for the patient, because there are several ways in which an appointment can be made.

Furthermore, this causes an error for the patient planning process, since not every Franciscus location is include when an appointment for a patient is scheduled.

Another defect occurs when a consultation hour is cancelled (see Figure 3.4). If a consultation hour is cancelled, all patients scheduled in that hour need to be contacted to inform them and to reschedule the appointments. Furthermore, in case a patient is not cancelled in time, the appointment is rescheduled after the patient arrives at the location. Both these situations are causing a lot of inconvenience for patients, which is an error in the service to patients.

3.3.1.2. Transportation

As already mentioned in the previous Section, there are two ways to refer, printed or digital. A printed referral causes transportation waste two times during the customer journey. Firstly, when the GP hands the printed letter to the patient (see Figure 3.3). Secondly, when the patient brings the reference letter to the appointment (see Figure 3.5). The printed version is causing unnecessary transportation, because digital referral does not include any transportation.

3.3.1.3. Motion

This kind of waste appears two times in the process (see Figure 3.4). It happens when a patient is not contacted in time when a consultation hour is cancelled. That person then travels unnecessary to one of the hospital location and the patient needs to travel back after rescheduling. The second motion waste occurs when a patient travels to the EOC without an appointment and/or without a reference letter. It that case, the patient needs to make an appointment for another day and after he or she has received a reference letter from a primary healthcare provider.

3.3.1.4. Waiting time

Two types of waiting time occur in this journey.
The most important type of waiting time is the waiting time between the moment of scheduling an appointment and the moment of the appointment (see Figure 3.4). The amount of waiting time differs per patient, however it is always multiple days.
The other kind of waiting time is waiting time on location (see Figure 3.6). After the patient is checked in at the EOC, one is referred to the waiting room and has to wait until the doctor's assistant or the specialist is ready to see the patient. Waiting time occurs when a patient arrives to early or when a delay has occurred during the consultation hour.

3.3.2. Conclusion

Thus, there are two events that cause the most waste in the customer journey for the patient. The first event is the appointment system of Franciscus that causes a defect. There are many ways a patient can make an appointment. This causes a chaotic and unclear system for both patients and employees of Franciscus. Moreover, this system makes it difficult to schedule the patient at the right location, since not every location is considered when an appointment is scheduled. The second event is the waiting time between the moment an appointment is scheduled and the moment of appointment. Both events are causing inconveniences for the patient and therefore a lack in service for the patients.

3.4. Data

The data of 2018 is analysed and used to calculate the KPIs for the current state of Franciscus. With this analysis, the current performance of the EOCs and the service for patients are determined. First, a short introduction is given explaining the data preparation. Then, the performance of the EOCs are calculated based on the supply and demand of the locations. Lastly, the service for patients is measured by the KPIs as determined in Section 2.7. This data analysis is carried out to determine whether there is a lack of performance caused by the bottlenecks established in Sections 3.2 and 3.3.

3.4.1. Introduction

The data analysis is conducted with data received from the business intelligence department of Franciscus. Before the data analysis is carried out, the data has been prepared and limited to the necessary data for this research. A short summary:

- The data analysis is executed for the year 2018, because this is the most recent completed year. 2019 is not taken into account, due to the fact that the data is not complete for the whole year. Therefore, the data is not comparable over years and between months.
- All Franciscus locations are considered, including the EOC Hoogvliet.
- This data analysis only includes specialties that offer consultation hours at minimal three out of seven locations. This ensures that a specialty offers consultation hours on at least one a external Franciscus location. Not all specialties can be offered at every location due to the lack of resources.
- There are several types of consults during a consultation hour of an outpatient clinic. The three main consults are included for this research: First, repeat and call consults.
- On every location there are general rooms, these are used for consultation hours of different specialties. Furthermore, there are other rooms that can only be used for specific treatments or activities, like X-rays and small surgeries. Because this research focusses on consultation hours provided by the specialist, only the general rooms are taken into consideration.
- The patients that are taken into account for this data analysis are originated from within the care area. This includes 95% of the total patients per year.
- The data is presented in hours, consultation hours consist of three and a half hours.

3.4.2. Supply

Supply of Franciscus is defined by the total number of consultation hours for all specialties in 2018. In total, Franciscus has held 2898 consultation hours in 2018. The circle diagram in Figure 3.7 shows the distribution of consultation hours over the locations in percentages. A large part of the consultation hour is provided at the main location, Gasthuis even holds 49% of the share. Only a minor share (12%) of the consultation hours is offered at the other locations. The EOCs Berkel and Maassluis both have had only 3% of the consultation hours in 2018.

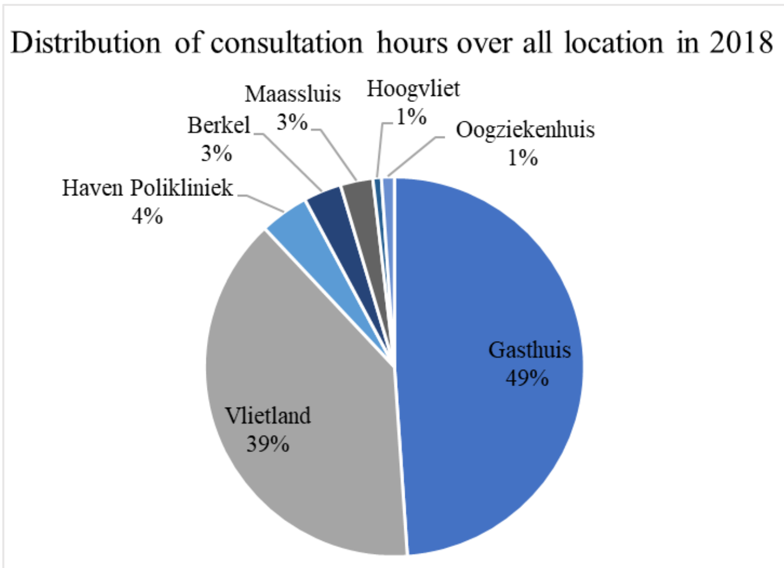

Figure 3.7 Supply per location in percentage in 2018

Subsequently, the supply is analysed in further detail. Per specialty, the distribution of consultation hours over all Franciscus locations is determined. Figure 3.8 shows the distribution for Dermatology and General Surgery. Circle diagrams for the other 13 specialties are presented in Appendix E.

For all specialties, the contribution of consultation hours at external locations is limited. Moreover, some specialties only have held under 5% of its consultation hours at external locations. For example, General Surgery, Neurology and Pulmonary Medicine. Other specialties have had more consultation hours at external locations, but all less than 25%. Haven Polikliniek has the largest share of consultation hours, followed by EOC Berkel. For Haven Polikliniek, Franciscus has clear agreements regarding consultation hours. Such agreements are not arranged for the EOC locations. At EOC Berkel, Cardiology has held the most consultation hours, followed by Dermatology and ENT. General surgery is in general focussed on the main locations and have held less than 2% of its consultation hours at EOCs. Notable is that Neurology has held few consultation hours at Berkel, meanwhile it has held relatively many consultation hours in Hoogvliet and Maassluis. Equally to Berkel, Maassluis have had a lot of consultation hours of Cardiology, Dermatology and ENT and only few of general surgery and geriatrics. Worth mentioning is that Rheumatology has had the most hours of all the specialties in Maassluis and Urology has barely been in Maassluis. The consultation hours at EOC Berkel are spread over several specialties. Om the contrary, at EOC Maassluis, there are a couple of specialties (Ophthalmology, Dermatology, ENT) responsible for a large share of the consultation hours, where the other specialties have held little consultation hours in Maassluis.

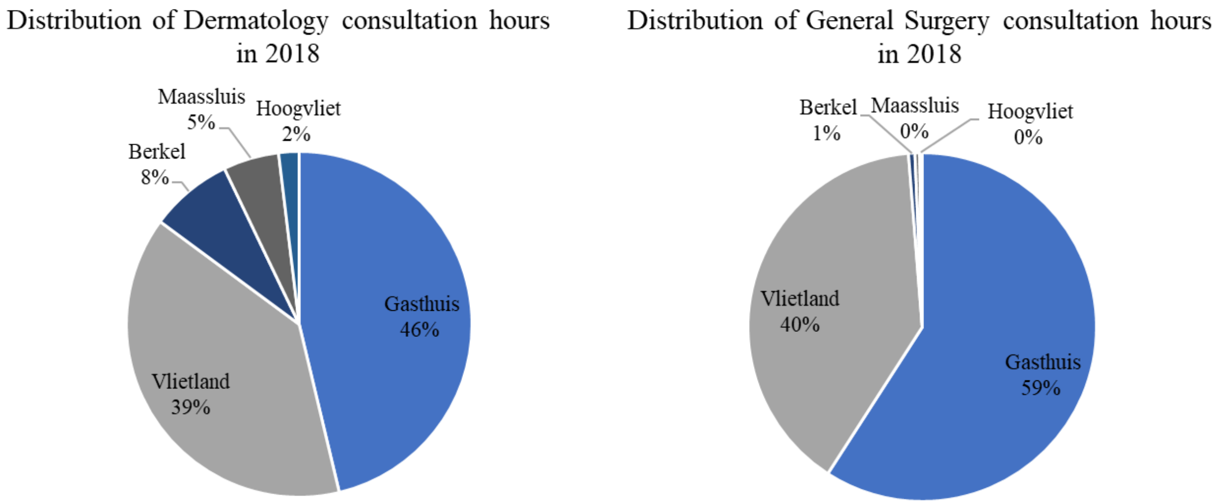

Figure 3.8 The distribution of supply of Dermatology and General Surgery

Furthermore, the supply is analysed for every location over the months in 2018, the figures are represented in Appendix E. All locations show approximately the same pattern over the year. Though, for Oogziekenhuis and Hoogvliet this pattern is minimal, due to the few consultation hours it has had in 2018. The consultation hours decrease in February, due to holidays. There is also a clear decrease of consultation hours in the summer months June, July, August and September. Notable is the drop in August in Berkel, this can be explained by the summer vacation. Specialists that normally have consultation hours at the EOC Berkel are rescheduled to Gasthuis or Vlietland, because the main locations always need to be manned,. In October and November the number of consultation hours increase, these are the months with the most consultation hours. In December the number decreases again, due to Christmas holidays.

3.4.2.1. Utilisation

For the current state analysis two types of utilisation are calculated. The utilisation rate of planned consultation hours and the utilisation rate of EOC locations.

Figure 3.9 represent the utilisation of planned consultation hours per specialty in Berkel. The figures for the other locations are presented in Appendix E. This utilisation is defined by the realised consultation hours divided by the number of consultation hours that are planned beforehand. Consultation hours are planned six weeks in advance, however the scheduled consultation hours are not always realised. This is due to cancellation or lack of patients.
Some specialties have a utilisation of over 100%, this can be explained by overtime. If a consultation hour is delayed, it will last longer than the scheduled time. Notable is that urology has value higher than 100% for all locations and scores even 145% at Gasthuis. The reason for this appearance is unclear. At the EOCs the values are approximately 80% or higher, except from Orthopaedics and Paediatrics. Paediatrics is a specialty that in general schedules more consultation hours than it realises, therefore it has one of the lowest utilisation rates at every location. The scheduled consultation hours are the most reliable at EOC Maassluis, all utilisation rates are between 80% and 100%. However, there is a low utilisation rate for paediatrics, this can be explained by the limited number of patient during the consultation hours at Maassluis.

Overall, the utilisation rates are higher at the EOCs Berkel and Maassluis than at Gasthuis and Vlietland. One reason could be that the specialists do not have a phone at the EOC, therefore they are less interrupted during their consultation hour. At the main locations, specialists get often called away for emergency situations or surgeries. This causes a delay during the consultation hour or even lead to cancellation of appointments. The EOCs only offers polyclinical appointments, so such interruptions do not occur at these locations.

A second reason can be that consultation hours need to be scheduled more precisely than consultation hours at the main location. This is due to the limited consultation hours a specialist has at an EOC location and the fact that it is an external location. The scores for specialties operating at the Haven polikliniek and Oogziekenhuis are relatively low in comparison to Berkel and Maassluis. However, the utilisation rates are still higher than at the main locations.

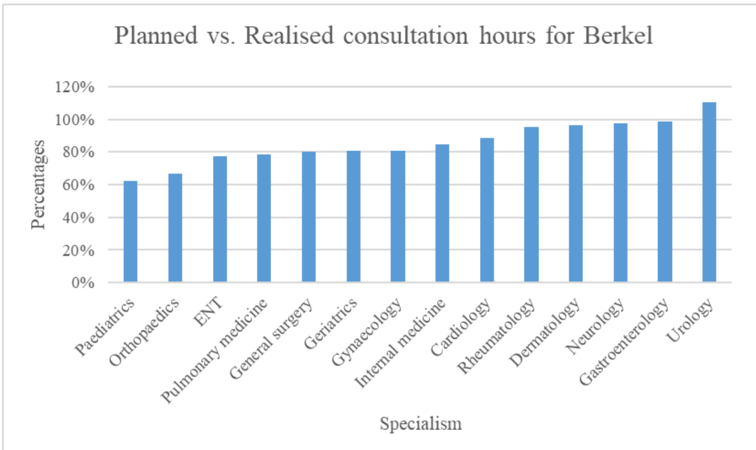

Figure 3.9 Utilisation of consultation hours in Berkel

The utilisation rate of EOCs is considered as one of the performance indicators for this study and is calculated by the following formula (Economie lokaal, 2019):

$$U = \frac{\text{realised consultation hours}}{\text{capacity consulation hours}} \times 100\%$$

The capacity per location is determined by the number of rooms and the opening hours of a location. In 2018, all EOCs were open for five days a week. Berkel has 8 rooms, Maassluis 7 rooms and Hoogvliet 2 rooms. Consultation hours have an average duration of 3,5 hours and are held twice a day. Because the duration of consultation hours differs per specialty per day, an overall average is calculated and used to calculate the capacity of consultation hours per location. The utilisation rate is calculated based on 12 months a year, because the EOC are always opened except for national holidays (Nisroe, 2019). The table below (Table 3.1) represents the utilisation of each EOC and the average overall utilisation of the EOC locations. Furthermore, the average utilisation rate of all Franciscus location are also calculated. In Gasthuis and Vlietland each specialty has several rooms for its own and the number of rooms differs per specialty. Therefore, to calculate the average utilisation rate of these locations, an average number of rooms is considered for each specialty. This is determined at 4 rooms per specialty. Haven Polikliniek has 4 rooms and Oogziekenhuis has 2 rooms. Subsequently, the current utilisation rates of the locations are compared to the ideal utilisation. The ideal utilisation is based on the situation wherein all patients of 2018 were seen at the location that is closest to their homes. This situation is used, since travel time is one of the factors that defines the service for patients. By comparing these utilisation rates, it can be determined that there is a lack of performance at the EOC locations. All EOC locations should have offered at least three times the current number of consultation hours to offer the best service for patients. Furthermore, the total average utilisation rate can also largely be increased by an increase in consultation hours at the EOC locations.

Table 3.1 Utilisation rate of the EOC locations

Location	Ideal utilisation	Current utilisation
Franciscus Berkel	71.2%	22.4%
Franciscus Maassluis	90.7%	21.3%
Franciscus Hoogvliet	98.9%	20.7%
Average EOCs	87.3%	21.4%
Total average Franciscus	83.3%	33.4%

3.4.3. Demand

Demand is defined by the patient flow of Franciscus. Based on the patients per location, the cost per consults can be calculated for every location.

3.4.3.1. Patient flow per location

The patients flow is defined by the number of appointments per location for 2018. Table 3.2 presents the number of appointments per location and the total number of patients that have visited Franciscus in 2018. Gasthuis received the most patients, followed by Vlietland (87% of the total patients). Berkel, Maassluis and Hoogvliet are only responsible for a small share (8%) of the total number of appointments.

Table 3.2 Patient visits per location in 2018

Location	Appointments in 2018 (#)
Franciscus Berkel	18,519
Franciscus Gasthuis	235,456
Haven Polikliniek	23,860
Franciscus Hoogvliet	3,966
Franciscus Maassluis	15,994
Oogziekenhuis, Rotterdam	4,638
Franciscus Vlietland	198,263
Total	500,969
Average/month	41,725

shows the top 5 origins of patients that visited the Franciscus locations. The top five of each Franciscus location lies within 13 cities. For each location, the total number of appointments are presented. Per origin in the top 5 of that Franciscus locations, a percentage is given that represents the share of appointments.

Notable is that patients from Vlaardingen and Schiedam are in the top five of 5 out of 7 locations, these patients apparently do not mind to travel to their location and most likely choose their location based on waiting time instead of travel time. 10,9% of the patients that visited Gasthuis are originated from the 3Bs region, whereas the EOC in Berkel is closer to their homes. The same accounts for Schiedam (4,2%), they should have gone to Vlietland, because this is closer to their

homes. 10,6% of the patients of Vlietland have been traveling from Maassluis and 2,3% from Hoek van Holland. EOC Maassluis is more convenient for these patients, causing them less travel time.
The people that visited the EOCs are mostly originated from the towns nearby. However, Rotterdam has a large share in the patient flow for EOC Berkel. This is most likely caused by the high waiting times at Gasthuis.

Table 3.3 Top 5 origins for every Franciscus location

	Berkel (18,519)	Gasthuis (235,456)	Hoogvliet (3,966)	Haven Polikliniek (23,860)	Maassluis (15,994)	Oogziekenhuis (4,638)	Vlietland (198,263)
Rotterdam	21%	68,2%	5,3%	83,3%		75%	8,6%
Berkel & Rodenrijs	40,2%	6,7%		1%		3,2%	
Bergschenhoek	19,3%	4,2%					
Bleiswijk	9,9%						
Pijnacker	3,9%						
Schiedam		4,2%	7,3%	2,3%	6%	3,9%	35,2%
Vlaardingen			6,1%	1,6%	13%	2,1%	34,8%
Maassluis					64,4%		10,6%
Maasland					3,5%		
Hoek van Holland					6%		2,3%
Spijkenisse			14,2%				
Hoogvliet			49,9%				
Capelle a/d IJssel		3,7%		6,9%		3,9%	

3.4.3.2. Average cost per consult per location

The average costs per patient are calculated by the total costs for a location (excl. depreciation expenses) divided by the number of consults on location. Table 3.4 shows the average costs per consult. The total costs for the EOC are provided by the planning & control department of Franciscus. The costs for the main locations, Haven Polikliniek and Oogziekenhuis are based on estimations. This is due to the lack of knowledge on costs for outpatient clinics within the locations. Furthermore, the overall average costs per patient are presented in the last row of the table.
The costs per consult are determined by the number of appointments at a location. Nevertheless, the cost per consult are significant higher for the main locations than the EOC locations. Considering the determined lack of performance for EOC locations in the previous Section, it can be concluded that the average costs per consult can be decreased. The improvement in performance of EOC locations could lead to less costs per consult.

Table 3.4 Cost per consult per location

	Total costs (€)	Number of consults (#)	Cost per consult (€)
Franciscus Berkel	718,130	18,519	38.78
Franciscus Gasthuis	10,000,000	235,456	42.47
Haven Polikliniek	500,000	23,860	20.96
Franciscus Hoogvliet	141,998	3,966	35.80
Franciscus Maassluis	495,147	15,994	30.96
Franciscus Vlietland	10,000,000	198,263	50.44
Het Oogziekenhuis	150,000	4,638	32.34
Overall average			35.96

3.4.4. Service for patients

In this Section the KPIs are calculated that measure the service for patients, these are the travel time and waiting time for patients. For both factors the overall average per patient is calculated.

3.4.4.1. Travel time

The travel time of patients is calculated with help of Google Maps. The travel times is determined from a fixed random day (10/17/2019) at a fixed random time (14:55). By taking a random day and a time other than during peak hours, Google maps shows a time range, an interval of minimum and maximum travel time. For each postal code, the upper limit of this time range is chosen as travel time. The travel time is calculated as the average travel time of the appointments that visited that location in 2018. Subsequently, the overall average travel time per patient is calculated by the number of appointments at that location times the average waiting time per location. The values are presented in Table 3.5.

The average travel time is compared to the ideal situation, where every patients visits the Franciscus location that is the closest to his or her home. As can been seen in Table 3.6 The average waiting time per specialty per locationTable 3.5, the average travel time can be reduced for 6 out of 7 locations. Striking is that the travel time for Hoogvliet is increased. This can be explained by the increase of patients for Hoogvliet. These patients might have longer travel times, nevertheless this is still the shortest travel time for them, can cause an longer average travel time.

Table 3.5 Average travel time per location in 2018

Location	Current average travel time (min)	Minimal average travel time (min)
Franciscus Berkel	14.5	8.0
Franciscus Gasthuis	17.6	13.4
Franciscus Haven Polikliniek	22.4	13.2
Franciscus Hoogvliet	11.5	13.8
Franciscus Maassluis	11.9	10.2
Het Oogziekenhuis, Rotterdam	25.9	13.2
Franciscus Vlietland	15.2	11.3
Average travel time per patient	16.6	11.7

3.4.4.2. Waiting time

Since August 2018, every hospital is obligated to present the current waiting times on their website in a fixed format (Nederlandse Zorgautoriteit, 2018). An example of this format that is used by Franciscus is given in Appendix F. The waiting times are given per location per specialty and are updated every week. The waiting times are defined by the third possible moment for a first consult.

Table 3.6 shows the average waiting time per specialty per location for 2018. Also, the overall average is calculated by the number of appointments of a specialty at a location multiplied by the corresponding waiting time. Oogziekenhuis Rotterdam is not included due to the fact that it is not an official Franciscus location. Cells are empty when specialties were not available on this location or because specialties did not provide the necessary information. In case the latter occurs, the data is not available and a star is noted in that cell. Another meaning of this star is that there is no possibility to make an appointment at that moment. The values that are marked in red are waiting times that pass the Treeknorm of 28 days. Neurology passed the Treeknorm at every location. On average, General Surgery, ENT and Orthopaedics have low average waiting time. However, Orthopaedics has been unavailable for several months due to organisational changes. Furthermore, Urology also has rather low waiting times, but has had stars for every location for several months of the year. Notable is that geriatrics has long waiting times for the EOC locations, this is caused by the fact that Geriatrics has had only few consultation hours at the EOC locations in 2018. Overall, EOC Berkel has long waiting times for its specialties. The waiting times at Haven polikliniek do not pass the Treeknorm for all available specialties.

Overall, the average waiting times of specialties and the average waiting on locations are relatively high, considering the official Treeknorm of 28 days. However, the overall average waiting time is under the Treeknorm. Nevertheless, there are four specialties that pass the Treeknorm on average, these are Geriatrics, Internal Medicine, Neurology and Ophthalmology. Furthermore, for some specialties the waiting time is higher at the EOC locations than at the main locations. Therefore, patients are more attracted to the main locations. This has impact on the performance of EOC, since less patients schedule their appointments at the EOCs due to the high waiting times. Moreover, the high average waiting time causes inconvenience for patients, affecting the service for patients.

Table 3.6 The average waiting time per specialty per location

Waiting time in days	Gasthuis	Vlietland	Berkel	Hoogvliet	Maassluis	Haven	Average per specialty
Cardiology	35	33	31	3	21	24	24
General Surgery	12	13	13	9	9		11
Dermatology	17	13	17	25	28		20
Gastroenterology	13	47	36	2	21		24
Geriatrics	21	15	35	32	55		31
Gynaecology	23	21	26	23	22		23
Internal medicine	27	36	35	25	26		30
Paediatrics	11	19	31	23	25		22
ENT	6	4	3	6	7	3	5
Pulmonary medicine	11	15	19		24	10	16
Neurology	48	38	58	35	51		46
Ophthalmology	38	37			20		31
Orthopaedics	10	9	11	6	3		8
Rheumatology	4	27	23	31	29		23
Urology	20	3	14		2	1	8
Average per location	20	22	25	18	23	10	
Overall average							20.37

3.5. Conclusion

In this chapter the analytical phase is carried out. In this phase, a current state analysis is performed for Franciscus. The aim of this chapter was to answer sub-question three:

What are the bottlenecks that create inefficient use of the external outpatient clinics of Franciscus?

For the current state analysis several components are examined and several methods are used. These combined methods have provided the answer to the third sub-question. The determined bottlenecks and the outcomes of the KPIs and other performance indicators are relevant information for the model that is designed in the next chapter. This information is used as base on which the model is designed.

The first bottleneck is caused by the specialists themselves. Consultation hours are planned based on the preference of specialists and therefore the schedule of the EOCs is directly depended on the availability of the specialists. Hence, the preference of the patient for a specific location plays a minor role. Furthermore, one of the agreements with specialists is that they schedule six weeks in advance, however this does not always happen. Nevertheless, there are no consequences for specialists when they cancel or reschedule consultation hours.

The second bottleneck is related to communication between locations and the recognition of the importance of EOC by the main locations. The employees at main locations experience the EOCs as additional locations, therefore there is a lack of communication towards the EOC locations. For example, department managers easily cancel consultation hours at EOCs if the specialist is needed at one of the main locations. Then, the consultation hours get blocked in HIX, but the cancellation is not communicated with the EOC location in question. The outpatient clinics at the main locations do not realise the consequences of this cancellation, such as rescheduling patients and overcapacity of doctor's assistants.

The third bottleneck is the appointment system. The bottlenecks is caused due to the different ways an appointment can be made. An appointment at Franciscus Gasthuis or Berkel is arranged by the speciality in question at Gasthuis. However, appointments for Vlietland or Maassluis are scheduled by the central call centre at Vlietland. Furthermore, patients can also contact the EOCs or Haven Polikliniek to schedule an appointment. Each main location only makes appointments for that location and either EOC Berkel or Maassluis, thus not every possible location is considered. Moreover, the call centre or doctor's assistants does not consider the origin of a patient when scheduling an appointment.

By means of a data analysis, the current performance of EOCs Berkel, Maassluis and Hoogvliet are measured. Subsequently, the current level of service of patients is determined. In general, the outcomes of the KPIs show that the bottlenecks affect the performance of EOCs and therefore the service for patients. There is a mismatch between demand and supply at the Franciscus locations, this causes lack of performance at the EOCs and therefore a lack of service for patients.

88% of the appointments is treated at the main locations, while the average utilisation rate of the EOC locations is only 21.4%. This should be 87.3% considering the ideal situation where every patient is treated at the Franciscus closest to their homes. The low utilisation rate and high patient flow at the main locations influence the costs per consult per patient and the overall average travel time per patient. The average costs per consult per patient is the highest at the main locations, despite the significant number of patients. Therefore, the overall average costs per consult per patient is relatively high (€36.96). Subsequently, the average travel time per patient per location is

compared to the average travel time for patients in the ideal situation. The average travel time per patient is longer than necessary for six out of seven locations.
Lastly, the average waiting time is calculated per specialty per location. The waiting time for patients is defined as the time between an appointments is scheduled and the moment of the appointment. The overall average waiting time per patient is less than the Treeknorm. However, tor four specialties (Geriatrics, Internal Medicine, Neurology and Ophthalmology), the average waiting time exceeds the Treeknorm. Furthermore, for some specialties (for example, Dermatology, Paediatrics) the waiting time is longer for the EOC locations than the main locations. This has a negative effect on the attractiveness of EOCs, since the waiting times at the main locations are shorter. This affect the patient flow at the EOC locations. Moreover, the high average waiting time causes inconvenience for patients, affecting the service for patients.

In the next phase, a model is designed to improve the performance of EOCs and the service for patients. In Section 6.3, further recommendations are provided regarding improvements to solve the bottlenecks.

4. Patient planning optimisation model

In the analytical phase, it is determined that there is a lack of performance and service for patients. This can be explained by a mismatch between supply and demand at Franciscus locations. In this phase, the design phase (see Figure 4.1), a model is designed to find the optimal allocation of patients over multiple locations by minimisation of the inconvenience cost for patients. The model seeks to find the perfect match between demand of patients and the supply of consultation hours at multiple locations.

First, the realisation of the model is explained and the modelling methodology is discussed. Subsequently, the model is described and the design of the model is elaborated. The optimisation model is used as tool to answer the fourth sub-question. The model is applied to evaluate the impact of measures on the performance of EOCs and the service for patients. The application of the model is part of the implementation phase and is presented in Chapter 5.

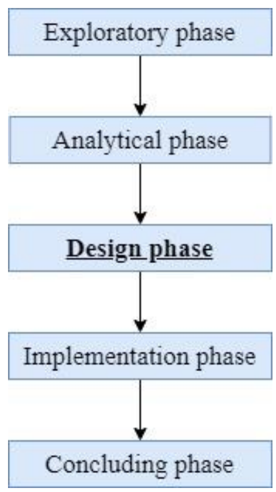

Figure 4.1 Design phase of this study

4.1. Model background

In the previous chapter, several bottlenecks have been identified that cause lack of performance of EOCs and service for patients. One of the main bottlenecks is the influence that specialists have on patient scheduling over all locations. The planning of specialists is leading for the schedule of specialties at the EOCs. The origin of the patient is not considered when consultation hours are scheduled at Franciscus locations. 88% of the patients is treated at the main locations, this was established from the data analysis in Section 3.4. Furthermore, the demand of patients per location is not taken into account. Based on these findings, it can be concluded that there is a mismatch between the supply and demand of Franciscus. Moreover, both EOC locations have an utilisation rate under 25%, resulting in high costs per consult at the EOC. Therefore, a model is designed to determine the optimal match of supply given the demand of patients. The outcome of the model gives an indication of the distribution of consultation hours of specialties over the locations to achieve the optimal allocation of patients.

A causal-relation diagram is set up (see Appendix G) to determine the factors that need to be taken into account for the design of the optimisation model. This diagram visualises the causal relation between factors and the KPIs for a Franciscus location.
The number of scheduled patients is influenced by the scheduled consultation hours, demand, waiting time and travel time. Subsequently, the number of scheduled patients on a location affects the cost per consult for a location. The scheduled consultation hours are influenced by the available hospital locations, the capacity of specialties, the capacity of specialists and the resource capacity. The capacity of specialists has impact on the capacity of specialties and resources and the capacity of specialties affects the travel time for patients. The scheduled consultation hours influences the waiting time for patients and the utilisation rate. The utilisation rate is determined by the scheduled consultation hours on a location and the room capacity of this location.
It is concluded that the availability of specialists have much impact on the scheduled consultation hours that determines the planning for patients over the locations. Therefore, the availability of specialists is not taken into account in the model, it is assumed that the specialist is able to work at any location depending on the demand of the patient. Factors that are included in the design of the model are: capacity of specialties, room capacity, number of hospital locations and the demand of patients. The resource capacity and the operating costs are fixed, it is assumed that the resource capacity is sufficient for the patient demand.

4.1.1. Theoretical background

The literature review in Section 2.6 has shown that LP is one of the commonly used mathematical models to optimise patients schedules. With LP, complex relationships can be depicted through linear functions to find the optimum. Real relationships are translated into linear formulas, which makes the model computationally efficient (Analytics Vidhya, 2017). This method can only be used if all formulas are linear. Unlike other methods, LP is able to solve large problems with many variables and constraints (Loucks & Beek, 2015). LP is applied in various fields of study, for example in telecommunications, manufacturing and transportation. It is used for planning, routing and scheduling problems. A LP model is based on three key elements: an objective function, decision variables and constraints. These are translated into a mathematical model, that can be programmed and then used to find the optimal solution for specific real life issues (Analytics Vidhya, 2017).

Firstly, the objective function describes how different variables contribute to a certain value that needs to be optimised. The goal of LP is to optimise these variables that influence the objective function (Hayes & Pakornrat, 2019). The objective function is either minimised or maximised. Secondly, decision variables are the key in an optimisation model and influence the output. By solving the model, the values of these variables are calculated (Loucks & Beek, 2015). Lastly, there are two types of constraints, functional and non-negativity. Functional constraints represent the requirements and boundaries of the model. In other words, these constraints form the frame of the model and are mostly limitations for the decision variables. Constraints are defined to create a valid model to match the actual situation as much as possible. The non-negativity constraints define the characteristics of the decision variables and parameters. For example, whether a variable is a binary or integer variable (Analytics Vidhya, 2017).

LP has many advantages. A couple of these advantages are (Martinich, 1997):

- It creates the possibility to evaluate possible solutions in a quick and inexpensive way, without actually experimenting and constructing;
- It helps structuring though processes, because it forces decision-makers to think through the problem and process in a concise, organised way;
- It facilitates what-if analysis. Because LP makes it relatively easy to find the optimal solution for scenarios, sensitivity analyses can be executed. Sensitivity analysis is applied when parameters need to be estimated and may differ in practice. With this analysis, it can be determined how sensitive the objective function is to the assumptions of the model.

Nevertheless, LP also has disadvantages. For example, since problems that are solved by LP can be very complex, there is the possibility the real model gets modelled wrong. For example, constraints could wrongly be formulated. Decision variables or constraints could be omitted or a model can be inappropriate for the situation. A second disadvantage is that all constraints and the objective function have to be quantified and linear in nature (Sherman, 2018). The model is programmed step by step for verification the model. Furthermore, the model is calibrated and validated. Verification, calibration and validation are done to eliminate mistakes and to ensure that the model works correctly.

4.1.2. Tools

The software that is used to program the model is Gurobi, which is a package in Python (Gurobi, 2019). Python is an object-oriented and interpreted programming language with dynamic semantics. It is known for its simple, easy to learn syntax and emphasizes readability (Stross-Radschinski, 2015). The program supports modules and packages, such as Gurobi. Gurobi is an optimisation solver, to solve mathematical programmed models. It delivers solutions fast and can cope with high complexity of models (Gurobi, 2019).

4.2. Model set up

Figure 4.1 gives a schematic representation of the functioning of the model: the input, the process and the output of the model. The input of the model is the demand of the patients, represented by appointments. Each appointment has three characteristics: postal code, specialty and consult type. The model distributes the appointments over the available locations. This distribution is based on inconvenience costs for an appointment, these are defined by the factors that influence hospital choice of patients: travel time and waiting time. The allocation of the appointment to a location depends on several components. Firstly, the constraints of the location capacity and the capacity of specialties at a location. Secondly, the travel time for an origin postal code of an appointment to each Franciscus location. Thirdly, the waiting time at each location. The waiting time depends on the utilisation of a location, the higher the utilisation of a location the higher the waiting time. Lastly, each appointment has a fixed duration, that is determined by the consult type of that appointment. Based on these components, the model calculates the optimal allocation of the appointments. A model run results in an optimal allocation over all locations and calculated minimal inconvenience costs.

4.2.1. Model assumptions

The model is a schematisation of reality, therefore several assumptions are made:

- For each appointment is presumed that the preference is at the first available moment for an appointment. The individual preferences are not taken into account, due to the complexity of adding preferences to single appointments.
- The objective function and constraints are linear functions (see Section 4.1), therefore waiting time is defined as a constant of the utilisation of consultation hours of a specialty on a location. The utility of a specialty of a location is divided in several ranges, each linked to a different waiting time. For example, a utilisation rate of 0-70% generates a waiting time of 2 weeks, a utilisation rate of 70%-100% generates 4 weeks of waiting time for an appointment.
- As mentioned in Section 4.1, the availability of specialists is not taken into consideration. It is assumed that every specialist is able to work at the location where a consultation hour is scheduled. These consultation hours are scheduled within the maximum capacity of that specialty on that location.
- The model focusses on appointments that are planned to be treated by specialists. This way consistency over the different specialties and different locations can be preserved. Patients seen by doctor's assistants or nurse specialists are not taken into account.
- The input of the model, the demand of the patients, is presented in appointments. Appointments are used instead of patients, due to the possibility that patients have to visit the hospital multiple times at different moments.

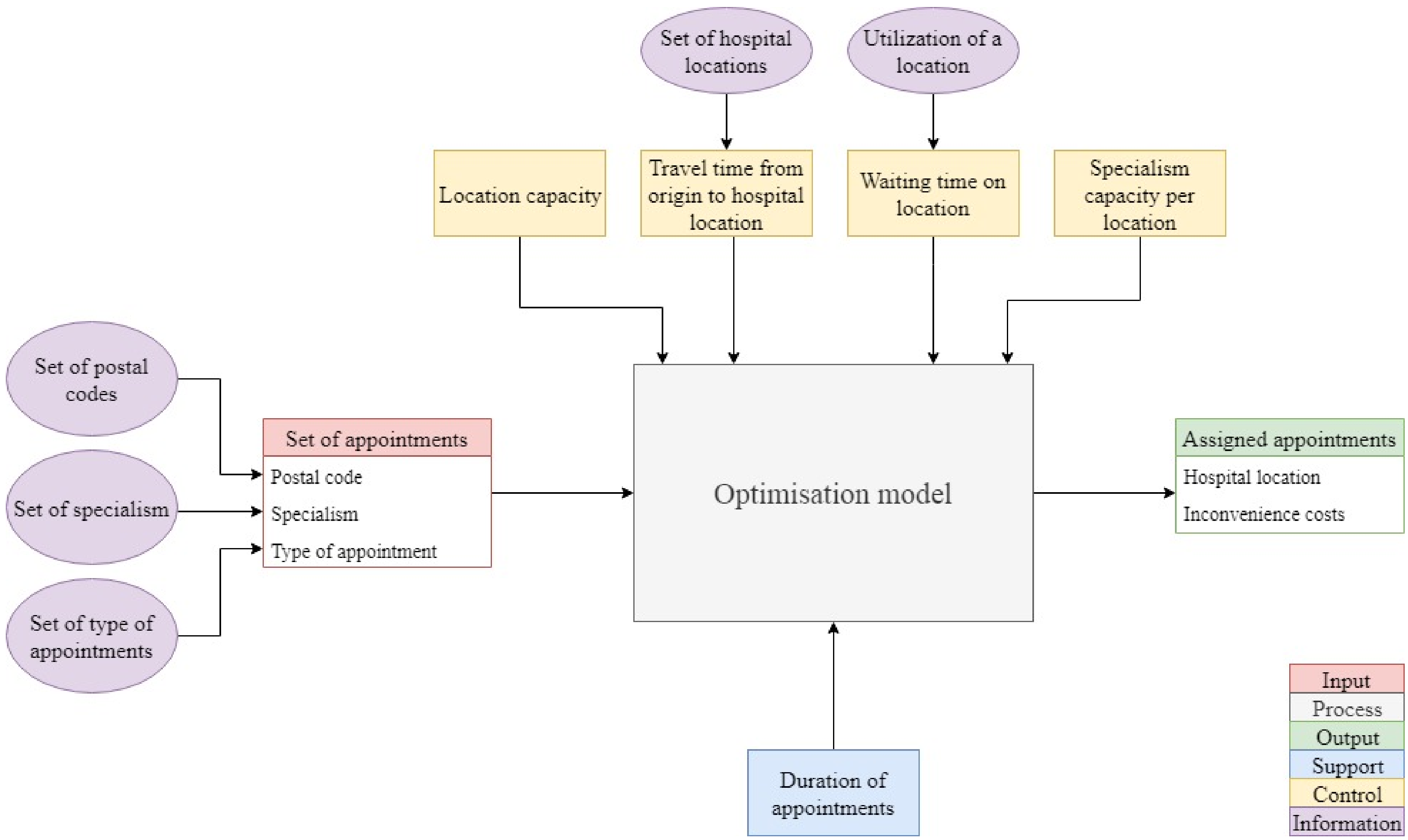

Figure 4.2 Functioning of the patient planning optimisation model

4.2.2. Design of the model

As mentioned in the previous Section, a LP model consists of an objective function, decision variables and constraints. Furthermore, the model includes indices and parameters. In the following Sections, each of these components is described in words as well as mathematically.

Indices

The indices are defined as lists of subjects that are involved in the LP model (Hiller & Lieberman, 2014). In this model five indices are defined. Each index has several variables which give information about this index. These variables are presented in the following paragraphs. Data of these indices are given in sets. For example, the index 'location' is linked to a set of all available locations of a hospital. The indices for this model are listed below, including the mathematically formulated as:

$$\mathrm{i} = \text{appointment type index}$$
$$\mathrm{j} = \text{location index}$$
$$\mathrm{p} = \text{postal code index}$$
$$\mathrm{k} = \text{specialty index}$$
$$\mathrm{a} = \text{appointment index}$$

Parameters

The parameters are input variables with fixed values. Parameters either belong to a decision variable or represent a restriction or requirement in the model (Martinich, 1997). The following parameters are included in the model:

- Travel times of an appointment to each location per location in minutes;
- The waiting time of each appointment in days per location per utilisation phase;
- Total capacity of a location over all specialties in minutes per month;
- Capacity of a specialty on a location in minutes per month;
- Duration of appointment types per specialty in minutes.

The parameters are also defined by a letter in the mathematical model. The indices involved for the parameters are presented by the letter defined for that index. The utilisation phases are defined as low, medium and high, taken into account as exponents L, M and H respectively. The parameters are shown below.

$$\mathrm{T_{Pj}} = \text{traveltime of postal codes p to location j}$$
$$\mathrm{W_j^L} = \text{constant for waiting time at location j in low utilisation interval}$$
$$\mathrm{W_j^M} = \text{constant for waiting time at location j in medium utilisation interval}$$
$$\mathrm{W_j^H} = \text{constant for waiting time at location j in high utilisation interval}$$
$$\mathrm{c_j} = \text{total capacity of location j}$$
$$\mathrm{u_{kj}} = \text{total capacity of specialty k at location j}$$
$$\mathrm{q_{ik}} = \text{duration of appointment i of specialty k in minute}$$

Decision variables

The model has four different decision variables. Three out of four decision variables define the same decision: the location choice of an appointment. The appointments are distributed over several locations and each appointment is assigned to one location. Therefore. the decision variable is a binary variable. The decision variable value is 1 when an appointment is assigned to that location and 0 for all the other locations. Assignment of appointments to a decision variable depends on the utilisation of the locations. Based on the utilisation of the location, the appointment is classified to one kind of decision variables. As mentioned in Section 4.2, the utilisation is divided into three ranges. Based on each range of utilisation rates a waiting time is determined for each location.

By running the model, the total costs are minimised, meaning that the perfect combination between travel time and waiting time needs to be found. At first, the model tries to fit every appointment in the first range of utilisation rates of a location, because this range has the lowest waiting times. Furthermore, the model aims to fit the appointment at the preferred location, and chooses the best available location otherwise. If the best allocation of an appointment fits in the first range of utilisation, the appointment is defined by the first decision variable. If this is not possible, the appointment is defined by the second decision variable in the medium utilisation rate, with a longer waiting time. If the appointment does not fit in the first or second range of utilisation rates, the appointment is defined by the decision variable of the high utilisation range.

The last decision variable defines the decision whether a specialty is offered at a location or not. Due to various locations and the availability of resources at a location, there is a possibility that not every specialty is offered at every location. If a specialty is offered at a location, the variable will be 1 and 0 otherwise. This decision variable is not used in the objective function, but for one of the constraints. With this decision variable, it can be determined whether a specialty is offered at a location while minimising the inconvenience costs for all appointments. The mathematical formulation for the parameters are as follows:

X_{aj}^{L} = whether an appointment a takes place at location j in low utilization phase
X_{aj}^{M} = whether an appointment a takes place at location j in medium utilization phase
X_{aj}^{H} = whether an appointment a takes place at location j in high utilization phase
Y_{kj} = whether specialty k is available at location j

Objective function

The model focusses on the distribution of appointments, this is based on patient preferences. These preference are determined by factors that influence choice of location for patients. As defined by the literature review in Section 2.6, the following factors are taken into account:

- Waiting time. Waiting time is the time between an appointment is scheduled and the moment of the appointment.
- Travel time. Travel time is defined as the relative travel time towards the preference location. The location that is the closest to the origin of the patient is assumed to be the preference location of that patient. Each other location causes the patient extra travel time. This extra travel time is used as travel time in the model. Only the extra travel time is considered, because the travel time to the preference location is the inevitable travel time. The inevitable travel time is not taken in consideration as inconvenience.

Due to the fact that both waiting time and travel time can cause inconvenience for patients, the aim of this model is to minimise the total inconvenience costs for all appointments over all locations. Each factor is given a weight to determine the amount of influence that factor has on the choice of a patient considering the other factors. The weight factors are defined as $\alpha_1$and α_2. Travel time is measured in minutes and waiting time in days. Due to the weight factors, these values are normalised and the value for both factors can be summed. The mathematical formula for the objective function of this model is:

$$\min \alpha_1 \sum_{a \in A} \sum_{j \in J} T_{p_{aj}}(X_{aj}^{L} + X_{aj}^{M} + X_{aj}^{H}) + \alpha_2 \sum_{a \in A} \sum_{j \in J} (W^{L}X_{aj}^{L} + W^{M}X_{aj}^{M} + W^{H}X_{aj}^{H}) \quad (1)$$

The first part sums up all travel times for each appointment travelling to the assigned location for all appointment for all locations. The second part sums up all appointments times the assigned waiting time, which are determined by the utilisation phases, for all appointments for all locations. Each part is multiplied by the weight factor.

The model considers possibilities per appointment and stops as the optimum value is found. The job of the model is to calculate the best distribution of appointments over multiple locations by minimising the total inconvenience costs for all appointments for all locations.

Constraints

Lastly, the constraints of the model are defined. Constraints are the rules and restrictions the model needs to consider while searching for the optimal value for the objective function (Loucks & Beek, 2015). The following constraints are added to the model:

- Each appointment is assigned to one location;
- Maximum capacity of a location, because a single location has a maximum amount of appointments per month;
- Maximum capacity of a specialty per location. The capacity is limited due to the total available consultation hours of a specialty. The decision variable for available specialties on a location is linked to this constraint.

Both capacity constraints are taken into account, because rooms can be used by multiple specialties at EOCs. It is possible that the total capacity of all specialties, summed together for a location, extends the maximum available capacity of a location.

Functional constraints

$$\sum_{i\in I}\sum_{a\in A}\sum_{k\in K} q_{ik}(X_{aj}^{L}+X_{aj}^{M}+X_{aj}^{H}) \leq c_j \qquad \forall\, j \in J \qquad (2)$$

$$\sum_{i\in I}\sum_{a\in A} q_{ik}X_{aj}^{L} \leq 0{,}2u_{kj}\,Y_{kj} \qquad \forall\, k \in K, j \in J \qquad (3)$$

$$\sum_{i\in I}\sum_{a\in A} q_{ik}X_{aj}^{M} \leq (0.7-0{,}2)u_{kj}\,Y_{kj} \qquad \forall\, k \in K, j \in J \qquad (4)$$

$$\sum_{i\in I}\sum_{a\in A} q_{ik}X_{aj}^{H} \leq (1-0.7)u_{kj}\,Y_{kj} \qquad \forall\, k \in K, j \in J \qquad (5)$$

$$\sum_{j\in J}(X_{aj}^{L}+X_{aj}^{M}+X_{aj}^{H}) = 1 \qquad \forall\, a \in A \qquad (6)$$

The constraint presented at (2) defines the capacity restriction for each location; the sum of all appointments on a location times the duration of these appointments is smaller or equal to the maximum capacity for that location. Constraints (3), (4) and (5) define the capacity constraint of specialties on a location; the sum of all appointments assigned to a location for a specialty in the [low, medium, high] utilisation phase times the duration of these appointments needs to be lower than the capacity of that specialty on that location if that specialty is available on that location. Constraint (3) defines the low utilisation phase, (4) the medium and (5) the high utilisation phase. Constraint (6) ensures that every appointment is assigned to one and only one location.

Other constraints

$$X_{aj}^{L} = \{0,1\} \qquad \forall\, a \in A, j \in J \qquad (7)$$
$$X_{aj}^{M} = \{0,1\} \qquad \forall\, a \in A, j \in J \qquad (8)$$
$$X_{aj}^{H} = \{0,1\} \qquad \forall\, a \in A, j \in J \qquad (9)$$
$$Y_{kj} = \{0,1\} \qquad \forall\, k \in K, j \in J \qquad (10)$$
$$T_{Pj} \geq 0 \qquad \forall\, p \in P, j \in J \qquad (11)$$
$$T_{Pj} \in R \qquad \forall\, p \in P, j \in J \qquad (12)$$

The constraints presented above define the characteristics of the variables. The first four constraints (7-10) are binary, whereas the other constraints (11-12) define an integer variable.

4.3. Conclusion

A LP model is designed for patient planning optimisation over multiple locations. Based on the outcomes of the KPIs during the current state analysis, it is determined that there is mismatch between demand of patients and supply of consultation hours at Franciscus locations. This is due to several bottlenecks and causes a lack of performance at EOC. Furthermore, the service of patients is affected by the mismatch of supply and demand. Considering the bottlenecks, the functioning of the model is established. A causal-relation diagram is set up to determine what factors should be considered for the design of the model. LP is used, since this method can large with complex problems in a relatively computationally efficient way. Furthermore, it is relatively easy to perform a sensitivity analysis with a LP model. Sensitivity analyses are used to measure the sensitivity of the objective function for estimated values of parameters.

The objective of the model is to minimise the inconvenience cost for patients, defined by the factors that influence the choice of location by patients; waiting time and travel time. Travel time is defined as extra time needed for travelling by the patient, when the location of treatment is different from the preference location. The inevitable travel time to the preference location is not considered as inconvenience. Waiting time is the time between the moment of scheduling an appointment and the appointment itself. Waiting time is determined based on the utilisation of a location. The more a specialty is utilised at a location by other appointments, the longer the waiting time. The objective function allocates all appointments over all locations while focussing on the service of the patient. The preferences of specialists are not taken into consideration. However, restrictions are defined in the model given the capacity of each location and the availability of specialties on that location.

The model designed in this design phase is a general model that can be used for any healthcare organisation with multiple locations. This model is applicable for the allocation of elective care patients of multiple specialities over multiple locations. In this study, the model is used as a first insight for the reallocation of patients of Franciscus over her locations. In the next phase, the implementation phase, the model is applied for Franciscus. Scenarios are set up with measures that could improve the performance of EOCs. These scenarios are applied in the model to analyse the effect of these measures on the service for patients. The outcomes of the model application for Franciscus are used to provide an answer for the fourth and last sub-question.

5. Model Application for Franciscus Gasthuis & Vlietland

The LP model designed for the optimisation of the allocation of patients over multiple locations by minimising the inconvenience costs for patients, is applied for Franciscus. This chapter contains the implementation phase, see Figure 5.1.

The first part of this chapter elaborates on the data which are used for the determination of the parameters and indices, as defined in the previous chapter. Subsequently, the values of the estimated parameters are determined by model calibration. Whereupon, the model is verified and validated by calculation by hand, sensitivity analyses and comparison of the values for KPIs for the actual and the simulated data. After the base model, which approaches the real situation, is run, the results are compared to the outcomes of the ideal situation. The base model and ideal situation are explained in the next paragraph. Based on this comparison, three scenarios are defined to test possible measures. Finally, the results of these scenarios are presented and an answer is given to the fourth sub-question.

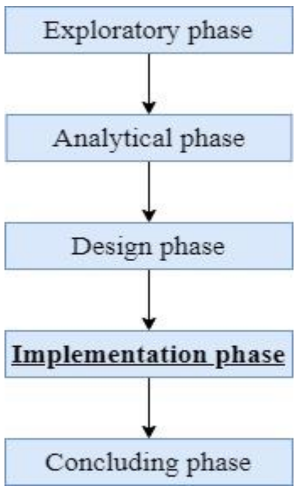

Figure 5.1 Implementation phase of this study

5.1.1. Programming in Python

The model is programmed in Python by means of an iterative process, where each factor and constraint is added one after another. This is done to verify and validate the model. The python code is shown in Appendix H.

Firstly, the appointments are defined by a matrix of postal codes and consult types per specialty. With a so-called loop the appointments are imported in the model consecutively to ensure that every single appointment is taken into account.

The obtained model only minimise the costs for travel time without any constraints to the capacity of each location. The results give the distribution of appointments in an ideal situation without any waiting time or capacity constraints, also referred to as the ideal situation. Subsequently, constraints are added. The runs show whether it is possible to see each patient on their preferred location.

Afterwards, the waiting times and utilisation phases are added. Now the model is completed and can be run based on real data. This run results in the base model and represents the real situation. The base model is used to set up scenarios as described Section 5.4 that are designed to test measures that could improve the performance of the EOCs.

5.2. Model input

The input is generated from data of the business intelligence department of Franciscus. These data is based on the statistics of one specific month to achieve the most reliable and valid results. The input values are based on the month March 2019, the data is presented in Appendix I.1. The month March is chosen based on the data analysis of Franciscus in Section 3.4. In this Section, the supply is analysed over the months of 2018. The month March is one of the months without holidays. This causes a steady supply over the month. Furthermore, the analysis points out that March has an average supply of consultation hours in comparison to the other months. Therefore, the month March is chosen as reference month. Furthermore, the data analysis is carried out for the year 2018, because the data of 2019 was not complete yet. However, the LP model requires input of one month, therefore March 2019 can be used. 2019 is used instead of 2018, because these data is more recent and therefore more relevant.

5.2.1. Data

The appointment data is gathered from DTCs in HIX. Each patient has a DTC with personal information where details of previous appointments and actions are administered. Every appointment of a patient is defined by several characteristics: a postal code of origin, a specialty and a consult type.
The set of locations includes all polyclinic locations of Franciscus:

- Gasthuis;
- Vlietland;
- Berkel;
- Maassluis;
- Haven;
- Oogziekenhuis.

Since Franciscus Hoogvliet has closed in November 2019, therefore Hoogvliet is excluded from this chapter, because the implementation phases focuses on measures for future improvements.
The set of specialties for each location is defined by data of consultation hours at each location.

Location capacity

The capacity of every location is calculated by taking into account the following elements:

- The number of rooms per location,
- Two shifts for consultation per day, in the morning and the afternoon.
- Consultation hours have a duration of 3.5 hours

The total capacity is calculated per location in minutes for a single month.

The capacity is defined per location. In Gasthuis and Vlietland multiple rooms are assigned to specific specialties and the number of assigned rooms varies per specialty. Notwithstanding, the capacity is defined by one value for each location. Therefore, an average number of rooms is considered for each specialty and is calculated at 4 rooms per specialty.
The rooms at the other locations are used by multiple specialties, thus the capacity is based on the total number of rooms. Table 5.1 presents the number of rooms and additionally the capacity per month for every Franciscus location.

Table 5.1 Capacity of Franciscus locations

Franciscus location	Consultation Rooms (#)	Capacity (hours/month)
Gasthuis	60	7,200
Vlietland	60	7,200
Berkel	8	960
Maassluis	7	840
Haven	4	480
Oogziekenhuis	2	240

Specialty capacity

Capacity of each specialty per location is defined by the available capacity of a specialty on a location. For the base model, the values of this constraint are based on the data from March 2019. The number of consultation hours for each specialty on each location is known for this month. The total number of consultation hours of each speciality is fixed, the distribution of these consultation hours over the Franciscus locations is not.

Appointment duration

The duration of each consult type differs per specialty. Although the duration for a single consult for one specific specialty can vary as well, the predefined duration for each consult type per specialty is used. This is in accordance with the most common time of that specific consult.

Travel time

The travel time is the time necessary to travel by car, since most patients travel by car to the hospital (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 2010). Each appointment has an origin that is represented by a four digit postal code, the two additional letters are left out due to privacy reasons. Nevertheless, the hospital locations are defined by their exact postal codes. For every postal code in the adherent area the travel time to each Franciscus location is calculated. These travel times are based on the available data in Google Maps, a random day and time is chosen, as explained in Section 3.4. Subsequently, the preferred location is determined by the lowest travel time and is used as reference to calculate the relative travel time to the other locations. This relative travel time is used to calculate the inconvenience cost for the objective function.

α_1 and α_2

These are the weight factors for the factors that influence the choice for a specific location by a patient. The total value of all weight factors combined is 1, representing 100%. The distribution of the weight factors is based on the interviews with involved staff of Franciscus (see Section 3.2). Both travel time and waiting time play an important role in the decision-making process. However, it is dependent on the individual patient which of the two is more decisive. According to the call centre elderly prefer the nearest locations while relatively younger people do not mind to travel further for their appointment. The model is designed for scheduling appointments independent of demographic characteristics of patients, so the values of α_1 and α_2 based on the answers provided by the interviewees regardless the individual preferences of patients. Based on all interviewees, it is likely that waiting time is slightly more decisive for the choice of the location than travel time. Hence, the location choice of a patient depends for 40% on the travel time to a location and for

60% on the waiting time at that location, see Table 5.2 for the values of alpha 1 and 2. Further research is required to determine exact values for these weight factors.

Table 5.2 Values for alpha 1 and 2

Parameter	Value
α_1	0.4
α_2	0.6

5.2.2. Waiting time calibration

The values for the indices and constraints are based on available data. However, there is no data available for the parameters for utilisation and waiting time. In Section 4.2, these parameters are explained in detail. The values for the utilisation ranges and the corresponding waiting times need to be estimated. Therefore, a calibration is carried out to determine the optimal values for these parameters to create a valid model.

Waiting time is equal for every specialty on a location and is dependent on the utilisation rate of the capacity of that specific specialty on a location. As is mentioned in Section 3.4, the waiting time is in reality a dynamic variable depending on time and often differs per specialty. In this model, waiting time is considered as a constant of the utilisation ranges of the capacity of a speciality on a location. This makes it difficult the validate the waiting time for a specialty on a location. Therefore, calibration is carried out to determine the optimal values that generate an overall weighted average that equals the weighted average calculate for March 2019. This average is 19.38 days, which is 1 day less than the overall average for 2018.

The utilisation ranges are taken into account by defining different waiting times for each phase. Each utilisation range has a specific interval of utilisation rates to which a number of appointments is assigned. This determines how many appointments get a certain value of waiting time. So, the intervals of each utilisation range influence the average waiting time per appointment.

The waiting times are determined based on the average waiting time of March 2019 for every specialty on every location, these are calculated based on the weekly updated waiting times. The waiting times of March 2019 are presented in Appendix I.1. Because the utilisation is divided over three phases, three values for waiting time are determined. According to the data of waiting time retrieved from Franciscus, it is highly unlikely that a patient can be seen immediately. See Appendix I.1 for the waiting times of March 2019 and Table 3.6 for the waiting times for 2019. Therefore, the waiting time for the first range of utilisation rates is assumed to be 7 days, based on the weekly overviews of waiting times of Franciscus in 2019. In the second range of utilisation rates, the waiting time is increased to 21 days. Lastly, for the third range of utilisations the waiting exceeds the Treeknorm of 28 days and becomes 42 days. The waiting times for the second and third utilisation range are also established based on the waiting times for March 2019. The waiting times of the specialties at the Franciscus locations can be divided in three groups, the specialties with low waiting times, the ones with medium waiting times and a group of specialties with waiting times that exceed the Treeknorm. The average of these groups are chosen as value for the waiting times of the second and third utilisation ranges. From the moment the cost for waiting time becomes too high in comparison to the cost of inconvenience to travel to another location, the appointment is scheduled to the other location.

For Franciscus the utilisation is split in three utilisation ranges. The first values for the utilisation phase are based on estimation on the interviews with stakeholders. The values are presented in run 1 in Table 5.3 and the utilisation ranges are respectively 0%-70%, 70%-90% and 90%-100%.

The focus of the calibration has mainly been on the values of the utilisation ranges, as the waiting times are based on real data and the utilisation ranges on rough estimations. The values during calibration are chosen based on previous outcomes and with the aim to keep the values as realistic as possible, see Table 5.3 for the calibration values and results. First, several models are run with the initial values for waiting times and different combinations of utilisation ranges. However, the average waiting time still remained too short in comparison to the real data. Therefore, the value of waiting time for the low utilisation range is increased by three days. The value of 10 days for waiting time for the low utilisation range is established in the same way as the waiting times for the second and third utilisation range: the average is calculated for the first group of specialties with low waiting times. The waiting time for the low utilisation range was initially based on assumptions of the interviewees. Therefore, this value is changed and is now also based on data of the waiting times of March 2019.

Table 5.3 Calibration of waiting time

Run	Values utilisation phases (Low, medium, high)	Values waiting time (days) (Low, medium, high)	Overall average waiting time (days)	Objective value
1	0.7 - 0.2 - 0.1	7 – 21 – 42	8.68	243,748
2	0.6 – 0.2 – 0.2	7 – 21 – 42	10.34	284,475
3	0.5 – 0.4 – 0.1	7 – 21 – 42	10.78	296,206
4	0.2 - 0.7 – 0.1	7 – 21 – 42	16.39	428,840
5	0.4 - 0.4 – 0.2	7 – 21 – 42	12.98	348,656
6	0.6 - 0.2 - 0.2	10 – 21 – 42	12.86	344,846
7	0.4 - 0.3 - 0.3	10 – 21 – 42	15,93	420,424
8	0.3 - 0.5 - 0.2	10 – 21 – 42	16,43	431,135
9	0.3 - 0.4 - 0.3	10 – 21 – 42	17,42	445,561
10	**0.2 - 0.4 - 0.4**	**7 – 21 – 42**	**19.52**	**506,739**
11	0.2 - 0.5 - 0.3	7 – 21 – 42	18.12	472,144
12	0.2 - 0.4 - 0.4	10 – 21 – 42	20.58	532,389
13	**0.2 - 0.5 - 0.3**	**10 – 21 – 42**	**19.18**	**497,779**

Eventually, two runs resulted in approximately the right average waiting time, runs 10 and 13. For these runs, the other KPIs are calculated for further validation, see Table 5.4. The cost per consult are for both runs significant lower than the real value. Furthermore, there is a difference of 3 minutes between the real average travel time and the generated average travel time. However, the waiting time is within a 5% margin of error, which is considered to be a good model result. Nevertheless, it is important to keep in mind that the cost per consult are underestimated with approximately 6 euros and the travel time with 3 minutes.

Table 5.4 Validation of the KPIs

	Waiting time (days)	Cost per consult (€)	Travel time (min)
Real	19,38	38,06	16,6
Model run 10	19,52	35,56	13,7
Model run 13	19,18	34.88	13,3

There are little differences between run 10 and 13, therefore the chosen values for parameter are likely to be most realistic. It is more likely that utilisation rates of 70%-100% of the capacity of a specialty causes long waiting times than that high waiting times already occur at a utilisation rate of 60% of the capacity of a specialty is utilised. Therefore, the values of model run 13 are chosen, the values are presented in Table 5.5. For these values the overall average of waiting time is approximately similar to the real data. It should be kept in mind that this model is valid for the overall average waiting time when results are discussed and conclusions are drawn.

Table 5.5 Values of the parameters for Franciscus

Parameter	Range 1	Range 2	Range 3
Utilisation	0-20%	20%-70%	70%-30%
Waiting time	10	21	42

5.3. Model validation

Besides calibration, the model is verified and further validated. Verification is carried out to make sure the model works as it is supposed to work. The model is verified in two ways: calculations by hand and a sensitivity analysis. Validation is done to check whether the outcomes of the model are comparable with real data, to determine whether the model functions as it is expected to function and generates reliable outcomes (Maropoulos & Ceglarek, 2010).

5.3.1. Verification

Firstly, verification is carried out by implementing the model step by step with small samples of values of appointments and parameters. Secondly, verification is performed based on sensitivity analysis of three parameters: alpha and waiting times. This analysis is also used to check the sensitivity of the objective function to these parameters. The sensitivity for the parameters of the utilisation are determined in Section 5.2.

Hand calculations

First, the model is run for a small number of appointments, so the model can be checked by calculations by hand. The model is built up in two steps, first the model is programmed with only travel time, to create the ideal situation without waiting time and constraints. Then, the waiting time and all constraints are added to complete the model. Both models are verified by calculations by hand, the results are presented in Table 5.6.

The calculations by hand match the outcomes of the model and the on hand calculations. The value of the model with only travel time was expected to become 0, but is 6.0 instead. An appointment for Ophthalmology is assigned to another location instead of the preference location, because Ophthalmology is not offered at its preference location. Only the first 60 appointments are used, therefore all appointments in the model with both travel time and waiting time are sorted in the first utilisation phase with only 10 days waiting time.

Secondly, the model is run with all appointments without constraints. The optimal value when running the model with only travel time should be 0.0, because there is no capacity restriction and every appointment is assigned to its preference location. The optimal value of the model with travel time and equal waiting time on every location without constraints should be the sum of the waiting time multiplied by the number of appointments times the weight factor. The cost of travel time is 0.0 and all appointments are assigned to the first phase of utilisation, so a 10 days waiting time for every appointment. As can be seen in Table 5.6 are all values equal for the model and by hand.

Therefore, it is concluded that according to the by hand calculation the model works as it is supposed to work.

Table 5.6 Verification by calculations by hand

Situation	Optimal value model	Optimal value by hand
Model only travel time with constraints for 60 appointments	6	6
Base model with constraints for 60 appointments	254	254
Model only travel time without constraints	0.0	0.0
Base model without constraints	170,074	170,074

Sensitivity analysis

This analysis is done for the parameters of waiting time and alpha. For each parameter, the model is run with a small change of a value. For every run, an expectation is given upfront concerning the expected values of the base model. The results of the analysis for alpha one and alpha two are presented in Table 5.7, the results for waiting time in Table 5.8.

Table 5.7 Sensitivity analysis of Alpha one and two

	Expectations	Optimal value
$\alpha_1 = 0.4$ and $\alpha_2 = 0.6$	Base model	497,779
$\alpha_1 = 0$ and $\alpha_2 = 1$	Higher	776,658
$\alpha_1 = 1$ and $\alpha_2 = 0$	Lower, same as model run without WT	71,168
$\alpha_1 = 0.5$ and $\alpha_2 = 0.5$	Lower	428,069
$\alpha_1 = 0.6$ and $\alpha_2 = 0.4$	Higher	358,169
$\alpha_1 = 0.3$ and $\alpha_2 = 0.7$	Higher	567,500
$\alpha_1 = 0.7$ and $\alpha_2 = 0.3$	Lower	287,701

Table 5.8 Sensitivity analysis for low, medium and high waiting time

Waiting times	Expectations	Optimal value
Wl: 10, Wm: 21, Wh:42	Base model	497,779
Wl: 7, Wm: 21, Wh; 42	Lower	472,144
Wl: 6, Wm: 21, Wh; 42	Lower	463,594
Wl: 11, Wm: 21, Wh; 42	Higher	506,344
Wl: 10, Wm: 20, Wh:42	Lower	484,409
Wl: 10, Wm: 22, Wh:42	Higher	511,160
Wl: 10, Wm: 21, Wh:41	Lower	495,409
Wl: 10, Wm: 21, Wh:43	Higher	500,155
EOCs waiting time decreased by 1 day	Lower	495,609
Main location decreased by 1 day	Lower	476,887
Main location increased by 1 day	Higher	518,664
Haven and Oog decreased by 1 day	Lower	496,532

For every change in value of the parameters, the objective value is changed as expected. Each parameter has significant influence on the objective function. A shift of 10% among α_1 and α_2, changes the objective function by 70,000, which is respectively high in comparison to the total value (see Table 5.7). However, a change of 10% over total value of 1 is also respectively much.

For the utilisation phases it becomes clear that each change of 10% has a significant influence on the objective value. Furthermore, a change in the low and high utilisation range influences the objective function more than the medium utilisation range, see Table 5.3.

Furthermore, an increase or decrease of one day waiting time changes the objective with 10,000, a large difference for one day. The low and medium waiting influence the objective value more than the high waiting time, see Table 5.8.

The model is verified by hand calculations and sensitivity analysis. Furthermore, the objective function is sensitive for the values of parameters α_1 and α_2 and the utilisation phases and less sensitive for the parameters of waiting time.

5.3.2. Validation

To check whether the model generates valid outcomes, the base model is compared to the real data of March 2019. In Section 5.2, the waiting time, travel time and cost per consult are already validated. To complete the validation of model, the following aspects are compared to the real data:

- The consultation hours;
- Average utilisation rates of EOCs;
- Average utilization rates of all locations;
- Number of appointment per location.

An elaborated comparison of consultation hours and appointment per specialty per location is presented in Appendix I.2.

It should be noticed that Franciscus Hoogvliet was still operating in March 2019, which causes an inconvenience. Because, this location is not taken into consideration in the model. Therefore, the model reallocates the consultation hours held and appointments treated at Hoogvliet over the other locations. This causes a difference between the real data and the stimulated results.

Table 5.9 shows the supply of consultation hours per location. There is a difference of 74 hours between the actual hours and the simulated hours by the model, this is caused by the average duration of consults. As mentioned in 5.2, the duration of the consult types of a specialty is determined as the predefined duration of that consult type. The simulated hours are based on the duration of the appointments, therefore a difference occurs. As can be seen in the last column of Table 5.9, the difference for 4 out of 6 location is less than 6%. Berkel has 8% more hours, this can be caused by the fact that Hoogvliet is not included in the model. The number of hours increased by 12% for Oogziekenhuis, this is high in comparison with the other locations.

The average utilisation rate for the EOCs and for all locations show little differences, less than 5% (see Table 5.10). This is considered to be a good model result. Based on the comparison in Table 5.9 and Table 5.10, it can be concluded that the model is valid for the supply of Franciscus.

Table 5.9 Validation of supply

Location	Actual Hours	Simulated Hours	Difference
Berkel	299	322	7.8%
Gasthuis	4,089	4,250	3.9%
Haven	299	315	5.4%
Hoogvliet	60		
Maassluis	239	243	1.7%
Oogziekenhuis	74	83	12.2%
Vlietland	3,444	3,365	-2.3%
Total	8,504	8,578	0.9%

Table 5.10 Validation of the utilisation rate

	Actual utilisation	Simulated utilisation	Difference
Average EOCs	22.4%	26.8%	2.0%
Total average Franciscus	34.9%	38.3%	1.5%

The results of the validation on number of appointments is presented in Table 5.11. The total number of appointments for Gasthuis, Vlietland and Haven are similar to the real data, as the difference is less than 5%. Nevertheless, the difference in appointment are significant for Berkel, Maassluis and Oogziekenhuis. This can be explained by the redistribution of the appointment of Hoogvliet. Furthermore, the increased available hours at these locations create the possibility for the model to assign more appointments to these locations. According to results in Table 5.11, it can be concluded that number of appointments simulated in the model is not completely valid. One should take into account that the model slightly overestimates the number of appointments for the EOCs and Oogziekenhuis.

Table 5.11 Validation of number of appointments

Location	Actual appointments	Simulated appointments	Difference
Berkel	1,616	1,982	22.6%
Gasthuis	18,841	18,209	-3.4%
Haven	1,757	1,680	-4.4%
Hoogvliet	328		
Maassluis	1,345	1,632	21.2%
Oogziekenhuis	301	378	25.2%
Vlietland	16,306	16,613	1.9%
Total	40,494	40,494	0.0%

5.3.3. Conclusion

From the verification and validation of the model can be concluded that:

- The model works as supposed to work
- The overall weighted average waiting time is valid. However, the waiting time per specialty per location is not. This is due to the fact that waiting time is considered as constant of utilisation and equal for every specialty at every location. Actual waiting time is a dynamic variable dependent of time and differs per specialty per location.
- The overall weighted travel time and the cost per consult are less than the actual values due to the overestimation of number of appointment for the EOCs. This must be taken into account when one applies the model.

5.4. Scenarios

To answer the fourth and last sub-question, scenarios are formulated to test the effect of different measures on the performance of the EOCs and the service for patients. These scenarios are created by analysing and comparing the results of the base model and the ideal situation as mentioned in Section 5.2. The ideal situation represents the ideal world where every patient can be seen at their preferred location without any waiting time. The results of this ideal model show the allocation of patients based on travel time and without any capacity constraints for specialties or locations. See Appendix I.3 for the outcomes of ideal model run. Furthermore, the information established in the current state analysis is also used for the set-up of scenarios.

The base and ideal models are compared by means of consultation hours, the comparison in shown in Appendix I.3. The ideal situation shows a significant difference in distribution of consultation hours among the Franciscus locations. According the outcomes of the ideal situation, the EOC locations Berkel and Maassluis should have had respectively 602 and 1051 consultation hours more per month. Furthermore, it can be concluded that Gasthuis receives patients that initially have a different preference location. The locations Vlietland, Haven and Oogziekenhuis obtained the right amount of consultation hours for the majority of the specialties. With this comparison, the mismatch established in the current state analysis is confirmed. With the knowledge obtained from this comparison and the current state analysis (for example, low utilisation rates for Berkel and Maassluis) three scenarios are set up, each focusing on different aspects:

1. Shift of consultation hours of specialty over locations.
2. Investment in EOC resources.
3. Forecast for 2020-2025.

Scenarios one and two are set up to analyse the effect of measures on the performance of EOCs and the KPIs for service for patients. Both measures are focused on increasing the patient flow at the EOCs Berkel and Maassluis, since this is desired by the patients according to the outcomes of the ideal situation. For scenario one, two datasets are created, subsequently the model is run with these new datasets. In scenario two, four different investments are proposed, so the model is run with four different datasets. Subsequently, a forecast scenario is created for the coming five years. In Section 1.2, it is explained that the number of patients is rapidly growing. Furthermore, there is already great pressure on Gasthuis and 49% of the patients is treated at this location (see Section 3.4 for further explanation). Therefore, the forecast scenario is set up to check whether the current location capacity and specialty capacity will be sufficient for the expected patient growth in the coming 5 years. Furthermore, with this scenario is determined what the effect of this patient growth will be on the KPIs of service for patients.

For every scenario an explanation is given and the results are presented by the performance indicators and the KPIs. Subsequently, the scenarios are compared and discussed and an answer is provided for the fourth sub-question.

5.4.1. Scenario 1 – Shift of consultation hours

As mentioned before, Franciscus Gasthuis receives too many patients with different locations preference. Furthermore, the number of appointments at EOCs Berkel and Maassluis could be increased. Therefore, a realistic shift in consultation hours can be established, considering the available resources and the availability of specialties on a location. The increases or decreases of consultation hours per location are determined per week, see Table 5.12. Based on the shift in consultation hours per week, the monthly capacity of specialties per location is adjusted in the database of the model. With this new database, the model is run once more, resulting in scenario 1.1.

Table 5.12 The shift in consultation hours per specialty per week over the Franciscus locations

	Cardiology	General Surgery	Dermatology	Geriatrics	Gynaecology	Internal Medicine	ENT	Paediatrics	Pulmonary Medicine	Gastroenterology	Neurology	Ophthalmology	Orthopaedics	Rheumatology	Urology
Gasthuis	+2	+4	+2	+1	+2	+4	+1	+2	+4	+1	+2		+1	+3	+2
Vlietland	-4	-4	-4	-1	-4	-11	-1	-4	-4	-2	-6	-1	-2	-5	-5
Berkel							-2		-1						-2
Maassluis	+2	+2	+2	+1	+2	+4	+2	+2	+2	+2	+4	+2	+1	+2	+4
Haven															
Oogziekenhuis		-2		-1		+3			-1	-1		-1			1
Difference	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Subsequently, a second sub-scenario (scenario 1.2) is created to see what effect even a small change has on the allocation of patients over the locations and the performance indicators of Franciscus. In this scenario, each specialty offers one extra consultation hour per week at both EOCs Berkel and Maassluis, at the expense of Gasthuis. The shift in consultation hours for scenario 1.2 is presented in Table 5.13. Scenario 1.2 is setup, because it is not likely that scenario 1.1 is implemented on short term. This is due to the fact that scenario 1.1 considers several extra consultation hours per week of multiple specialties, which causes a significant change for specialists of specialties. It takes time to get specialties to cooperate on the implementation.

Table 5.13 Shift in consultation hours for scenario 1.2

	Cardiology	General Surgery	Dermatology	Geriatrics	Gynaecology	Internal Medicine	ENT	Paediatrics	Pulmonary Medicine	Gastroenterology	Neurology	Ophthalmology	Orthopaedics	Rheumatology	Urology
Gasthuis	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-1	-2	-2	-2
Vlietland															
Berkel	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1
Maassluis	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1		+1	+1	+1
Haven															
Oogziekenhuis															
Difference	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5.14 and Table 5.15 show the changes in allocation of consultation hours and supply for the scenarios 1.1 and 1.2. Both scenarios show a large shift in patients and consultation hours towards Berkel and Maassluis. Notable is that for scenario 1.1. the number of appointment has doubled for Maassluis and has caused an large decrease of appointments for Gasthuis and Vlietland. Scenario 1.2 causes a larger decrease for Vlietland compared to scenario 1.1. The total number of consultation hours is constant for both scenarios, only the distribution is different. Both scenarios cause an increase in the utilisation rate of the EOCs, but also an increase of the total average utilisation rate for Franciscus (Table 5.16). The average utilisation rate of EOC increases 15% more in scenario 1.1. Nevertheless, the difference in overall average utilisation rate between scenario 1.1 and 1.2 is small, only 2%.

Table 5.14 Patient flow scenario 1 in appointments

Locations	Base	Scenario 1.1	Scenario 1.2
Berkel	1,982	3,240	2,794
Gasthuis	18,209	16,114	17,377
Haven	1,680	1,496	1,682
Maassluis	1,630	3,408	2,552
Oogziekenhuis	378	376	386
Vlietland	16,613	15,860	15,703
Total	40,494	40,494	40,494

Table 5.15 Supply scenario 1 in consultation hours

Base	Scenario 1.1	Scenario 1.2
107	203	163
1,417	1,248	1,361
105	91	105
81	197	136
28	28	28
1,122	1,093	1,066
2,859	2,859	2,859

Table 5.16 Utilisation rates scenario 1

	Base	Scenario 1.1	Scenario 1.2
Average utilisation EOCs	26.8%	57.3%	42.6%
Total average utilisation	38.3%	46.1%	44.2%

5.4.1.1. Results

Subsequently, the KPIs have been calculated, see . The overall average waiting time per patient is not changed at all due to the scenarios, which can be explained by the functioning of the model. The model always searches for the minimal cost and therefore for the optimal combination of waiting time and travel time for an appointment. Waiting time is defined by the utilisation of capacity of a specialty on a location. The utilisation of capacity is divided in three ranges. Each range has a different waiting time, respectively 10, 21 and 42 days. The waiting times are equal for every specialty and specialty. The model tries to fit ever appointment in the utilisation range with the shortest waiting time, to minimise the total inconvenience costs. If this range of utilisation is filled with appointments, the model assigns the appointments to the utilisation range with waiting of 21 days. Lastly, appointments get assigned to 42 waiting days. Although the optimal combination of waiting time and travel time is sought for the appointment, the utilisation ranges with low and medium waiting times are always completely used. Reason for this is that there is a large difference between the possible waiting times. Furthermore, the weight factor for waiting times is higher than for travel time. Therefore, the costs are severely influenced by the waiting time. Additionally, the waiting times are equal for every specialty and specialty. Furthermore, the average wating time per specialty is compared to the average waiting times per specialty of the base model. As established in Section 5.2, the waiting time is only valid for the overall average waiting time. However, the model is verified in Section 5.3 and works as it supposed to work. Therefore, the outcomes of the scenarios for the average waiting time per specialty are compared to base model, to determine the effect of the measure on the waiting time.
Thus, the utilisation ranges with low and medium waiting times are always completely used. The remainder of the appointments have high waiting times. Furthermore, every appointment has equal waiting times, regardless of the specialty or location. Therefore, the waiting time will always remain the same if the number of appointments is not changed.

Although the overall average waiting time is not changed by the shift in consultation hours in the scenarios, the average waiting per specialty is. The effect of the sub-scenarios differs per specialty, see Appendix I.4 for an overview of average waiting time per specialty. The waiting time is decreased for some specialties, such as Ophthalmology, Paediatrics and Rheumatology. For others, the waiting time is barely changed or increased a little. The average waiting time are equal to the base model, among others, for Geriatrics and Cardiology and is increased for, for example, Urology and General Surgery. Due to the different effects of the scenarios on specialties, further research on the effect of reallocation of consultation hours per individual specialty is recommended.

Table 5.17 KPIs for scenario 1

	Base	Scenario 1.1	Scenario 1.2
Cost per consults (€)	34.88	32.66	32.63
Waiting time (days)	19.18	19.18	19.18
Travel time (min)	13.24	12.63	12.36

Nevertheless, the average travel time per patient does decrease due to the scenarios. Notable is that the travel time decreases more when only one extra consultation hour per week is offered at the EOC location(Scenario 1.2). The average cost per consult is decreased by 2 euro for both scenarios.

This scenario causes less travel time for the patients and is beneficial for Franciscus, as it causes a decrease in the costs per consult without any investments. Therefore, this a cheap and relatively easy measure to improve the performance of EOCs Berkel and Maassluis and thereby improve the service for patients.

5.4.1.2. Consequences of the measure

Despite the positive effects of this measure and the fact that no investments are required, the implementation of this measure can be hampered by the involved stakeholders. With the implementation of this measure, more consultation hours will be held at the EOC locations. An inevitable result is that specialists are obligated to work at an EOC location more often. Currently, specialist do not consider the demand of patients at locations. They schedule their consultation hours based on their own preferences. This measure can only be implemented if specialists and supporting staff at the main locations are made aware of the demand of patients at EOC locations. This creates understanding and willingness of specialist to have more consultation hours at the EOC locations. Awareness can be created by communication of the EOC managers to the department managers and specialists of the outpatient clinic of specialties in question. A second way to support the implementation of this measure is to set up agreements between an EOC and a specialism.

Furthermore, an second important factor is the availability of specialists. Some specialists are often needed at the main location for clinical visits or surgeries. Consequently, specialists are not or less available for consultation hours at an EOC, e.g. specialists of General Surgery or ENT. This can cause difficulties for the shift of consultation hours towards the EOC locations.

If specialties agree to offer more consultation hours at EOC locations, one need to ensure that these consultation hours are completely occupied with appointments. As established in Section 3.3, the call centre in Vlietland and the outpatient clinics of Gasthuis are responsible for scheduling patients. They need to offer the EOCs as a possible location for appointments whenever a patient makes an appointment. This way the extra consultation hours get properly assigned. Scenario 1.1 is based on adding multiple consultation hours of specialties at EOC locations per week. Due to the requirements mentioned in the previous paragraph, this is will not be achieved on the short term. Therefore, scenario 1.2 is created. In Scenario 1.2, specialism offers only one extra consultation hours per week at both EOCs. The results show that just one extra consultation hour per specialism at the each EOC has a positive impact on the service for patients.

5.4.2. Scenario 2 – Investments

Not all specialties are offered at every location, either due to an agreement with the concerned party at that location or to the lack of recourses at a location.

Franciscus has an agreement with Oogziekenhuis to have consultation hours for Internal Medicine for four days a week in their hospital. Furthermore, Franciscus has an agreement with the other hospitals she collaborates with at Haven Polikliniek, she is responsible for the consultation hours of cardiology, ENT, Pulmonary medicine and Urology. Therefore, the types of specialties are fixed for Haven and Oogziekenhuis.

Due to a lack of resources at EOCs Berkel and Maassluis, not every specialty is available at these locations. Some specialties (for example, ophthalmology and ENT) require special devices for diagnosis and treatment of patients during their consultation hours. This causes inconveniences for specialists and makes the EOC locations less attractive to have consultation hours. Besides, this causes a lack of service for the patients, because patients need to make an extra appointment at a different location. Therefore, this scenario is created to test whether investments would be beneficial for the service for patients. The following investments are tested:

- Scenario Opht: Ophthalmic equipment for Berkel. By installing this equipment, ophthalmology becomes available at the EOC Berkel. Due to this investment, Ophthalmology can be offered twice a week in Berkel, so the number of consultation hours is increased by eight consultation hours per month for Berkel. Whereupon, both Gasthuis and Vlietland can drop one consultation hour per week, so four consultation hours per month.
- Scenario ENT: An audio booth for ENT in Berkel. This is a small noise cancelling booth where audio tests are executed by the ENT. This investment provides two extra consultation hours per week, so eight per month, for ENT at Berkel. This increase for Berkel is at the expense of consultation hours at Gasthuis.
- Scenario Car: A home trainer for Cardiology in Maassluis. Cardiology performs a bike proof by patients to test their endurance and functioning of the heart. This results in two extra consultation hours per week at Maassluis causing a decrease of consultation hours for the main locations.
- Scenario Rad: An X-ray and ultrasound in Maassluis. Many specialties make use of at least one of these device to diagnose their patient, being General Surgery, Internal medicine, Pulmonary medicine, Cardiology, Orthopaedics and Gynaecology. The consultation hours at Maassluis increase with respectively 4, 4, 4, 4, 2 consultation hours per week when these devices are installed. These are merely distracted from the consultation hours in Gasthuis.

Table 5.18 gives an overview of the redistribution of consultation hours per month caused by the investments.

Table 5.18 The shift in consultation hours per scenario per month over the Franciscus locations

Locations	Scenario Opht	Scenario ENT	Scenario Car	Scenario Rad
Berkel	8	6		
Gasthuis	-7	-4	-5	-69
Haven				
Maassluis			6	78
Oogziekenhuis				
Vlietland	-1	-2	-1	-9
Difference	0	0	0	0

5.4.2.1. Results

The outcomes of the scenario show a shift of appointments towards either the EOC Berkel or Maassluis, decreasing the number of appointments at the main locations. The effects of scenario Opht, ENT and Car are limited, but the investment of the X-ray and ultrasound increases the number of appointments with approximately 1,000 for EOC Maassluis. Table 5.19 and Table 5.20 present the patient flow and consultation hours per location for all scenarios.

Table 5.19 Patient flow for scenario 2 in appointments

Locations	Base	Scenario Opht	Scenario ENT	Scenario Car	Scenario Rad
Berkel	1,982	2,185	2,078	1,979	1,980
Gasthuis	18,209	18,039	18,153	18,154	17,400
Haven	1,680	1,681	1,680	1,678	1,684
Maassluis	1,630	1,631	1,631	1,722	2,744
Oogziekenhuis	378	386	378	384	379
Vlietland	16,613	16,572	16,574	16,577	16,307
Total	40,494	40,494	40,494	40,494	40,494

Table 5.20 Supply for scenario 2 in consultation hours

Locations	Base	Scenario Opht	Scenario ENT	Scenario Car	Scenario Rad
Berkel	107	115	113	107	107
Gasthuis	1,417	1,410	1,413	1,412	1,348
Haven	105	105	105	105	105
Maassluis	81	81	81	87	159
Oogziekenhuis	28	28	28	28	28
Vlietland	1,122	1,121	1,120	1,121	1,113
Total	2,859	2,859	2,859	2,859	2,859

Table 5.21 shows the average utilisation rates for the EOCs and all locations. Each scenario has positive influence on the utilisation of the EOCs and the total average utilisation. However, this influence is very little for the scenarios Opth, ENT and Car. The scenario Rad causes an more significant increase of the utilisation rate of EOCs, but the total average utilisation is still increased by only 3.5%. The little effects of the scenarios can be explained by the small change in capacity of specialties on a location. The investments for scenarios Opht, ENT and Car only causes a change in distribution of consultation hours of one specialty. Therefore, the effect is small, since all locations offer consultation hours of at least 14 specialties. For these other specialties, the distribution of the consultation hours have not changed. Scenario Rad has effect on multiple specialties, therefore the changes in patient flow and average utilisation rates are more significant.

Table 5.21 Utilisation rates for scenario 2

	Base	Scenario Opth	Scenario ENT	Scenario Car	Scenario Rad
Average utilisation EOCs	26.8%	27.9%	27.5%	27.6%	38.9%
Total average utilisation	38.3%	38.9%	38.5%	38.6%	41.8%

Subsequently, the KPIs are calculated for each scenario, the results are shown in Table 5.23. As explained in the previous Section, the overall average waiting time is not changed by scenarios with investments. However, the average waiting time per specialty is changed due to the investments, Appendix I.4 for an overview of average waiting time per specialty. In Table 5.22, the average waiting times of the involved specialties are presented. Scenarios Opth and ENT cause an decrease in waiting time for respectively Ophthalmology and ENT. The scenario Car does not influence the average waiting time for Cardiology. Lastly, the scenario Rad has different effects on the affected specialties. The waiting times for specialties Cardiology and Internal Medicine are decrease. On the contrary, the waiting times for specialties General Surgery, Orthopaedics and Pulmonary Medicine are increased a little. For Gynaecology, the waiting time remains equal to the base model. Due to this results, it can be concluded that the scenario RAD has different effects on the average waiting time for the involved specialties. Franciscus should take these different effects into account when a decision is made considering this implementation.

Table 5.22 Average waiting time per specialty in days for scenario 2

Specialties	Base	2.Opth	2.ENT	2.Car	2.Rad
Cardiology	16,7			16,7	16,6
ENT	20,6		20,3		
General surgery	16,3				16,7
Gynaecology	21,7				21,7
Internal medicine	16,8				16,5
Ophthalmology	19,3	18,9			
Orthopaedics	22,2				22,6
Pulmonary medicine	22,4				22,7

The average travel time is increased in three out of four scenarios, as can be seen in Table 5.23. This increase was not expected and indicates that the scenarios have a negative effect on the service for patients. However, the changes for travel time are minimal for every scenario. The run of Scenario Rad results in a decrease of travel time.

Finally, Table 5.23 shows a reduction of the cost per consult for all four investments. The scenario that includes an X-ray and ultrasound device in Maassluis has the most positive effect on the cost per consult, this scenario causes a decrease of 1.22 euro. The ophthalmology equipment has caused a decrease of half an euro per consult, Scenario ENT 18 cents and Scenario Car 26 cents.

Table 5.23 KPIs for scenario 2

	Base	Scenario Opht	Scenario ENT	Scenario Car	Scenario Rad
Cost per consult (€)	34.88	34.39	34.70	34.62	33.66
Waiting time (days)	19.18	19.18	19.18	19.18	19.18
Travel time (min)	13.24	13.33	13.37	13.36	13.08

Investment costs are the inevitable result of the previously introduced scenarios. The investment costs for each scenario are given in Table 5.24. For each investment is determined whether it would beneficial to implement the devices. This is carried out based on the extra appointments the implementation generates for the location in question. Whereupon, the benefit per appointment is calculated by the difference between the current cost per consult and the new cost per consult. The total benefit per year is determined to calculate how many years it will take to cover the expenses of the investment by the benefit of that investment (see Table 5.24).

The investment scenario for the home trainer (CAR) and the radiology equipment (RAD) are very beneficial, the latter will be paid off in two years and the home trainer would not even take a year. For the scenarios Opht and ENT it will take respectively 29 and 58 years before the expenses are covered. Whether this is acceptable depends on the lifespan of the equipment and the considerations of Franciscus, regarding their strategical goals for the EOCs. In case the equipment last at least 40 years it might be an option, but if the equipment has a lifespan of five years, the investment is not beneficuial at all. It highly unlikely for the equipment to last the years it needs to cover the expenses. Therefore, the investments are assumed to be non-profitable.

Table 5.24 Cost and benefit of scenario 2

	Cost (€)	Benefit (€/consult)	Extra appointments	Total benefit/year (euros)	Years needed
Scenario Opht	200,000	2.80	203	6,820,-	29
Scenario ENT	100,000	1.49	96	1,716,-	58
Scenario Car	200	1.35	92	1,490,-	< 1
Scenario Rad	330,000	10.27	1,114	137,289,-	2.5

5.4.2.2. Consequences of the measure

The investment in Radiology equipment increases the number of appointments during consultation hours. However, the patients that need to visit the Radiology department are not considered in the calculated average cost per consult, because only three consult types are included. Consequently, the number of appointments grows even more for the EOC Maassluis and therefore the total costs per consult is further decreased. Furthermore, due to the implementation of the devices, patients do not have to arrange an new appointment at another location anymore. They can most likely be treated directly before or after their appointment with the specialist. This causes an increases in service for patients.
The investment would also increase the attractiveness for specialists to work at the EOC Maassluis. Now, they can do a full diagnoses at once and do not have to see the same patient at various locations anymore.
However, for the installation of the X-ray device a room needs to be rebuild, which is at the expense of the room capacity of a location. The room capacity decreases and less patients can be seen at the EOC Maassluis. Nevertheless, not all rooms at Maassluis are currently occupied, hence the capacity will still be sufficient for the expected demand (Korthorst & Stelt, 2019).

5.4.3. Scenario 3 – Forecast

This scenario is set up to determine whether the current location capacity is sufficient for the coming five years. Furthermore, the scenario is used to evaluate whether the current number of consultation hours of specialists can cope with the increasing number of patients. If not, measures should be taken to keep up with the patient growth over the years. The model is run for the years 2020-2025, including the patient growth. Other values for variables and parameters are equal to the base model., since it is assumed that the supply of Franciscus remains the same. The patient growth is based on the expected population growth of the cities and towns in the care area (RIVM, 2019). For each year a database is created where new appointments are added for each town based on the growth with respect to the previous year. Figure 5.2 shows the patient growth curve for every town in the care area.

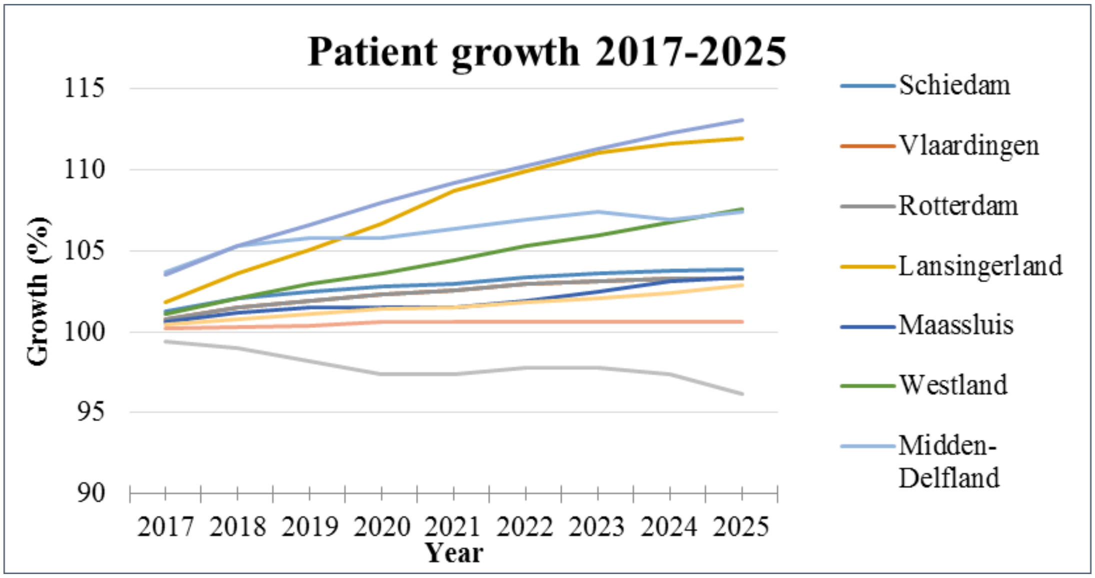

Figure 5.2 Patient growth 2017-2025

Lansingerland (3B area) and Midden-Delfland are expected to have a growth of more than 10% in the coming years. Especially the growth of Lansingerland has significant influence on the total patient growth due to her current population of 61,601 inhabitants and the growth of over 10%. Rotterdam is the biggest city in the care area of Franciscus, this city has 10 times more inhabitants than every other city. Although the expected population growth for Rotterdam is limited (3%), this growth has the biggest impact on patient growth for patients. Hence, 44% of the patients of Franciscus are originated from Rotterdam. The population growth is negative for Albrandsewaard. Nevertheless, this development has little effect on the patient growth due to its small contribution the number of patients (1,2%). In Appendix I.4, the patient growth is presented.

The new appointments are added to the database based on the average distribution of consult types among consultation hours in 2019: 30% first consults, 65% repeat consults and 5% call consults. Hence, for every year for every place the growth is calculated and distributed over the types of consults. Subsequently, the appointments are added randomly spread over the postal codes of the town or city and equally distributed over the specialties.

5.4.3.1. Results

Before optimising, the model first checks its data to determine whether there is enough capacity to assign all appointments. Otherwise, the model becomes infeasible and an optimal value cannot be found. The current capacity of the Franciscus locations is sufficient for the patient growth in the coming five years. However, there an inadequate shortage of capacity for several specialties. The capacity of consultation hours of Geriatrics is already insufficient for the coming year, 2020. Moreover, the current capacity of Urology will not be enough from the year 2021 on. Lastly, the capacity of Neurology is insufficient from 2024.

To compensate these shortages, the capacity of these specialties are adjusted. For the scenario of 2020 four consultation hours per week for Geriatrics are added to the EOC Berkel and Maassluis. The same accounts for Urology for the scenario of the year 2021. For the scenario 2023, the capacity of Geriatrics is further increased with four consultation hours per week in Gasthuis and Vlietland. Furthermore, the capacity of Neurology is enlarged with four consultation hours a week in Maassluis and Berkel. An overview is presented in Table 5.25. The number of consultation hours that are added for specialities, are the minimal consultation hours needed to achieve sufficient capacity.

Table 5.25 Added consultation hours for scenario 3

Consultation hours/month	Geriatrics	Urology	Neurology
Gasthuis			
Vlietland			
Berkel	32	16	16
Maassluis	32	16	16
Haven			
Oog			
Difference	64	16	16

The results of patient flow and supply for this scenario are represented in Appendix I.4. In 2025, the total number of appointments is increased by 1020 appointments per month. The patient flow and consultation hours are mainly increased for the location Berkel and Gasthuis. This is due to the increased number of consultation hours and the large share Lansingerland and Rotterdam have in the patient growth. The flow and supply for Maassluis and Vlietland have increased and they barely changed for Oogziekenhuis and Haven. In Figure 5.3, the development of the utilisation rates for the EOCs and the average over all locations is presented. The average utilisation rates have increased, but are hardly influenced by the appointment growth. Furthermore, the utilisation rate for the EOCs is increased by less than 5% and the locations are still occupied by only 30%.

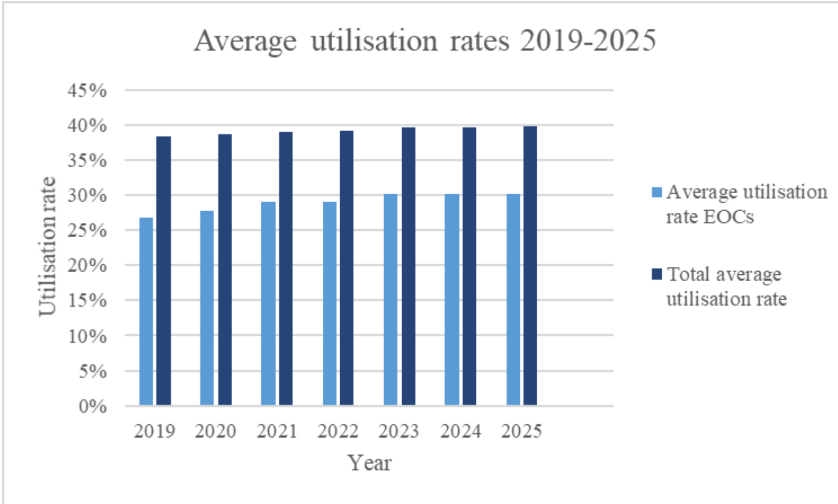

Figure 5.3 Utilisation rates for 2019-2025

Subsequently, the values for the KPIs are presented by figures that show the development of the KPIs values through the coming five years (see Figure 5.3-5.5). In case the total costs for the locations of Franciscus remain the same for the upcoming years, the patient growth causes a decrease in the cost per consult. As depicted in Figure 5.3, the growth of 1020 appointments given the current capacity of specialties on locations decreases by approximately one euro per consult. This saves Franciscus a significant amount of money given the total patient flow per year (430.000 polyclinical appointments in 2019).

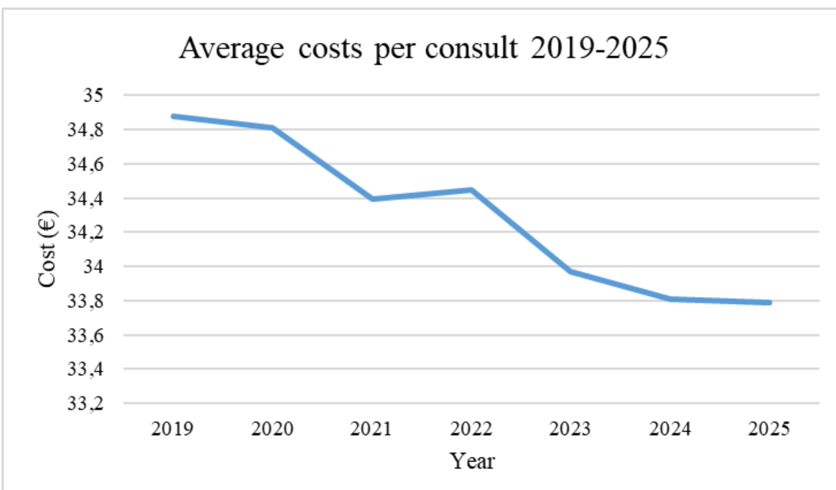

Figure 5.4 Cost per consult for 2019-2025

Over the next five years, the waiting time is increased, see Figure 5.5. The model shows an increase of just 0.25 days per appointment. This can be explained due to the growth of number of appointments per month, this is less than 3% of the current number of appointments. Nevertheless, each extra appointment causes an increase for the average waiting time per patient. Furthermore, the average waiting time per specialty is analysed. The waiting time for every specialty is increased, except for the specialties wherefore the capacity is enhanced. The waiting time is decreased for these specialties, since more appointments can be scheduled in the utilisation ranges with low or medium waiting times. This is due to the enlarged capacity.

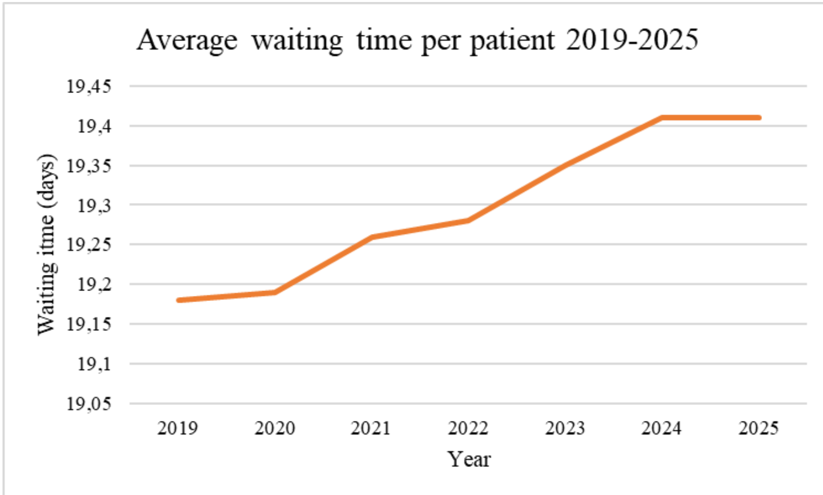

Figure 5.5 Waiting time for 2019-2025

The average travel time per patient is barely influenced by the increasing number of appointments. As can be seen in Figure 5.6, the average travel time increases in 2020 and decreases again in 2022. The next three years the travel time is more or less constant. In this scenario, the model is forced to allocate more appointments over the Franciscus locations given the same capacity of specialties over locations, except for Geriatrics, Neurology and Urology. This causes a small increase in the travel time. However, because the supply at locations remains more or less the same for the forecast scenario, patients are allocated in the same way by the model. The results of this scenario show that the average travel time per patient is barely influenced by the number of patients.

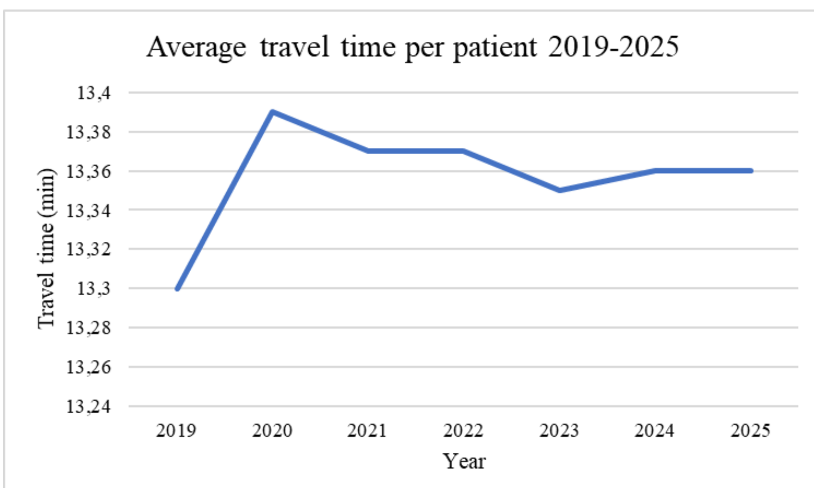

Figure 5.6 Travel time for 2019-2025

The patient growth used for this scenario is based on the population growth in the care area. However, the scenario neglected the fact that the ‘grey pressure’ is increasing. The grey pressure represents the percentage of elderly (people that are 65 years or older) with respect to the total

population. This pressure will grow for every region in the coming years with an average of 4%. In general elderly require more care, so the growth of patients can be higher than estimated in this report. As mention in Section 2.2, it is becoming more important to provide care closer to the patients home, among other, due to aging. Elderly are less able to travel for their care, therefore care has to be provided close to their homes. Consequently, EOC locations are of high importance for these patients.
A second development that is not taken into account is the upcoming e-health, the digital healthcare. This development makes it possible for patients to diagnose themselves and visits to the hospital will become redundant (Zorgvisie, 2019). Due to this development the growth of patients can be overestimated.

5.4.4. Conclusion

This chapter contains the implementation phase. In this phase, the LP model is applied for Franciscus. Based on the results of the application of the model, the last sub-question can be answered:

What possible measures can increase the performance of the external outpatient clinics of Franciscus Gasthuis & Vlietland and what is the effect of these measures?

To answer the sub-question several measures have been contemplated, based on the current state analysis and the theoretical base that is created in the explorative phase. The measures are as follows:

- A shift in consultation hours of specialties over the Franciscus locations;
- Investments for the EOC locations.

The first measure causes a shift in consultation hours towards the EOCs Berkel and Maassluis, which improves the performance of EOCs. This measure can be implemented without any investments and increases the average utilisation rate for EOCs and the overall average utilisation rate. Furthermore, this measure decrease the average travel time per patient. Due to the way the model functions, waiting time is not affected by the scenarios. The effect on the average waiting time for specialties differs per specialty. The waiting times are decreased for some, but remain equal for others. Due to the different effects of the scenarios on specialties, further research on the effect of reallocation of consultation hours per individual specialty is recommended. In general, this measure increases the service for patients, because it decreases the average travel time per patient and decreases the average waiting time for some specialties.

The implementation of this measure could be hampered by involved stakeholders. To achieve a shift in consultation hours towards the EOC locations, specialists need to be willing to offer consultation hours at these locations. To achieve more willingness, specialists and supporting staff of outpatient clinics need to be more aware of the demand of patients at the EOC locations. This can be achieved by better communication between Manager EOC, specialists and department managers. Furthermore, the availability of specialist also influences the implementation of the measure. Specialist that often need to be present at the main locations for surgery or clinical visits, are less available for consultation hours at the EOC locations. Therefore, this can cause a bottleneck for the shift in consultation hours towards the EOC locations. Lastly, the call centre and outpatient clinics at Gasthuis are responsible for filling the extra consultation hours with patients. If the extra consultation hours are not completely occupied, the measure will not last. Sequentially, specialists will cancel the consultation hours or shift back to the main location.

The second measure is investing in equipment to increase the consultation hours of specific specialties at EOC locations. Four investments are analysed:

- Ophthalmology equipment at EOC Berkel
- Audio booth at EOC Berkel
- Home trainer at EOC Maassluis
- Radiology equipment (an X-ray and ultrasound device) at EOC Maassluis

For all investments, the performance indicators and KPIs are calculated. Additionally, a small cost/benefit analysis is carried out. Based on the results, it is determined that only Radiology equipment would be a good measure.
The investment of Radiology equipment increases the utilisation rate of the EOCs and the overall average utilisation rate and decreases the costs per consult for. Besides, this investment increases the service for patient. The Radiology equipment at Maassluis decreases the average travel time for patients. Furthermore, the effect on average waiting time per specialty differs per specialty. The waiting time decreases for some specialties and increases for others. Franciscus should take these different effects into account when a decision is made considering the implementation of these devices. Furthermore, the investment costs of this equipment will be covered within three years. This is calculated based on the increased number of appointments at the EOC locations due to the investment and the difference in costs per consult. Based on this information, it is determined how long it takes for the investment to become beneficial.

The investment also attracts people for Radiology, this includes appointments that are not included in the dataset of the scenario. As mentioned in Section 0, it is not necessary to schedule an appointment for X-rays. Therefore, the number of patients grows even more, which causes a positive effect on the average costs per consult. Furthermore, the investment increase the service for patients. Patients no longer need an extra appointment at another location and can be directly treated before or after their consult in Maassluis. Besides, Maassluis also becomes more attractive for specialists, since they now can complete their diagnosis for patients at once. The investment requires the space of one room, causing an decrease in location capacity. However, currently there are unused rooms during opening hours in Maassluis, therefore the implementation of the equipment will not cause any capacity difficulties.

Concluding, there are two types of measures that improve the performance of EOC locations. Both types of measures cause an increase of consultation hours at the EOC locations. The first measure contains a shift of consultation hours without any investments. The second measure is an investment that causes a shift of consultation hours. Both measures cause a decrease in average travel time per patient. The effect on average waiting time per specialty differs per specialty and should be further investigated before implementing one of the measures.

6. Conclusion

The concluding phase is the final phase of this study, see Figure 6.1. In the last phase, the main research question is answered. The answer is provided by the sub-question that have been answered throughout the different phases of this study. Subsequently, the methodology and the model used in this research to provide an answer to the research question are discussed. Lastly, recommendations for future research are given.

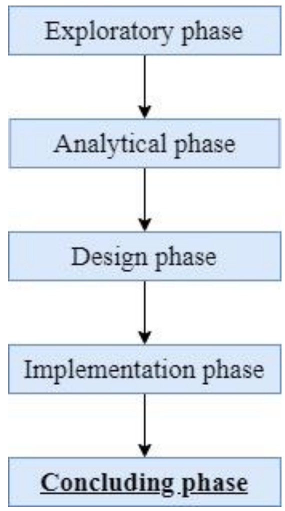

Figure 6.1 Exploratory phase of this study

6.1. Main conclusion

The main objective of this research was to find measures to improve the performance of the EOCs to in order to increase the service for patients. This was translated into the following research question:

How can the performance of the external outpatient clinics of Franciscus Gasthuis & Vlietland be improved to increase the service for patients?

This research was divided in five phases, each phase is performed with different methods. Sub-questions one and two are answered in the exploratory phase. This phase created a theoretical base for the following phases. In the analytical phase, bottlenecks are established for the current state of Franciscus. Subsequently, the performance indicators and KPIs are measured to determine the current performance of the EOC locations and the service for patients. The outcomes of the analytical phase are used as base for the design of the model in the design phase. In the design phase, a LP model is designed. This model is applied for Franciscus in the implementation phase. In the last, concluding phase, the findings of all phases are used to answer the main research question of this study. In this section, the answer to the main research question is provided by means of the answers to the sub-questions.

6.1.1. The role of EOCs in the Dutch Healthcare System & Franciscus

EOCs are clinics set up by hospitals on the edge of their care areas or between two hospital locations of the same hospital organisation. These clinics are used for polyclinical appointments of one or several specialties. With an EOC, the hospital aims to increase the number of patients and provides care closer to the patient's home. The latter has become the main purpose for the use of EOCs for hospitals, because of recent developments in the hospital sector. As a result of the implementation of the ZVW in 2006, the focus lies more and more on the service for patients and accessible high quality care. If a hospital provides care of good quality, it is more likely to have an agreement with healthcare insurance companies. Furthermore, providers of primary healthcare rather refer to hospitals with a good reputation. Among other, by means of EOCs, elective, chronic and acute care are spread over various locations. At the same time, highly complex care is concentrated at the main location. The EOCs contribute to the initiative of "The right care at the right place", which aims to achieve accessible care for everyone. Moreover, the EOCs support transmural care by improving the collaboration of primary and secondary healthcare providers. These initiatives aim to improve the availability of the required care by the right provider.
Franciscus has set up EOCs on the edge of her care area to attract patients and to offer patients care closer to their homes. EOC Berkel focuses on patients from the 3Bs (Berkel, Bergschenhoek and Bleiswijk). Moreover, this location is used to attract patients from Delft, Pijnacker and the towns in between, to strengthen the position of the Franciscus with respect to Reinier de Graaf in Delft. The EOC Maassluis is set up for patients in Maassluis and Westland, since no hospitals are present in a close proximity to this area. Franciscus is still the only hospital in Maassluis and surrounded areas that provides specialised secondary healthcare. The EOC Hoogvliet has been set up after bankruptcy of the Ruwaard van Putten hospital. However, this location has been closed since November 2019. The number of patients was decreasing due the MC Spijkenisse and the location had become not beneficial anymore. The EOCs also contribute to transmural care as both EOCs work closely with GPs.

Thus, EOCs are used by hospitals to provide care closer to the patients' home and therefore benefits the service for patients. Franciscus has also set up EOCs for this purpose and to enlarge her care area. EOCs contribute to initiatives as "The right care at the right place", transmural care and concentration and localisation of specialised care. These initiatives are set up to in the quality and accessibility of care for patients.

6.1.2. Decision factors for hospital location choice of patients

Service for patients has become increasingly important for hospitals. The availability of the services at the EOCs are important for the performance of the EOCs. To improve the performance of EOCs, factors that influence the hospital location choice for patients are determined. The factors are established by a literature review. Eventually, several factors have been determined that influence the location choice for patients the most:

- Travel time
- Waiting time
- Quality of care
- Availability of facilities
- Influence of General Practitioners
- Recommendations of family and friends

Since each type of care is provided by the same specialists at every location, the quality of care is assumed to be equal for every location and therefore insignificant for this study. For this reason, the influence of general practitioners and the recommendations of family and friends are also irrelevant. Moreover, availability of facilities also influences the choice of hospital for clinical patients. However, this study is focused on polyclinical patients, therefore food and accommodation are not provided for these patients. Considering these circumstances, the availability of facilities is not taken into account as factor for hospital choice.

Hence, Travel time and waiting time are the factors that define the service for patients. Each patient prefers to have the shortest travel time and the shortest waiting time for their appointment. Waiting time is defined by the time between scheduling an appointment and the moment of the appointment. Travel time is the time it least for a patient to travel to the location in question. These factors define the service for patients in this study.

6.1.3. The bottlenecks of EOCs Franciscus

Bottlenecks have been identified in the current state analysis for Franciscus. Subsequently, the effect of these bottlenecks on the performance of EOCs and service for patients have been quantified. Three components have been analysed: The stakeholder, the customer journey and the data. A stakeholder analysis resulted in insight in the role of stakeholders towards the EOCs, the key players have been determined. These key players have a significant influence on the decision-making process considering the EOC locations. Subsequently, an impression of the attitude towards EOCs and the general reputation of the EOCs is obtained. Furthermore, the customer journey represents the activities carried out by the hospital and the patient during a visit of an EOC. Based on a visualisation of the customer journey, waste is determined which causes a reduction in performance. The following bottlenecks are identified in the systems of Franciscus and its EOCs:

- The specialists have a lot of influence on the utilisation of the EOCs, because the schedules of the EOCs are fully dependent on the planning of the specialist. The schedules of specialists are based on the preferences of specialists and the demand of patients is not taken into account.
- The importance of the EOCs are underestimated by the main locations. Consultation hours are easily cancelled at EOCs if a specialist is needed at the main location. Furthermore, there are no consequences if a consultation hour is cancelled too late.
- The waiting time for patients is often exceeds the Treeknorm of 28 days. For some specialties the waiting time is higher at the EOCs than at the main locations. This causes a lack of service for patients and influences the referring choice of primary healthcare providers.
- A lack of communication between the main locations and the EOCs. For example, EOCs do not get notice when consultation hours are cancelled. Furthermore, the coordinator does not receive any information concerning the planning of the specialists. They have to look for the planning of each specialist in HER of Franciscus, HIX. This causes them a severe amount of time, since they have to check the schedule of every individual specialist.
- Franciscus has an inefficient appointment system. There is a different system for every locations. For an appointment at Vlietland or Maassluis patients need to call the call centre at Franciscus. Whereas, appointments at Gasthuis or Berkel are scheduled by the outpatient clinics. Furthermore, both locations do not schedule appointments for the other main locations. Therefore, not every location is taken into account when an appointment is scheduled.

Lastly, with the data retrieved from the Business Intelligence department of Franciscus, an data analysis is performed. The current performance and service for patients for the year 2018 are quantified by performance indicators and KPIs.
In general, it is concluded that there is a mismatch between demand and supply at the Franciscus locations, due to the established bottlenecks. This causes lack of performance at the EOCs and therefore a lack of service for patients. The low average utilisation rate of the EOCs(21.4%) and the large share of patients (88%) at the main locations have a negative effect on the costs per consult per patient and the overall average travel time per patient. The average travel time per patient is longer than necessary for six out of seven locations. Furthermore, the overall average waiting time per patient is less than the Treeknorm. However, for four specialties (Geriatrics, Internal Medicine, Neurology and Ophthalmology), the average waiting time exceeds the Treeknorm. Besides, for several specialties (for example, Dermatology, Paediatrics) the waiting time is longer for the EOC locations than the main locations. This has a negative effect on the attractiveness of EOCs and patient flow at the EOC locations. Moreover, the high average waiting time causes inconvenience for patients, affecting the service for patients.

6.1.4. Measures to increase the performance of EOCs Franciscus

The bottlenecks determined in the current state analysis for Franciscus, cause a mismatch in supply and demand at her locations. This affects the performance of EOCs and the service for patients. Service for patients has become increasingly important for hospitals and EOCs benefit the service for patients, therefore their performance need to be increased. A LP model is designed to match supply of consultation hours and demand of patients for multiple hospital locations. The LP model optimises the allocation of appointments of patients over multiple locations to minimise the inconvenience cost of waiting time and travel time for all appointment for all locations. The model optimises considering the capacity constraints of locations and specialties on locations. The appointments are allocated based on patients preferences instead of specialist preferences. It is assumed that specialist are able to work at every location given the demand of patients and the maximum total capacity of consultation hours for the specialty in question. The model assigns each appointment based on origin of the appointment and consult type to any possible location. The waiting time is taken into account as constant depending on the utilisation rate of specialty capacity. The utilisation of a specialty is divided in different ranges, each range has a different value of waiting time. Furthermore, the model uses weight factors to determine the influence of travel time and waiting time on the total inconvenience costs for appointments.

The model is applied for Franciscus. Data of March 2019 is used to validate the model and to set up a base model. The values of the estimated parameters are calibrated and, subsequently, the model is verified and validated. From validation can be concluded that the model slightly overestimates the number of appointments for the EOCs. This causes a small decrease in the average utilisation rate for EOCs and the average cost per consult. Therefore, conclusions are drawn on the effect of measure, but the actual values are not taken into account. With scenarios, the effect of several measures are analysed. The scenarios are focused on three different aspects:

- Measure 1. Shift in consultation hours of specialties over the locations;
- Measure 2. Investments in resources on the EOCs;
- Forecast for 2020-2025.

For each scenario run, the results are quantified by performance indicators and the KPIs. Due to the functioning of the model, the overall average waiting time per patient has not changed for the first and second scenario. In these scenarios, the number of appointments remained the same, due to the equal waiting for every location overall average wating time per patient is unchanged. Therefore, the effect of the measure on the waiting time cannot be measured due to the design of the model. Nevertheless, the effect on service for patients can be determined by the change in travel time for patients.

A good measure to improve the performance is to increase the number of consultation hours for specialties at the EOCs Berkel and Maassluis. According to the results of scenario 1, one extra consultation hour of each specialty at both locations already has a positive effect on the service for patients. The average utilisation rate of the EOCs is increased by 15% and the average cost per consult decreases by 2 euro per patient. Besides, the average travel time patient is decreased by 1 minute. This is relatively much given the current value of 13.24 minutes. Furthermore, more consultation hours at the EOCs decreases the pressure on the main location. Besides, patients are able to receive care closer to their homes, making care more accessible for the patients. To be able to implement this measure, changes in the organisation of Franciscus are necessary. Specialist need to be willing the have more consultation hours at the EOC locations. Furthermore, the appointment systems need to be adjusted to ensure that patients receive care at the right locations. Only then, extra consultation hours at EOCs can be complete occupied.

A second measure is the implementation of investments to increase the consultation hours at one of the EOC locations. In total, four investments are tested:

- Ophthalmology equipment for EOC Berkel;
- Audio booth for EOC Berkel;
- Home trainer for EOC Maassluis;
- Radiology equipment for EOC Maassluis.

Nevertheless, the results of the model runs of these investments and the small cost-benefit analysis show that only one investment is beneficial for Franciscus: radiology equipment for EOC Maassluis. These devices have rather high investment costs, but the cost is covered within three years. This is concluded from cost/benefit analysis based on the extra number of appointments the investment causes for EOC Maassluis. The average utilisation rate of the EOCs are increased by 12% and the average cost per consult is decreased by 1 euro. Nevertheless, the service for patients as determined for the model does not improve much due to this investment. The travel time is only slightly decreased. However, these devices do contribute to the service for patients due to the possibility for patients to have multiple appointments at once at the same location. Without these devices, the patient needs to schedule an extra appointment at another time and location. Besides, the investment creates a more attractive environment for specialists to work in. Multiple specialties use one of these device for diagnosis of their patients. Specialists will schedule more consultation hours at the EOC locations, which causes a positive effect on the performance of EOCs and the service for patients.

Lastly, the capacity of Franciscus locations are sufficient for the patient growth from 2020-2025. However, the total capacity of Geriatrics, Urology and Neurology needs to be increased by a couple of consultation hours per week to cope with the expected patient growth.

Thus, the performance of the EOC locations can be improved by two measures. The measure to increase consultation hours at EOC locations at the expense of the main locations and the investment in Radiology equipment for EOC Maassluis. Both cause an decrease for the average travel time per patient and average cost per consults. Therefore, the service for patients is increased, since patients can receive care closer to their homes. Recommendations are provided for future work and for Franciscus with possible measures that were out of scope for the research.

6.2. Discussion

This Section contains a reflection on the methodology and model used to answer the main research question of this study. The aim of this research is to find possible measures to improve the performance of the EOCs of Franciscus. This is done by designing a LP model that optimises the allocation of patients over multiple locations based on patient preferences. This Section discusses the uncertainties of the model, its assumptions and the methodologies applied.

A literature review is carried out to determine the factors that influence the choice of a hospital location for patients. Subsequently, a second literature review is carried out on models that are used for patient planning optimisation. For both reviews, literature is searched based on keywords chosen by the researcher, creating subjectivity. Furthermore, the literature that is used as a result of this search is based on judgement of the researcher as well. Nevertheless, both reviews are clearly structured, which makes the literature study reproducible for other researchers. The literature reviews create an overview of research that is already carried out and prevents unnecessary reproduction. The decision-making factors that are presented in the review are limited to factors that could be relevant for this study. Not all factors are taken into consideration in the rest of this research, due to the fact that all locations belong to the same organisation. Consequently, factors as quality and recommendations by friends or GPs are excluded. Nevertheless, these factors can be relevant for other research involving multiple hospital organisations.

The current state analysis is carried out for one single hospital and can only be used for this specific hospital. The stakeholder analysis and the customer journey are merely based on observations and conversations with employees of Franciscus. Due to the interviews with a variety of stakeholders, the reputation of EOCs at Franciscus can be put in broader perspective. Nevertheless, each stakeholder is biased by their own function and not every stakeholder is interviewed. This causes difficulties to set up a general representation of the methods and activities of Franciscus. Furthermore, the data analysis is based on data provided by Franciscus and is gathered by the Business Intelligence Department. The utilisation rates of realised consultation hours versus the planned consultation hours per location are likely to be miscalculated for the specialty Urology due to its high values. One of the causes could be the turbulent year for Urology at Franciscus. In 2018, it was often uncertain whether Urology consultation hours were available or not. Therefore, consultation hours were perhaps scheduled last minute and were only taken into account as scheduled consultation hours. However, the exact error cannot be identified, because the data is not accessible for the researcher. The current state analysis is mostly relevant for Franciscus itself, this analysis creates insight in the missed opportunities, the lack of performance and bottlenecks that cause inefficiency for Franciscus.

The modelling method used to design the model is LP. This method is often used for planning and scheduling problems. It has the ability to solve large problems with many variables and constraints (Loucks & Beek, 2015). One of the advantages of LP is that it facilitates sensitivity analysis. This analysis is used to determine the sensitivity of the objective function to assumed parameters in the model. Within the designed model, several parameters are estimated. Further research is required to determine the actual values for these parameters. Therefore, sensitivity analysis is relevant to determine the sensitivity of the model towards these assumptions.

The LP method can only be used both the objective function and constraints are linear. Due to this property, waiting time is taken into account as linear variable. However, waiting time is actually a non-linear dynamic variable that changes over time. This causes deficiency of validation of the model, effecting the usability of the model. In hindsight, a different method for the design of the model could have provided a more accurate model. The LP method is mainly chosen on skill of the researcher and based on previous research. The method is not chosen on an elaborated comparison with other methods. Such comparison could have led to the decision to use a different method. For example, discrete event simulation. This method can include dynamic variables as waiting time, which could have a positive impact on the outcomes of this study. With dynamic waiting time, more valid and therefore reliable outcomes could be simulated. However, discrete event simulation is less suitable for calibration and sensitivity analysis, due to long running times. In this study, calibration is used to find values for estimated parameters to validate the model. With discrete event modelling, this could not have been carried out, which could cause a lack in validation. The model that is created for this study is a first design for the optimisation of the allocation of patients for multiple specialties over multiple hospital locations. Therefore, the model is not yet applied or reviewed by other researchers.

The model is applied for Franciscus to find measures that improve the performance of EOCs and increases the service for patients. Data of a single month, March 2019, is used for the application of the model. In the hospital sector the patient flow differs per month, due to holidays and characteristics of the month, for example weather and temperature could influence illness and injuries. Therefore, the data of one month is used to validate the model as good as possible. March 2019 is chosen because it is a month in the most recent year and March is a relatively average month without any holidays or extreme characteristics. It is also considered to create an average month based on the data of Franciscus. The advantage of an average month is that it creates the opportunity to draw conclusions on a yearly base and more useful when focusing on the long term. However, due to the reasons mentioned before, the data would not be representative for busy months, such as October and November.

The model uses total capacity of locations as constraint. This is mostly relevant for EOC locations where rooms are used by multiple specialties. The capacity of rooms could cause a constraint when specialties are scheduled over the different locations. The main locations have separate rooms for each specialty, therefore an average number of rooms is taken for every specialty. This is a simplification of reality to prevent further complexity of the model Due to lack of time and data, this average of rooms is estimated based on a few specialties instead of all specialties. The total capacity can cause the model to assign too many appointments to a specialty at the main locations. Thence, the average number of rooms is assumed to be enough for every specialty at the main location. An valuable addition to the design of the model would be constraints that define the capacity of rooms per location per specialty. This would increase the validation of the model, the model would simulate more accurate outcomes.

The sensitivity analysis of the model indicates that the model is sensitive for parameter fluctuation. The results are now based on estimated parameters for, waiting time and utilisation ranges, this causes uncertainty for the results of the model. This causes uncertainty, because the values for the parameters are guessed and not determined by research or data. Further research is required to determine valid values for the parameters, to generate more reliable results. The values for α could, for example, be established by a survey for patients and a multinomial logit model. The values for waiting time and utilisation range can be determined by further research in the behaviour of waiting time, As mentioned before, waiting time is taken into account as linear variable dependent on utilisation phases. The model is calibrated for validation. Further validation shows that the model is valid for the overall average waiting time. However, the model overestimates the allocation of appointments to the EOCs, causing lower average cost per consult and overall average travel time. This makes the model not completely adequate, further research on the function of the model is needed to determine the cause of the overestimations towards the EOCs. Nevertheless, the model is verified and the effects caused by the scenarios can be used to answer the main research question. Though, due to the functioning of the model is waiting time only changed by a change in number of appointments. The waiting time is assumed to be equal for every location for every specialty, causing the waiting time to stay equal if the number of appointments remains the same. Therefore, the effect on waiting time cannot be measured by the model. This causes a problem to answer the main research questions as waiting time is one of the two factors that define the service for patients. Therefore, conclusions on the service for patients are mainly focused on the average travel time. In hindsight, it would have been beneficial to determine different waiting time per location, to determine the effect of measures on waiting times. The waiting times are initially set as equal for every location, because there was no clear difference in waiting times per location established with the available data.

The change in consultation hours for scenario 2 are based on estimates of the researcher, since the effect on the consultation hours of such investments are unknown. The shift in consultation hours are based on the comparison of the base model and the ideal situation and the interviews with specialists and employees of the EOCs. Furthermore, the cost/benefit analysis is carried out based on estimated costs for Gasthuis, Vlietland, Haven and Oogziekenhuis. Franciscus was not able to provide information on the costs for outpatient clinics. The results of the KPI costs per consult would become more reliable if these costs were known.
Besides, for the forecast scenario, the increased number of appointments is randomly added, without any further knowledge of distribution over specialties or consult types. This can cause under or overestimation for growth of appointments for specialties. General effects of the scenarios can be used to provide an answer to the main research question. However, further research is advised to provide more reliable values. One possibility of future work is executing a sensitive analysis on the change in consultation hours and the increasing number of appointments. Another option for further research is to focus on a specific specialty. By focusing on one specialty, the number of patients can be forecasted in detail based on data.
Thus, the model can be used to determine effects of scenarios on patient planning over multiple locations and the change of performance can be measured by the KPIs. Furthermore, the change in service for patient can be analysed by the weighted average travel time per patient. However, future work is required to analyse to effect of measures in more detail.

Concluding, based on the considerations in the previous paragraphs, there are several implications that influence the quality of this research. For all chapters there is a level of uncertainty and assumptions made by the researcher. Therefore, there is room for improvement and further research and validation is recommended.

6.3. Recommendations

This research offers plenty of opportunities for future work. In this Section, several recommendations are given that could help further develop the LP model for patient allocation over multiple locations. Subsequently, additional recommendations are provided for improvement of the performance of the EOCs at Franciscus.

6.3.1. Research recommendations

Usage of different modelling methods.

The current used modelling method only includes linear functions. Therefore, waiting time is taken into account as linear variable, while waiting time actually is a dynamic variable that changes over time. Therefore, an interesting future research direction is to design a model that includes dynamic waiting times. Methods that can be used for this kind of models are discrete event simulation or stochastic optimisation.

Inclusion of other constraints in the LP model.

The designed model includes capacity constraints for locations and specialties. Other constraints can also have influence on the allocation of patients, for example the available resources or FTEs of supporting staff. An interesting concept for further research would be to expand the current model by adding more constraints.

Extend the definition of service for patients.

The service for patients is currently defined by two factors, waiting time and travel time. Elaborated research to the decision-making of patients considering location choice, could led to more factors that define the location choice for patients. For example, opening times or facilities of a hospital location.

Determination of weight factors.

In the model weight factors are used to define the influence that each factor has on the location choice for an appointment. These weight factors are, for this study, based on assumptions and are not researched in dept. As the model is sensitive to parameter fluctuation, further research into the weight of decision-making factors on location choice will have a large added value for the model. Reliable values for these weight factors causes more reliable outcomes when the model is applied. A proposed method to find the balance between the factors that influence the decision-making for patients is with stated choice experiments.

Validation of the model.

During this study is determined that the current model overestimates the number of appointments assigned to the EOC location. An interesting research topic is to solve this overestimation to make the model completely valid. Then, the model will simulate completely valid values for the KPIs for average cost per consult and weighted average travel time.

6.3.2. Recommendation for Franciscus

Improve communication between EOCs and main location.

There is a lack of communication between the locations. This causes unawareness of the EOCs at the main locations and causes inefficiency for the EOCs. Communication considering consultation hours can be improved by agreements with the outpatient clinics. For example, the agreement to send an email to the EOCs when consultation hours of specialists are planned. This would safe time for the first employee of EOCs and causes doctor's assistants at the outpatient clincis only a few minutes. Furthermore, notifications of cancellation of specialists beforehand enable first employees to schedule their rooms and employees of the EOC more precisely. Therefore, the resources and supporting staff on the EOC locations can be used more efficiently.

One general appointment system.

The current appointment system differs per location, this causes uncertainties and inconveniences for patients. One general appointment system creates clarity for both patients and personnel of Franciscus. This could either be one central call centre for every location or a system that every specialties arrange appointments for themselves. By implementing a new appointment system Franciscus must focus on the location planning of a patient. When an appointment is scheduled, one must prioritise on the origin of the patient and consider all Franciscus locations. According to the outcomes of the model, this can lead to an increase of patient flow at the EOCs and decreases pressure on the main locations.

Research into causes of waiting time

Waiting time is a serious problem for Franciscus, since the waiting times exceed the Treeknorm for several specialty on several locations. Waiting time is an important factor that influences the choice of referral of primary healthcare providers. Therefore, it is necessary to keep the waiting times as low as possible. Before waiting times can be tackled, there must be insight in the causes of waiting time for specialties. Due to the lack of knowledge on the development of waiting time, Franciscus has not been able to do so yet. Further research in the causes of waiting time is needed to be able to improve these waiting times.

Financial insight

At this moment it is difficult to calculate the profit for EOCs locations, because revenue per patient is only known per DTC. The revenue of a DTC is linked to the first location where a patient is seen. However, it is possible that the patient has been treated at several locations during its care path. It is therefore difficult to link revenues to locations, which causes the lack of insight in profit for EOC location. It is recommended to execute further research into the possibilities to determine revenue for patients, to be able to determine the profit per locations.

Furthermore, the average cost per consult that are calculated in this study are based on estimated costs for the main locations, Oogziekenhuis and Haven. This is due to lack of information on the total costs for outpatient clinics at these locations. It is necessary to determine the costs for polyclinics to be able to calculate the actual average costs per consult.

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A. Appendix – Laws of the Dutch Healthcare System

This appendix contains an explanation of the laws that make up the Dutch healthcare system. Figure A.1 presents an overview of the laws and the executors of these laws. Subsequently, the laws are discussed one by one.

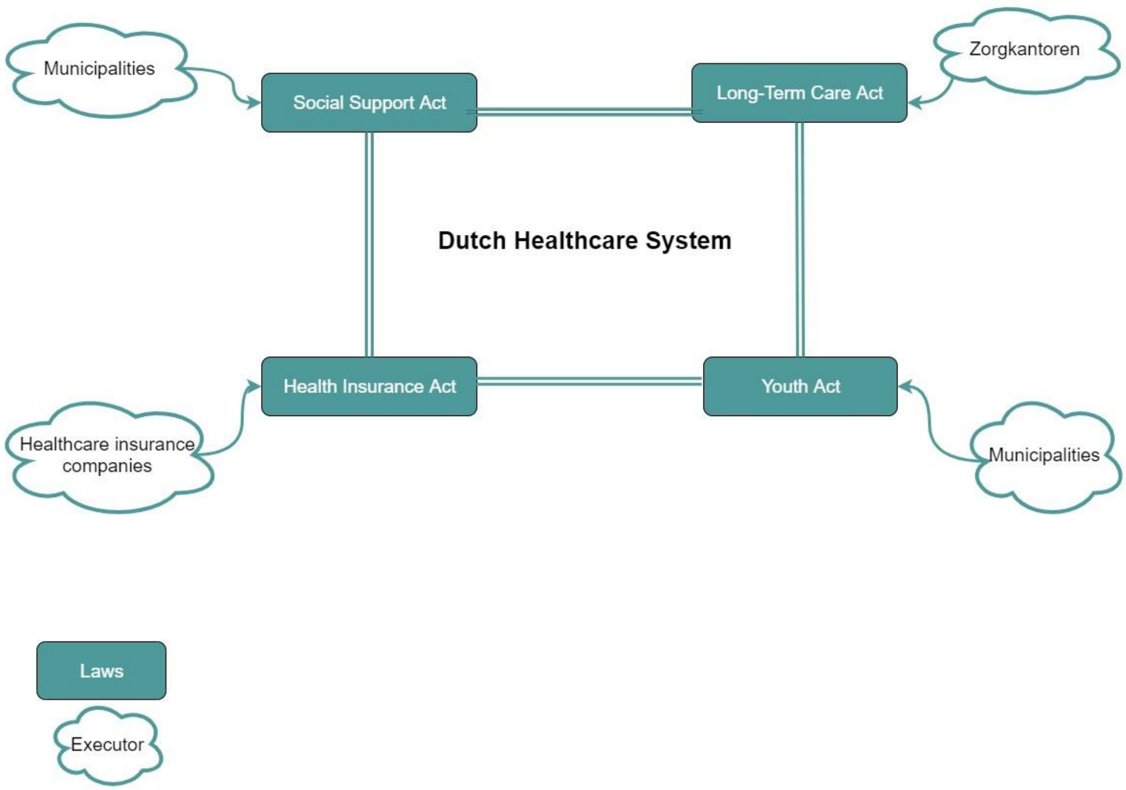

Figure A.1 Dutch Healthcare system. Based on NVZ (2016).

A.1. ZVW

The ZVW is officially implemented in 2006. This law ensures a broad basic healthcare insurance for every Dutch civilian. Every person aged 18 years or older is obligated to have an basic care insurance, which covers the standard care, for example a consult at the GP or necessary hospital visits. Children are insured for free and are included in the insurance package of one of the parents (Ziektekostenverzekering.nl, 2019). Healthcare insurance companies and providers are responsible for the execution of the ZVW. The implementation of the ZVW creates a more regulated competition, because the executors are private organisations. Therefore, the healthcare system is transformed from a supply-driven system to a more demand driven system. Insurance companies can put pressure on the efficiency and quality of care offered by the providers, because they can selectively contract healthcare providers (VWS, 2016). The strong role of the government to realise public interests completes the private character of the system, making the market a regulated market". The boundary conditions as stated by the government are (Zo Werkt de Zorg, 2018):

- Insurance companies are not allowed to deny people if they request a basic care insurance, no matter their condition.
- All Dutch civilians are obligated to have a basic healthcare insurance and are free to choose at which insurance company.
- The costs of the offered polis needs to be equal for every insured person, nevertheless their health, age or background.
- The content of the basic healthcare package is legally determined.
- Health insurance companies have a duty of care. They need to be able to ensure the care in the basic healthcare package for every insured person.

The government has determined specific medical healthcare, medicines and medical resources that must be included in the basic package. By whom or where this care is provided is up to the insurance companies. This determined by negotiations with and selectively contracting of healthcare providers based on gathered information about quality, efficiency and customer experiences (VWS, 2016). Approximately 60% of the government budget for healthcare is circulated within the ZVW (Zo Werkt de Zorg, 2018).

Besides the basic healthcare package, insurance companies also offer additional insurances. Civilians can decide whether they make use of these additional insurances, and whether they take these at the same insurance company. Additional insurances are fully private, without involvement of the government (VWS, 2016).

A.2. WLZ

This law is used by Dutch citizens in need of 24-hour care or supervision. The organisation "Centrum Indicatiestelling Zorg"(CIZ) decides what kind of care a person is entitled to and to what extent (VWS, 2016). The care a citizen can receive from WLZ is defined in a list of functions that is determined by the government. A few examples of these functions are (Zo Werkt de Zorg, 2018):

- Personal care. For example, getting dressed, being washed and eating and drinking.
- Nursing. This is medical help in cases of, for example wound care or infections.
- Stay in an institution. This could be a long-term stay or housing in a nursing home.
- Transport from and to daily activities or day treatment in case the client is not able to do so.

The description of functions is rather broad. Therefore, the person in need can specify and organise the indicated healthcare in collaboration with the healthcare provider.
The law is nationally executed by WLZ-organisations on behalf of the government, these organisations have devoted the actual execution to so called "Zorgkantoren" (Ziektekostenverzekering.nl, 2019). There are 31 Zorgkantoren in the Netherlands, one Zorgkantoor per region is responsible for the supply of care. After the necessary care is indicated, the CIZ passes this information on to a Zorgkantoor and at this Zorgkantoor the long-term care is arranged in consultation with the patient (VWS, 2016).

A.3. WMO

This law offers support for Dutch citizens to participate in the society and the opportunity to live at their own home as long as possible. This law is executed by the municipalities by order of the government. The execution is based on individual approaches and customisation. The services for the WMO provided by the municipality are divided in two Sections; the general services and the customise services. Examples of services provided by the municipalities are (VWS, 2016):

- Guidance and day activities.
- Support of caregiver.
- Society shelter, for example for homeless people.
- Shelter for men, women and children in case of domestic violence.

When a person is in need of help from the WMO one can send a request to the municipality. Then an appointment is set up for a first consult. Then, research is carried out to determine what the client is still capable of on its own and with just general services. Based on this research, an advice is given on how to support that client.

A.4. Youth Act

This law includes support, help and care for youth and families of youngster with growth and/or education problems or physical problems and disorders. The law is also executed by municipalities. The support of municipalities varies from general prevention to forced care. The aim of this law is to give children the opportunity to grow up in a safe and healthy environment. Furthermore, the law supports youngsters to become independent and participate in the society on their own equity. Municipalities are also responsible for child protection measures and juvenile rehabilitation (Zo Werkt de Zorg, 2018).

Many municipalities have set up neighbourhood teams, who are able to support youth. In case the youngster or parents prefer different support can they go back to the municipalities to discuss their matter (VWS, 2016).

B. Appendix – Stakeholder description

In this Appendix all relevant stakeholders are briefly described, per stakeholder is explained what their function and involvement with regard to the EOCs are.

Ministry of VWS

The ministry of Health, Welfare and Sport aims to keep the Dutch civilians healthy as long as possible. Furthermore, to restore the sick people to health as quickly as possible. She is responsible for the availability of hospitals, GPs and other healthcare for everyone in need. She makes sure that there are sufficient facilities together with health insurers, healthcare providers and patient organisations. Hospitals as Franciscus have to operate conform the laws and rules imposed by the ministry (Government.nl, 2019).

Healthcare insurance companies

As mentioned in Section 2.2 are healthcare insurance companies responsible for purchasing care for her insured customers. The companies have to make sure they buy enough care, to ensure the right care for her customers. On the other hand, care providers, like Franciscus, have to negotiate with these companies to make sure they receive patients. The healthcare insurance companies are not obligated to sign a contract with every care provider (Nederlands Zorgautoriteit, 2019). The most important insurance companies for Franciscus are DSM and Zilver Kruis.

Board of directors

The board of directors of Franciscus consists of a group of three. Together they are responsible for the organisation of Franciscus Gasthuis & Vlietland. This contains the business operations as well as the quality of the given care to patients. The board is supported by a secretary and the secretary of the board of advisory. The board of directors aims for the best care and strives to fulfil the mission and ambitions that are stated in their strategical hospital plan 2018-2023. Therefore, she wants the EOCs to be used as efficient as possible, to optimise the service for patients and to receive as much patients as possible.

Board of advisory

This board advises and has supervision over the board of directors and the organisation in general. The board consists of five to seven independent members. Each decision that is taken by the board of directors is checked and evaluated by the board of advisory.

Cooperation of specialists Franciscus

All specialists are part of this cooperation. The cooperation delivers high qualified specialists for Franciscus. The board of this cooperation is responsible for delivering the highest quality of care to achieve the best service for patients. Meanwhile, Franciscus is dependent on this cooperation for her specialists to occupy all Franciscus locations.

Manager transmural care and external outpatient clinics

This person is the head of the transmural care department, this department is responsible for the communication and collaboration with primary healthcare providers. The department also helps and cooperates with referrers and specialists concerning transmural issues and communication. Besides, she is also business manager of the EOCs which fits well with her transmural care function. Clear communication between primary providers and the EOCs is essential to receive as many patients as possible and to provide the best care for patients.

Manager external outpatient clinics
This manager is responsible for the organisation and coordination of all EOCs. For example, this person is responsible for sufficient employees and facilities at the EOCs. Efficient use of these location are of high importance to this manager, because this increases the performance of the locations under her responsibility.

Department managers
There are several department managers at Franciscus Gasthuis & Vlietland. Each manger is responsible for one or more specialty, either on the polyclinic or clinic side. The department managers that are involved with the EOCs, are the managers on the polyclinic side. These managers needs to communicate with all locations to make sure the specialists of their specialty can have their consultation hours. Furthermore, they are responsible optimal use of consultation hours, the achievement of volume standards and optimal service for patients.

Specialists
The specialist has multiple consultation hours per week, these can be held in the morning or the afternoon or both. Here, the specialist sees patients for consults and diagnosis, for example for a first consult or a repeat consult to check up after surgery. In consultation with all specialists is decided when and where every specialist has consultation hours. This needs to be done six weeks in advance, so each location can schedule the needed resources and supported staff based on their schedule.

First employees EOC
There is one first employee per EOC, this is the coordinator of that location. She is responsible for the organisation of the EOC. One task is to check the rosters of specialist every month in the EPD system of Franciscus, to schedule her rooms, resources and employees. Besides, she is the contact person for the manager EOC.

Doctor's assistants
Every location has doctor's assistants to assist the doctor. However, doctor's assistant at EOCs are all-rounders. They also work at the service counter, take blood samples and do other small tasks. The doctor's assistants at the main locations in Rotterdam and Schiedam work at the polyclinic of one specific specialty, doctor's assistants at OECs rotate between specialty.

Nurse specialist
These are nurses who are educated to deliver limited care independently. These nurses can take on several tasks of the specialist, so the specialist can focus on diagnosing and other treatments. Some specialties have consultation hours held by nurse specialists at the EOCs.

Service desk employee
These employees welcome and register arriving patients at the EOCs. They also answer the phone and make new appointments for patients after seeing the specialists.

Laboratory employee
Some of the doctor's assistant at the EOC are specialised in the laboratory and only work at the laboratory. They do not rotate with the other doctor's assistants.

Patients
These are the people visiting one of the Franciscus locations to receive the right care for their health complains. The location depends on their own preferences and the availability of the specialists.

Primary healthcare providers
As mentioned in Section 2.2, primary healthcare providers refer patients if specialised care is needed. Therefore, a good relationship, short waiting list and locations nearby are, among others, important factors to receive as much patients as possible. EOCs provide specialised care closer to patients home.

Pharmacies
Patients receive their prescribed medicines here. Pharmacies benefit from an EOC that is located nearby. Pharmacies are sometimes even positioned in the same building. Hospitals are valuable partners for them, because they refer patients to the pharmacy for medicines. Besides, having an pharmacy in the same building or nearby is a service facility for patients.

Manager Capacity Expertise Centre (CEC)
This department is founded to improve the capacity use of all deparments, including the EOCs. At this moment they are mostly working on the main locations. Nevertheless, they can take this study into account as base for further analysis.

Integral capacity Management (ICM)
This is a program set up to reorganise departments of hospital, with focus on capacity utilisation. They calculate the current utilisation of a polyclinics and clinics. ICM sets up a plan to improve the utilisation in consult with the department. The results of this research contributes to the analyses of the current utilisation of the EOCs. Furthermore, the suggested measure for improvements can be taken into account as advice for further research.

C. Appendix – Interviews

This appendix contains questionnaires of the structured interviews. Furthermore, several interviews are elaborated.

C.1. Questionnaire for interview with first employee

1. Hoe komt de planning van de buitenpolikliniek tot stand?
2. Kun je me dat laten zien?
3. Hoeveel tijd kost dit jou ongeveer?
4. Hoe zou het volgens jou beter kunnen? Heb je hier ideeën over?
5. Wordt er genoteerd als een spreekuur niet door gaat?
6. Wordt er een reden gegeven als een spreekuur wordt geannuleerd? Of merken jullie dat gewoon op vanuit HIX? Hoe komen jullie daar achter?
7. Welke spreekuren worden volgens jou het meest geannuleerd? En welke worden nooit geannuleerd?
8. Moeten er vaak patiënten verplaatst worden? Hoe reageren patiënten daar op?
9. Gaan patiënten daardoor ook wel eens naar een ander ziekenhuis?
10. Gebeurd het wel eens dat er patiënten naar Berkel/Maassluis komen en dat het spreekuur dan niet doorgaat? Hoe vaak gebeurd dit?
11. Zijn er specialtyes die vaak uitlopen? Welke wel en welke niet?
12. Maken jullie ook afspraken voor andere locaties?
13. En doen jullie dan alleen herhaal afspraken of ook andere soorten afspraken, zoals een mri of kleine ingreep?
14. Hoe is jullie communicatie naar de andere locaties? Gaat dit soepel? Of brengt dit moeilijkheden met zich mee?
15. Vinden specialisten het fijn om in Berkel te werken?

C.2. Questionnaire for interview with specialists

1. Hoe ervaart u het om op de deze locatie te werken?
2. Hoeveel spreekuren draait u nu?
3. Zijn uw spreekuren altijd gevuld, wanneer u in Berkel/Maassluis zit? Is dit anders dan op de hoofdlocaties?
4. Bepaalt u zelf of u in Berkel/Maassluis spreekuren gaat draaien of wordt dit in overleg gedaan met de vakgroep?
5. Wordt dit doorgegeven aan Berkel/Maassluis?
6. Hoe staat Berkel/Maassluis bekend binnen de vakgroep? Draaien specialisten hier graag spreekuren?
7. Gebeurt het wel eens dat u een spreekuur af moet zeggen? Hoe ver van te voren geeft u dat aan?
8. Wat zijn zoal de redenen om het spreekuur te annuleren?
9. Doet u dit sneller bij spreekuren in Berkel/Maassluis dan op de hoofdlocaties?
10. Zou u er voor open staan om vaker in Berkel/Maassluis spreekuren te draaien?
11. Zijn er dingen die voor u verbeterd kunnen worden, waardoor Berkel/Maassluis toegankelijker zou worden? Bijvoorbeeld materialen die ontbreken, of de beschikbaarheid van kamers?

C.3. Questionnaire for interview with call centre

1. These are some of the questions asked to the coordinator of the call centre:
2. Kiezen patiënten altijd voor de kortste wachttijd? Of is dit ook afhankelijk van een voorkeurslocatie?
3. Kun je een inschatting maken hoe belangrijk wachttijd en voorkeurslocatie zijn voor een patiënt? Bijvoorbeeld op schaal van 1 tot 10. Verschilt dit per specialtye?
4. Hoor je ook wel eens andere dingen die meespelen als een patiënt een locatie kiest? Zoals parkeerkosten of type vervoer?
5. Heb je wel eens patiënten die een ander ziekenhuis kiezen, doordat de wachttijd bij Franciscus te lang is?
6. Kiezen patiënten er wel eens voor om naar een andere Franciscus locatie te bellen, om te kijken of de wachttijd daar korter is?
7. Kun je een indicatie geven hoeveel wachttijd voor een patiënt acceptabel is? Zit hier verschil in per specialtye?

C.4. Interview Lizette van der Stelt – Manager EOCs

One of the tasks of Lizette is to make sure every EOC location has enough employees, but she only has a fixed amount of FTEs to distribute over the locations. She stated that communication between the specialties on the main locations and the EOCs is stiff. Doctor's assistants sometimes call to the polyclinic at the main location for explanation or advice on a matter. Sometimes, the polyclinics react unfriendly or are not really willing to help.

Furthermore, Lizette feels that the EOCs are not enough acknowledged by the main locations. For example, EOCs do not receive notifications considering changes in the schedules of consultation hours. She experiences that specialists cancel consultation hours rather easy and last minute due to activities with higher priority on the main locations. This is understandable, but this causes difficulties due the lack of communication towards the EOCs.

C.5. Specialists

Specialists that have been interviewed are specialists that have consultation hours at one of the EOCs. Three specialists that have consultation hours at Berkel: Dr. Bonnet (ENT), Dr ir, Kappen (Pulmonary medicine) and Dr. West (gastroenterology) and two specialists that have consultation hours in Maassluis: Dr. Schoenmakers (ENT) and Dr. Sunamura (Cardiology).

The questions asked to the specialists are questions considering the reputation of EOCs among specialists and considering their experiences at the EOC. First of all, it is noticed that all specialists enjoy working at the EOCs. The main reason for this is that working at the EOCs is quiet and informal. Furthermore, there are no phone calls or emergencies that can distract them for their patients. Besides, it is easy to consult with specialists from other specialties. For example, for gastroenterology it can be useful to consult with specialists of internal medicine for diagnosis or treatment. Lastly, for some specialist EOCs are close to their homes.

In general, specialists are willing to work at EOCs. However, there are some specialists that rather not work at the EOCs, for example some specialists of Pulmonary medicine. On one hand, this is due to travel time. On the other hand, they have to work at too many different locations. The most common reason for cancellation is that the main location have priority during holidays. There need to be a specialist on the main location, thus consultation hours are cancelled at the EOCs in case of limited availability of specialists. Dr. Bonnet also mentioned that surgeries have priority, so if a time window is available at the operation rooms, he will cancel his consultation hour at that moment. This is independent of the location. Also Dr. Kappen mentioned that he does not cancel a consultation hour based on location.

Lastly, there were mixed reaction on the question if they would be willing to work have more consultation hours at the EOCs. In Berkel Dr West and Dr Kappen were very willing to have more consultation hours, but Dr Bonnet mentioned that this would become difficult due to continuity on the locations, mostly the main locations. After surgery a specialist is obligated to continually check up on the patient, that becomes difficult when one works at other locations too often. In Maassluis both the specialist mentioned that it is not necessary to have more consultation hours at that location, because there is not enough demand in that area for extra consultation hours.

C.6. Interview Maltie - First employee

Maltie has explained her working method for the schedule of the EOC Berkel, she does this every month. Each month she checks whether there has been any changes in the schedule of the specialists. She does this based on HIX and searches the planning of each specialist. Furthermore, General surgery and Gynaecology use a different program that it somewhat more clear, but uses different methods within this program. Besides, Paediatrics and Orthopaedics sent an overview of specialists that have consultation hours at the EOC in the upcoming six weeks. It would be the ideal for Maltie if she receives such overviews for every specialty, preferably six weeks in advance.

Every Friday, Maltie checks the schedule of the next week. She does this because consultation hours sometimes get cancelled last minute, without a notification to the EOC. Therefore, patients need to be rescheduled. Remarkably patients never decide to go to another hospital.

According to Maltie, the communication with the location Gasthuis is good. Each specialty is signed to one of her doctor's assistants, so polyclinics at Gasthuis have one communication person at the EOC. This improves the communication between the locations.

C.7. Interview Nicole van der Meer - Call centre coordinator

Nicole has explained the appointment system of Franciscus, this system is elaborated in Section 3.3. The call centre experience difficulties when scheduling appointments for patients on the right locations, because of the limited access to Gasthuis and Berkel. Nevertheless, the call centre employees offer multiple locations when scheduling an appointment. Furthermore, communication with Gasthuis is stiff, because they often get send to voicemail when sending a patient through. Also, they are not allowed to make appointments for every specialty at Vlietland, for example general surgery schedules all of their own appointments.

The influence of factors for location choice depend on the patient. This is more dependent on the age of patients than on specialties. Nicole explained that elderly stick to their preference location and younger patients, younger than 60, are willing to drive to another location in case of a shorter waiting list. According to her, patients choice based on waiting time and preference locations. Furthermore, it often happens that patients decide to go to another hospital due to the long waiting times for their first appointment.

Determination of maximum waiting time for a patient is difficult, because this is really dependent on the health complaint and the setting of the patient. Some patients are in a hurry, others do not mind to wait a few week longer. Nevertheless, it became clear that patients are willing to wait longer than the Treeknorm of 28 days.

C.8. Interview Monique Helmer – Department manager

In conversation with Monique Helmer, the current state of EOCs within the polyclinics is analysed. EOCs do not have priority when it comes to organising the consultation hours. She explains that is rather easy to cancel consultation hours at the EOCs. Furthermore, it is not communicated with the EOCs when consultation hours are cancelled, in case specialists are needed at the main locations.. Most polyclinics at the main locations do not value EOCs for what they are. They are often seen as an extra location.

D. Appendix – Customer journey

This appendix contains the total customer journey of a patient visiting an EOC to receive specialised healthcare. The complete customer journey is a combination of all steps that are explained in Section 3.2.

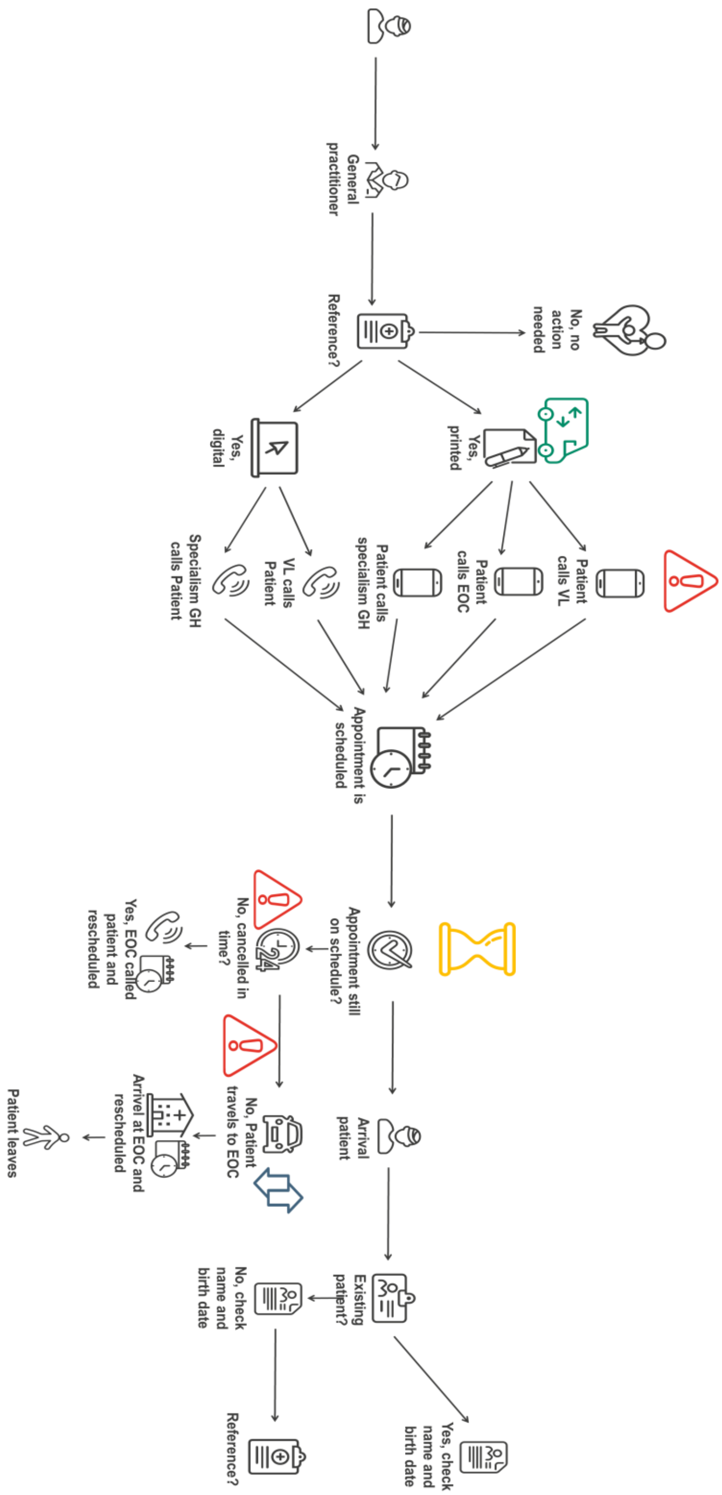

Figure D.1 Customer journey at an EOC, part 1

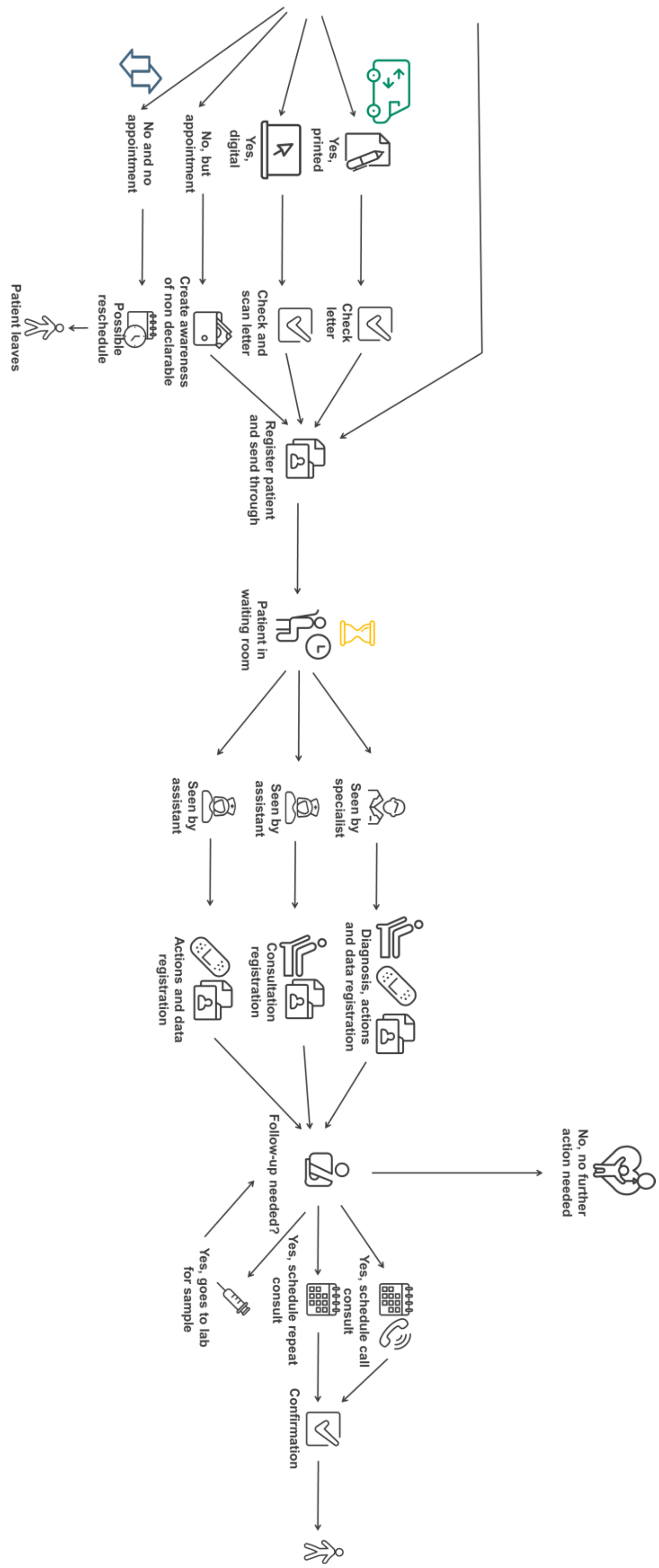

Figure D.2 Customer journey at an EOC, part 2

E. Appendix – Current state data

This appendix contains data that is used for the current state analysis of Franciscus. Figure E.1 and Figure E.2 present the distribution of consultation hours per specialty. For every specialty, it can be concluded that the main locations have the greatest share of consultation hours. It differs per specialty whether more consultation hours are held at Gasthuis or Vlietland.

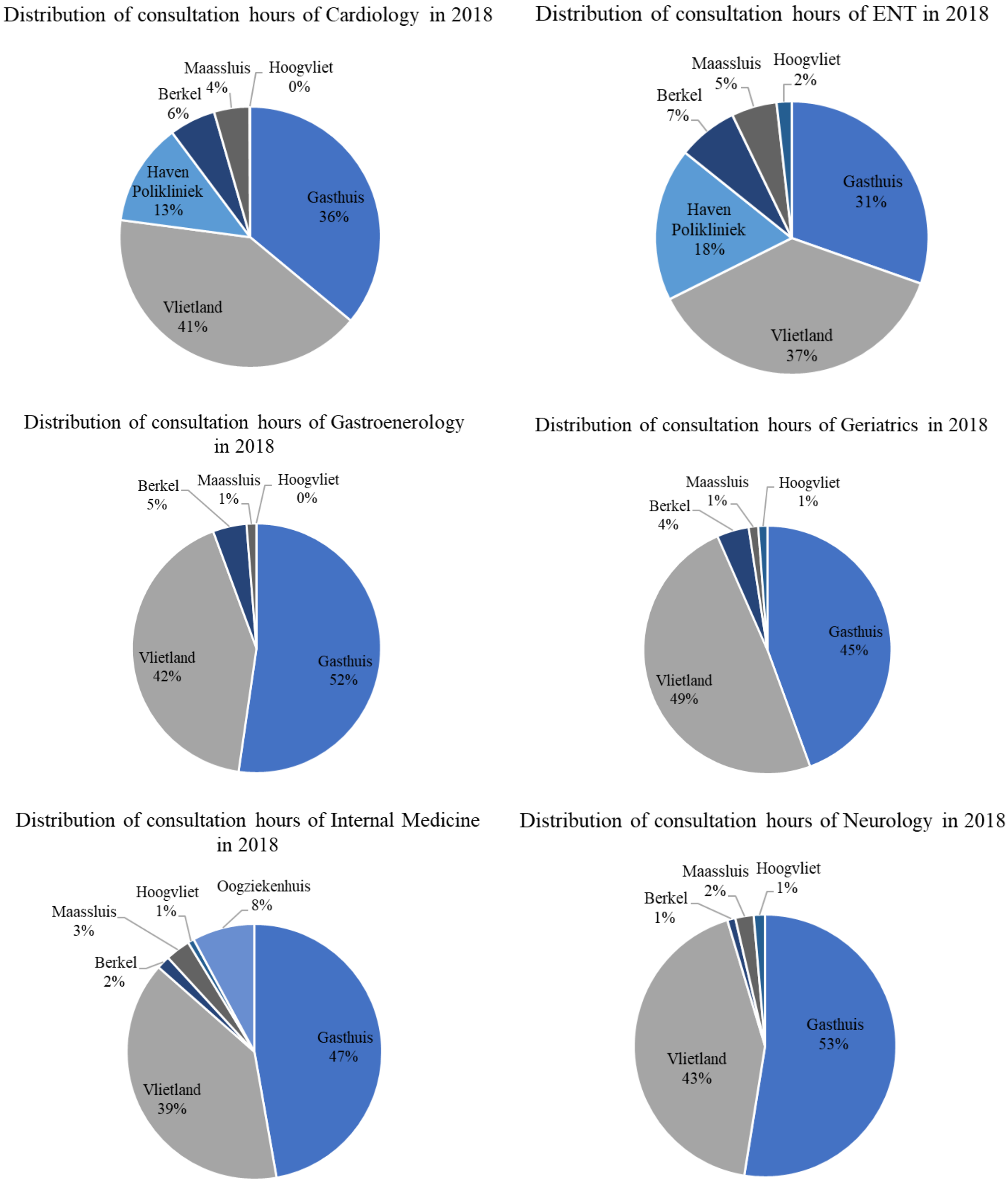

Figure E.1 Distribution of consultation hours per specialty

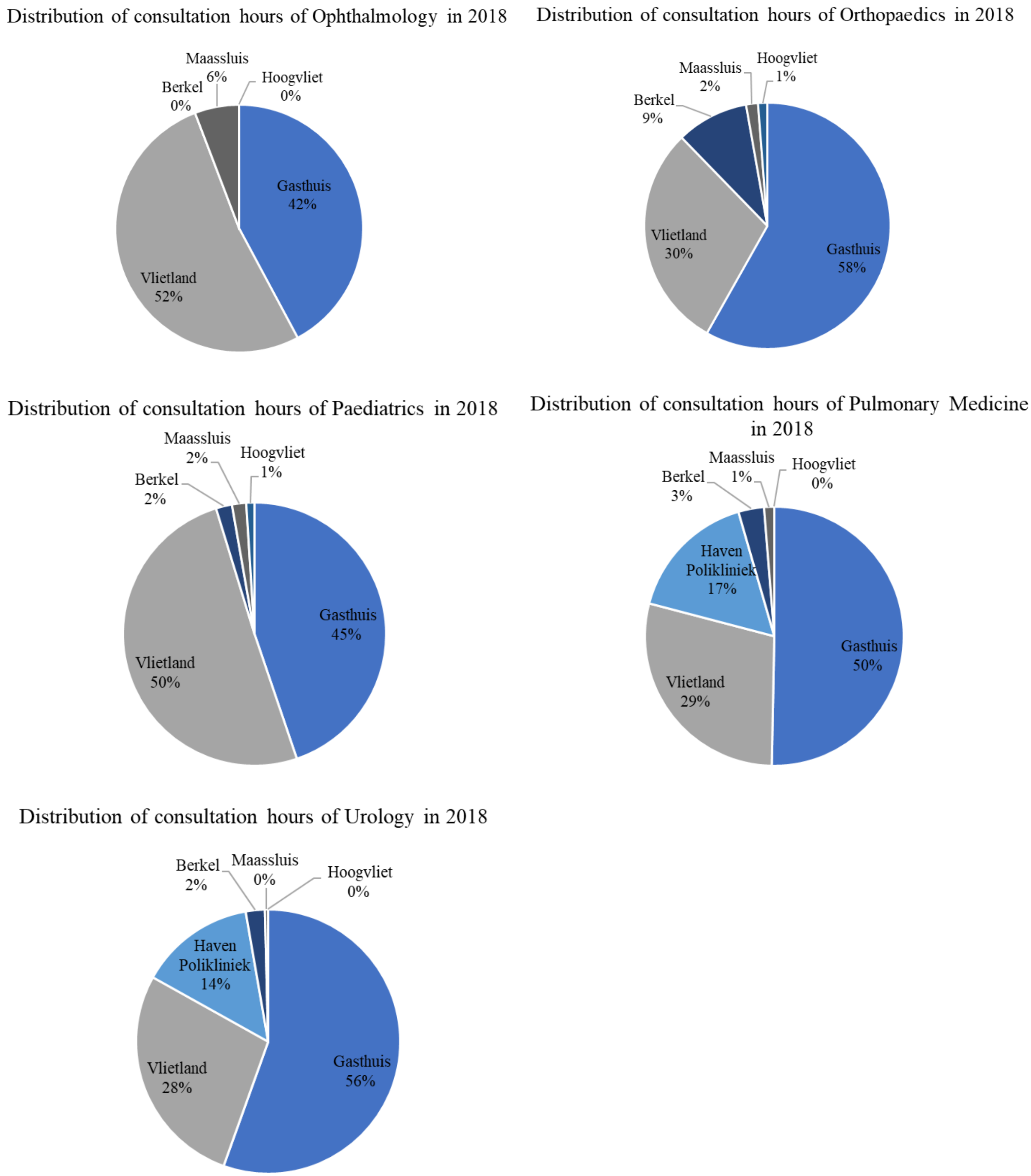

Figure E.2 Distribution of consultation hours per specialty

Figure E.3 and Figure E.4 are used to analyse the flow of consultation hours and appointment per location during the year. It is determined that holidays have impact on the supply of consultation hours. Therefore, it also affect the number of appointments. October and November are the peak months for Gasthuis and Vlietland.

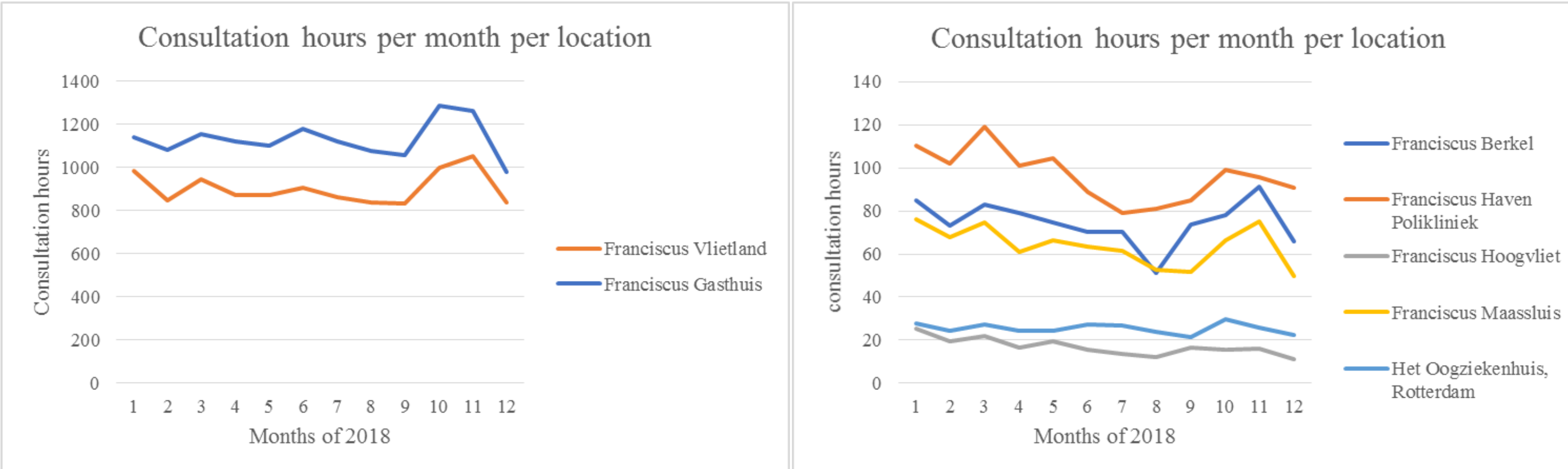

Figure E.3 Consultation hours per month per location

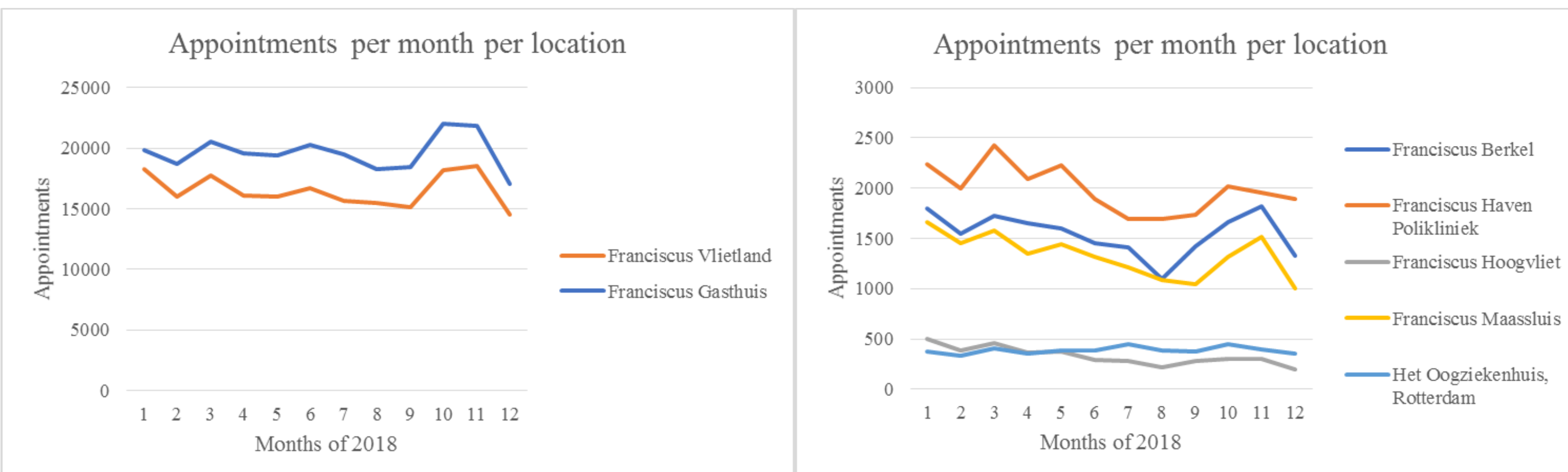

Figure E.4 Appointments per month per location

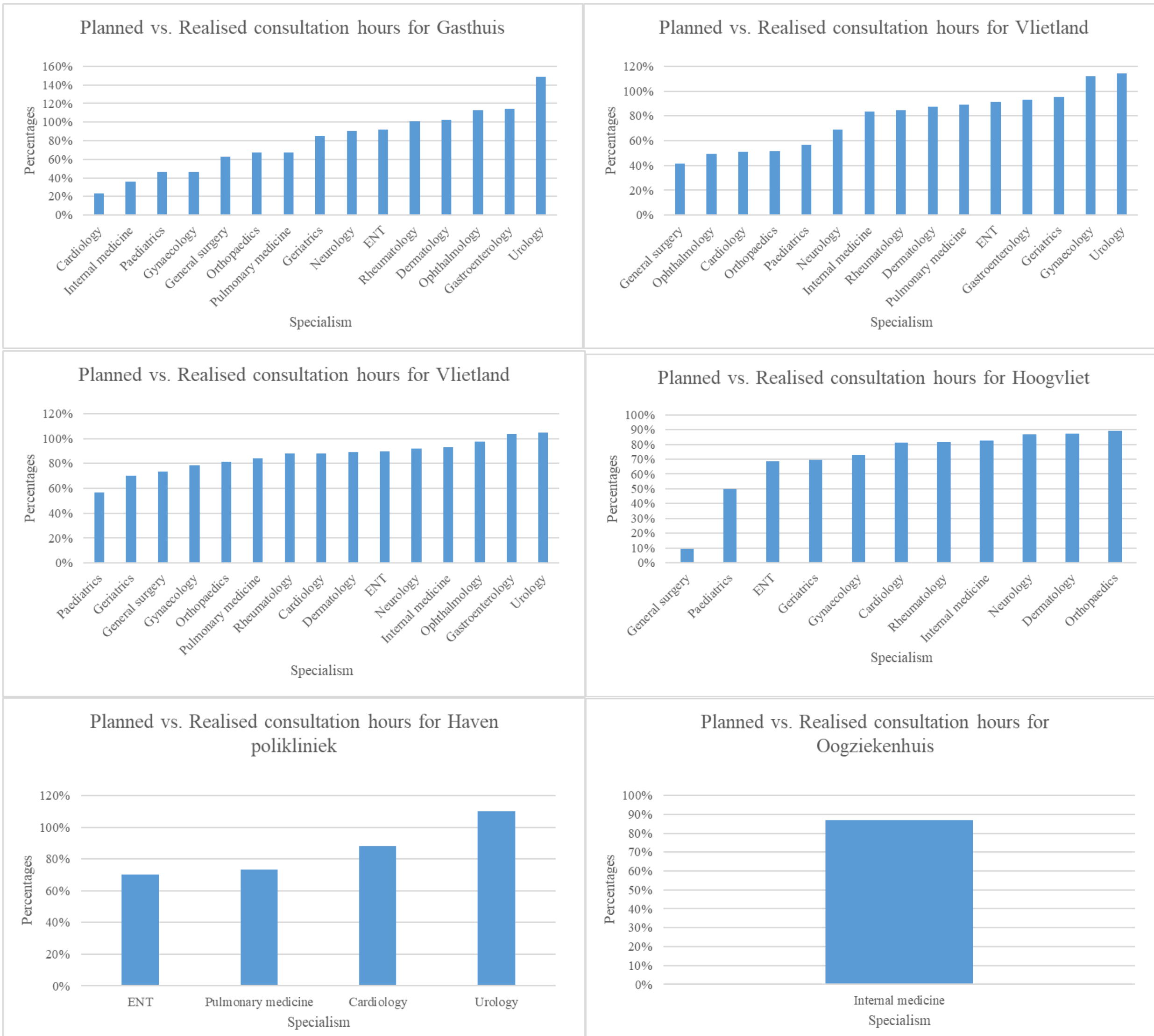

Figure E.5 Utilisation rates of consultation hours per specialty for each location

Figure E.5 presents the utilisation rates of consultation hours of specialties per location. The utilisation rate is determined as the executed consultation hours divided by the planned consultation hours. The utilisation rates are relatively low for the main locations. This can be caused by cancellation of consultation hours for emergencies or an open time window for the surgery room.

F. Appendix – General waiting time template

This appendix shows the obligated format of waiting times for Franciscus. This is represented in Figure F.1 and Figure F.2.

Actuele toegangstijden poliklinieken en diagnostiek in dagen					
Peildatum: 20-01-2020	*Locaties Franciscus Gasthuis & Vlietland* *uitleg: de wachttijd is in dagen*				
Specialisme	**Gasthuis**	**Vlietland**	**Berkel**	**Maassluis**	**Haven**
Cardiologie	7	4	17	10	1
ECG	0	0	0	0	
Event recorder	n.v.t.	14	n.v.t.	n.v.t.	*
Fietsproef	n.v.t.	n.v.t.	n.v.t.	n.v.t.	n.v.t.
Chirurgie	3	2	25	8	n.v.t.
Doppler	2	3	n.v.t.	n.v.t.	n.v.t.
Borstkliniek	2	2	n.v.t.	n.v.t.	n.v.t.
Dermatologie	24	15	45	29	n.v.t.
Flebologie	43	108	n.v.t	n.v.t.	n.v.t.
Gastro-enterologie (MDL)	94	*	70	29	n.v.t.
Colonoscopie	35	2	n.v.t.	n.v.t.	n.v.t.
Gastroscopie	42	2	n.v.t.	n.v.t.	n.v.t.
Geriatrie	17	11	67	*	n.v.t.
Gynaecologie/Verloskunde	18	17	28	16	n.v.t.
Gynaecologische echo	22	*	n.v.t.	n.v.t.	n.v.t.
Bekkenbodemcentrum	24	16	n.v.t.	n.v.t.	n.v.t.
Interne Geneeskunde	49	31	33	14	n.v.t.
Kaakchirurgie	8	15	n.v.t.	n.v.t.	n.v.t.
Keel-, Neus- & Oorheelkunde	8	4	4	3	1
Kindergeneeskunde	17	17	44	23	n.v.t.

Figure F.1 Official waiting time template

Longgeneeskunde	22	24	14	32	15
Longfunctie onderzoek	35	18	*	11	1
Nefrologie	9	15	45	n.v.t.	n.v.t.
Neurochirurgie	17	23	n.v.t.	n.v.t.	n.v.t.
Neurologie	51	43	59	52	n.v.t.
Hoofdpijnpolikliniek	35	65	n.v.t.	n.v.t.	n.v.t.
Oogheelkunde	51	64	*	59	n.v.t.
Kinderen tot 12 jaar	120	81	n.v.t.	n.v.t.	n.v.t.
Fundusfoto	n.v.t.	8	n.v.t.	n.v.t.	n.v.t.
Orthopedie	n.v.t.	n.v.t.	n.v.t.	n.v.t.	n.v.t.
Schoudergewricht/elleboog	46	32	21	*	n.v.t.
Enkel-/voetgewricht	15	12	28	n.v.t.	n.v.t.
Heup/knie	3	2	2	49	n.v.t.
Pijnbestrijding	65	37	n.v.t.	n.v.t.	n.v.t.
Plastische Chirurgie	24	45	*	n.v.t.	n.v.t.
Psychiatrie	n.v.t.	n.v.t.	n.v.t.	n.v.t.	n.v.t.
Radiologie:					
CT scan	24	18	n.v.t.	n.v.t.	n.v.t.
MRI scan	31	30	n.v.t.	n.v.t.	n.v.t.
Reumatologie	7	16	25	29	n.v.t.
Revalidatie	35	n.v.t.	n.v.t.	n.v.t.	n.v.t.
Urologie	32	*	36	*	30
Prostaatcentrum zuidwest Nederland	*	n.v.t.	n.v.t.	n.v.t.	n.v.t.

*momenteel geen afspraak mogelijk

Figure F.2 Official waiting time template

G. Appendix – Causal-relation diagram

This appendix contains the casual-relation diagram, see Figure G.1. This diagram is used to determine the factors that needed to be taken into consideration for the design of the model. Furthermore, this causal-relation diagram represents the relations and therefore the effect of factors on the performance indicators and KPIs.

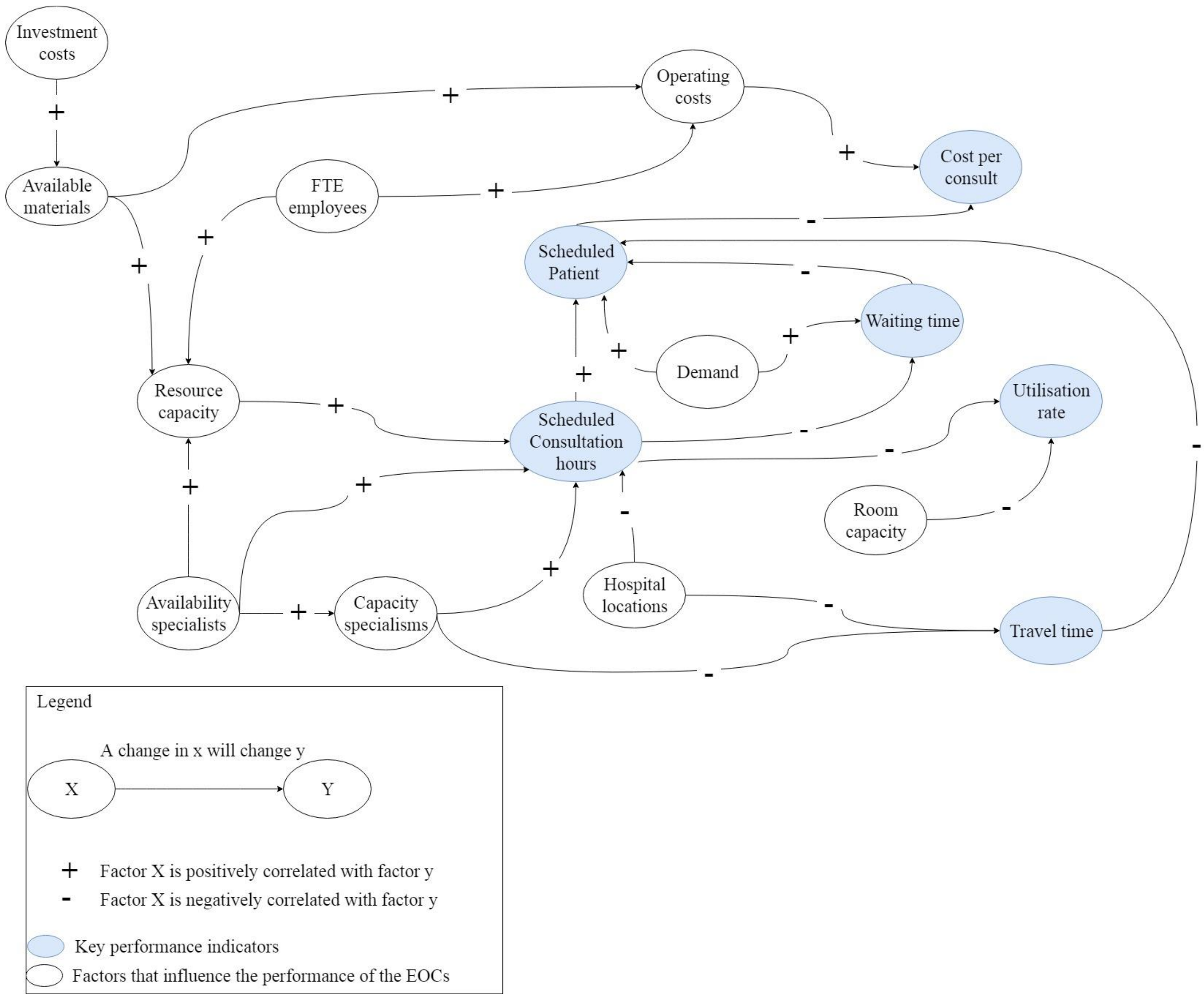

Figure G.1 Causal-relation diagram for the performance of EOCs

H. Appendix – Model code

In Figure H.1-H.3, the model code is presented. This model code contains the model that is presented in Section 4.2 programmed in Python.

Model code in python

```
@author: joyce
"""

from gurobipy import *
from openpyxl import load_workbook
import numpy as np
import pandas as pd

# Define all sets and parameters

# Type of appointments
I = ('First', 'Repeat', 'Phone')
# Locations
J = ('Gasthuis', 'Vlietland', 'Berkel', 'Maassluis', 'Haven', 'Oog')
# Specialisms
K = ('Car', "Chi", "Derma", "Ger", "Gyn", "Interne", "KNO", "Kinder", "Long", "MDL", "Neuro", "Oog", "Ortho", "Reuma", "Uro")


# Input
wb = load_workbook("Data5.0.xlsx", read_only=True)
ws = wb['Afspraken']
Appointments= np.array([[i.value for i in j] for j in ws['A3':'AT157']])
ws = wb['Afstanden Diff']
Traveltime= np.array([[i.value for i in j] for j in ws['A2':'G169']])
ws = wb['Capaciteiten']
Capacities= np.array([[i.value for i in j] for j in ws['A2':'Q7']])
ws = wb['Consults']
ConsultTimes= np.array([[i.value for i in j] for j in ws['A2':'P4']])


# Appointments
A = {}
a = 1
for row in Appointments:
    k = 1
    while k <= 15:
        i = 1
        while i <= 3:
            number_appointments = row[((k-1)*3)+i]
            if not number_appointments:
                number_appointments = 0
            for n in range(1, (number_appointments + 1)):
                A[a] = ((row[0]), K[k-1], I[i-1])
                a = a + 1
            i = i + 1
        k = k + 1

# Traveltimes between postcodes and locations
TT = {}
# Postcodes
P = {}
p = 1
for row in Traveltime:
    P[p] = row[0]
```

Figure H.1 Model code in python

```python
    j = 0
    while j <= len(J)-1:
        TT[P[p],J[j]] = row[j+1]
        j = j + 1
    p = p + 1

# Consult types and duration
CT = {}
for row in ConsultTimes:
    consult = row[0]
    k = 0
    while k < len(K):
        CT[consult,K[k]] = float (row[k+1])
        k = k + 1

# Capacities specialisms and location capacity
CapSpL = {}
TotCap = {}
for row in Capacities:
    location = row[0]
    TotCap[location] = float (row[1])
    k = 0
    while k < len(K):
        CapSpL[location,K[k]] = float (row[k+2])
        k = k + 1

# Waiting times low, Medium and High per location
Wl = {}
Wl[J[0]] = 10
Wl[J[1]] = 10
Wl[J[2]] = 10
Wl[J[3]] = 10
Wl[J[4]] = 10
Wl[J[5]] = 10

Wm = {}
Wm[J[0]] = 21
Wm[J[1]] = 21
Wm[J[2]] = 21
Wm[J[3]] = 21
Wm[J[4]] = 21
Wm[J[5]] = 21

Wh = {}
Wh[J[0]] = 42
Wh[J[1]] = 42
Wh[J[2]] = 42
Wh[J[3]] = 42
Wh[J[4]] = 42
Wh[J[5]] = 42


# Model
print ('\nStart defining the model...')
m = Model ('Patient Hospital Assignment Problem')

# Decision variables
Xl = {}
for a in A:
    for j in J:
        Xl[a,j] = m.addVar(vtype=GRB.BINARY, name='Xl(' + str(a) + ',' + str(j) + ')' )

Xm = {}
for a in A:
    for j in J:
```

Figure H.2 Model code in python

```python
        Xm[a,j] = m.addVar(vtype=GRB.BINARY, name='Xm(' + str(a) + ',' + str(j) + ')' )

Xh = {}
for a in A:
    for j in J:
        Xh[a,j] = m.addVar(vtype=GRB.BINARY, name='Xh(' + str(a) + ',' + str(j) + ')' )

Y = {}
for j in J:
    for k in K:
        Y[j,k] = m.addVar(vtype=GRB.BINARY, name='Y(' + str(j) + ',' + str(k) + ')' )

m.update()

# Objective function
m.setObjective ( quicksum (0.4 * ( TT[A[a][0],j] * (Xl[a,j] + Xm[a,j] + Xh[a,j])) for a in A for j in J) +
                 quicksum (0.6 * (Wl[j] * Xl[a,j] + Wm[j] * Xm[a,j] + Wh[j] * Xh[a,j]) for a in A for j in J),
                 GRB.MINIMIZE)

# Define constraints

# All appointments must be assigned to 1 and only 1 location
for a in A:
    m.addConstr(quicksum ((Xl[a,j] + Xm[a,j] + Xh[a,j]) for j in J) == 1)

# Total capacity of a location
for j in J:
    m.addConstr (quicksum((Xl[a,j] + Xm[a,j] + Xh[a,j]) * CT[A[a][2],A[a][1]] for a in A) <= TotCap[j] )

# Specialism capacity at each location

# Specialims cpacity of low utilisation
for j in J:
    for k in K:
        m.addConstr ( ( quicksum (Xl[a,j] * CT['First' ,k] for a in A if (A[a][2]=='First'  and A[a][1]==k) )
                      + quicksum (Xl[a,j] * CT['Repeat',k] for a in A if (A[a][2]=='Repeat' and A[a][1]==k) )
                      + quicksum (Xl[a,j] * CT['Phone' ,k] for a in A if (A[a][2]=='Phone'  and A[a][1]==k) ) ) <= 0.2 * CapSpL[j,k] * Y[j,k] )

# Specialims cpacity of Medium utilisation
for j in J:
    for k in K:
        m.addConstr ( ( quicksum (Xm[a,j] * CT['First' ,k] for a in A if (A[a][2]=='First'  and A[a][1]==k) )
                      + quicksum (Xm[a,j] * CT['Repeat',k] for a in A if (A[a][2]=='Repeat' and A[a][1]==k) )
                      + quicksum (Xm[a,j] * CT['Phone' ,k] for a in A if (A[a][2]=='Phone'  and A[a][1]==k) ) ) <= 0.5 *  CapSpL[j,k] * Y[j,k] )

# Specialims cpacity of High utilisation
for j in J:
    for k in K:
        m.addConstr ( ( quicksum (Xh[a,j] * CT['First' ,k] for a in A if (A[a][2]=='First'  and A[a][1]==k) )
                      + quicksum (Xh[a,j] * CT[ 'Repeat',k] for a in A if (A[a][2]=='Repeat' and A[a][1]==k) )
                      + quicksum (Xh[a,j] * CT['Phone' ,k] for a in A if (A[a][2]=='Phone'  and A[a][1]==k) ) ) <= 0.3 * CapSpL[j,k] * Y[j,k] )

m.setParam ('OutputFlag', True)  # show Gurobi output
m.setParam ('MIPGap', 0);        # find the optimal solution with 0% gap
m.write ("output.lp")            # print the model in .lp format file

print ('Start solving...')
m.optimize ()
print ('Finished solving...')


# --- Print results ---

if m.status == GRB.Status.OPTIMAL: # If optimal solution is found
    print ('\nOptimal solution value: %s\n' % m.objVal)
else:
    print ('\nNo solution')
```

Figure H.3 Model code in python

I. Appendix – Modelling data

This appendix contains all modelling data used in this study. First, the real data of 2019 is presented. Subsequently, the base model is validated. The scenarios are set up based on the comparison of the base and ideal model. The differences are presented in I.3.3. Lastly, the outcomes of the scenarios are shown.

I.1. The real data for March 2019

As can be seen in Table I.1, nearly 50% of the appointments are treated in Gasthuis. The main locations combined cover about 35,000 out of 40,494 appointments. Franciscus Berkel, Maassluis and Haven have received approximately the same number of appointments.

Table I.1 Appointments per location for March 2019

Location	Appointments
Franciscus Gasthuis	18,842
Franciscus Vlietland	16,307
Franciscus Berkel	1,617
Franciscus Maassluis	1,346
Franciscus Haven	1,758
Franciscus Hoogvliet	329
Het Oogziekenhuis	302
Total	40,494

Table I.2 presents the distribution of appointments over locations per specialty. Some specialty (general surgery, geriatrics and paediatrics) focus on the main locations, whereas others treated a significant number of patients at the external locations (Cardiology, Dermatology and Gastroenterology).

Table I.2 Appointments per location per specialty for March 2019

Appointments	Berkel	Gasthuis	Haven	Hoogvliet	Maassluis	Oog	Vlietland	Total
Cardiology	228	1,390	327		160		1,303	3,408
Dermatology	321	1,950		96	240		1,349	3,956
ENT	299	1,251	731	73	257		1,545	4,156
Gastroenterology	115	712			40		668	1,535
General surgery	36	2,440		30	9		2,112	4,627
Geriatrics	8	83			3		187	281
Gynaecology	58	1,078		30	85		1,090	2,341
Internal medicine	95	2,061		26	137	302	2,040	4,661
Neurology	31	1,396		34	45		966	2,472
Ophthalmology		912			136		954	2,002
Orthopaedics	128	993			8		1,067	2,196
Paediatrics	59	898		24	48		990	2,019
Pulmonary medicine	149	1,494	367		58		972	3,040
Rheumatology	68	1,290		16	120		615	2,109
Urology	22	894	333				449	1,698
Total	1,617	18,842	1,758	329	1,346	302	16,307	40,494

The distribution of patients is caused by the distribution of consultation hours. Therefore, the distribution of consultation hours is similar to the distribution of appointments. See Table I.3.

Table I.3 Supply per specialty per location for March 2019

Hours/location	Berkel	Gasthuis	Haven	Hoogvliet	Maassluis	Oog	Vlietland	Total
Cardiology	41	249	59		28		225	602
Dermatology	35	234		11	32		167	478
ENT	38	151	90	10	34		186	509
Gastroenterology	27	152			9		172	361
General surgery	6	511		6	2		446	970
Geriatrics	5	57			2		93	158
Gynaecology	14	282		7	19		247	569
Internal medicine	21	483		5	31	74	447	1,061
Neurology	8	414		8	9		269	708
Ophthalmology		120			15		131	266
Orthopaedics	26	177			2		206	410
Paediatrics	20	326		8	13		370	738
Pulmonary medicine	31	341	81		11		210	674
Rheumatology	20	368		5	34		182	609
Urology	5	223	68				95	392
Total	299	4,089	299	60	239	74	3,444	8,504

Table I.4 show the average travel time per patient for each location. Notable is that Franciscus Haven and Oogziekenhuis have high travel times. This indicates a bottleneck in patient scheduling. It can also be explained due to the location. Rotterdam is very car-unfriendly. Furthermore, Franciscus Berkel and Maassluis have relatively low average travel times per patient.

Table I.4 Travel time per patient per location for March 2019

Location	Average Travel time
Franciscus Gasthuis	17.58
Franciscus Vlietland	15.29
Franciscus Berkel	13.70
Franciscus Maassluis	12.14
Franciscus Haven	23,21
Het Oogziekenhuis	24,96
Overall weighted average	13,30

Table I.5 represents the waiting times per specialty per locations. There are several specialty that exceed the Treeknorm. Gastroenterology, geriatrics, internal medicine and ophthalmology also exceed the Treenorm on average over all locations.

Table I.5 Actual average waiting time in March 2019

Actual waiting time	Berkel	Gasthuis	Haven	Maassluis	Oog	Vlietland	Average
Cardiology	27	32	40	29			33
Dermatology	21	5		24		17	17
ENT	5	5	2	7		7	5
Gastroenterology	60					57	59
General surgery	15	19		26		9	17
Geriatrics	49	34		102		20	51
Gynaecology	35	25		16		16	23
Internal medicine	91	38		22		39	48
Neurology	71	16		38		31	39
Ophthalmology	0	43					43
Orthopaedics	26	7					16
Paediatrics	33	10				23	22
Pulmonary medicine	14	22	17	19		13	17
Rheumatology	25	10		19		17	18
Urology		34	16				25

I.2. Validation

Table I.6 and Table I.7 show the simulated demand and supply for March 2019. Differences can be found per specialty per locations. However, the total supply and demand per location is valid, as the differences are within a margin of 5% error.

Table I.6 Simulated appointments for March 2019 in appointments

Simulated appointments	Berkel	Gasthuis	Haven	Maassluis	Oog	Vlietland	Total
Cardiology	194	1,839	282	132		961	3,408
Dermatology	368	1,731		352		1,504	3,955
ENT	333	1,213	806	276		1,527	4,155
Gastroenterology	163	595		49		728	1,535
General surgery	35	2,264		19		2,305	4,623
Geriatrics	14	94		11		162	281
Gynaecology	79	1,155		107		1,000	2,341
Internal medicine	126	2,152		162	376	1,845	4,661
Neurology	57	1,294		55		1,066	2,472
Ophthalmology	0	743		156		1,103	2,002
Orthopaedics	151	953		11		1,081	2,196
Paediatrics	94	831		54		1,040	2,019
Pulmonary medicine	172	1,554	407	64		843	3,040
Rheumatology	83	1153		130		743	2,109
Urology	59	894	309			435	1,697
Total	1,928	18,465	1,804	1,578	376	16,343	40,494

Table I.7 Simulated supply for March 2019 in hours

Simulated supply	Berkel	Gasthuis	Haven	Maassluis	Oog	Vlietland	Total
Cardiology	32	354	52	21		171	631
Dermatology	38	185		38		169	430
ENT	40	144	84	35		198	501
Gastroenterology	29	137		9		174	349
General surgery	5	553		2		564	1,123
Geriatrics	6	75		2		100	183
Gynaecology	16	286		21		210	532
Internal medicine	19	550		24	83	306	983
Neurology	10	442		10		283	745
Ophthalmology		91		16		126	234
Orthopaedics	28	194		2		216	440
Paediatrics	25	287		15		327	654
Pulmonary medicine	40	398	99	12		202	751
Rheumatology	22	320		38		212	592
Urology	12	235	80			105	431
Total	322	4,250	315	243	83	3,365	8,578

The waiting times per specialty per location differ significantly with the real data of March 2019, see Table I.8. The simulated waiting times are all established between 15-25. For the real data, there are large differences between specialties. Furthermore, in the real data the waiting times for specialties differ per location. In the simulated data, the waiting times also differ, however these differences are too small.

Table I.8 Simulated average waiting time in March 2019 in days

Simulated waiting time	Berkel	Gasthuis	Haven	Maassluis	Oog	Vlietland	Total
Cardiology	18	14	17	17		17	17
Dermatology	22	18		22		21	21
ENT	22	20	16	22		22	21
Gastroenterology	19	18		20		20	19
General surgery	15	17		16		18	16
Geriatrics	21	19		20		19	20
Gynaecology	22	21		22		22	22
Internal medicine	17	16		17	17	17	17
Neurology	19	20		19		20	20
Ophthalmology		19		22		17	19
Orthopaedics	23	22		21		23	22
Paediatrics	20	16		21		17	19
Pulmonary medicine	23	22	23	21		23	22
Rheumatology	20	17		21		21	20
Urology	21	23	23			22	23
Average	19	20	20	20	20	17	
Overall average							19.18

I.3. Comparison Base model and ideal situation

The outcomes of the base model are merely presented in the previous section. In this section, the simulated outcomes of the ideal situation is presented. Subsequently, the outcomes of the base model and the ideal situation are compared.

I.3.1. Base model

Table I.9 provides an overview of supply and demand of the base model.

Table I.9 Demand and supply simulated for the base model

	Appointments	Supply (min)	Supply (hours)
Gasthuis	18,465	258,360	4,306
Vlietland	16,343	199,085	3,318
Berkel	1,928	18,540	309
Maassluis	1,578	13,765	229
Haven	1,804	19,915	332
Oog	376	5,000	83

I.3.2. Ideal situation

Table I.10 presents the supply and demand of the ideal situation per location.

Table I.10 Demand and supply simulated for the ideal situation

	Appointments	Supply (min)	Supply (hours)
Gasthuis	9,969	128,510	2,142
Vlietland	14,446	184,010	3,067
Berkel	4,397	54,660	911
Maassluis	6,203	76,840	1,281
Haven	2,755	35,320	589
Oog	2,724	35,325	589

Table I.11 and Table I.12 show the simulated demand and supply per specialty per location in the ideal situation.

Table I.11 Distribution of appointments for ideal situation

Appointments	Berkel	Gasthuis	Haven	Maassluis	Oog	Vlietland
Cardiology	381	838	273	481	264	1,171
Dermatology	604	1,082	210	634	194	1,231
ENT	448	941	375	617	368	1,406
Gastroenterology	196	373	87	198	121	560
General surgery	491	1,129	301	690	312	1,700
Geriatrics	19	54	7	72	5	124
Gynaecology	203	507	124	408	170	929
Internal medicine	410	1,090	308	769	322	1,762
Neurology	234	650	149	388	166	885
Ophthalmology	237	424	65	445	57	774
Orthopaedics	242	523	120	320	111	880
Paediatrics	245	391	130	282	117	854
Pulmonary medicine	265	850	284	373	263	1,005
Rheumatology	242	659	167	260	124	657
Urology	180	458	155	266	130	508
Total	4,397	9,969	2,755	6,203	2,724	14,446

Table I.12 Supply for ideal situation per situation per specialty

Supply	Berkel	Gasthuis	Haven	Maassluis	Oog	Vlietland	Total
Cardiology	71	158	51	86	49	216	631
Dermatology	67	119	23	65	23	133	430
ENT	55	114	45	75	46	167	501
Gastroenterology	43	81	21	50	29	125	349
General surgery	119	273	74	167	76	415	1123
Geriatrics	14	35	2	42	4	86	183
Gynaecology	48	123	29	89	39	205	532
Internal medicine	85	243	67	159	71	359	983
Neurology	73	200	48	114	50	261	745
Ophthalmology	29	53	9	48	7	87	234
Orthopaedics	49	104	25	64	22	176	440
Paediatrics	80	128	43	92	37	275	654
Pulmonary medicine	71	158	51	86	49	216	631
Rheumatology	67	119	23	65	23	133	430
Urology	55	114	45	75	46	167	501

I.3.3. Models compared

The outcomes of the base model and ideal situation are compared to each other. The differences in supply and demand are presented by Table I.13-I.15. It is concluded that there is indeed a mismatch between supply and demand for all locations, but for Gasthuis, Berkel and Maassluis particularly. Gasthuis receives too many patients with a different preference location. Furthermore, the number of patients should be increased for Berkel and Maasluis.

Table I.13 Difference in demand and supply for base model and ideal situation

	Appointments	Duration	Hours
Gasthuis	-8,496	-129,850	-2,164
Vlietland	-1,897	-15,075	-251
Berkel	+2,469	+36,120	+602
Maassluis	+4,625	+63,075	+1,051
Haven	+951	+15,405	+257
Oog	+2,348	+30,325	+505

Table I.14 Difference in allocation of appointments for base model and ideal situation

Number of Appointments	Berkel	Gasthuis	Haven	Maassluis	Oog	Vlietland
Cardiology	187	-1,001	-9	349	264	210
Dermatology	236	-649	210	282	194	-273
ENT	115	-272	-431	341	368	-121
Gastroenterology	33	-222	87	149	121	-168
General surgery	456	-1,135	301	671	312	-605
Geriatrics	5	-40	7	61	5	-38
Gynaecology	124	-648	124	301	170	-71
Internal medicine	284	-1,062	308	607	-54	-83
Neurology	177	-644	149	333	166	-181
Ophthalmology	237	-319	65	289	57	-329
Orthopaedics	91	-430	120	309	111	-201
Paediatrics	151	-440	130	228	117	-186
Pulmonary medicine	93	-704	-123	309	263	162
Rheumatology	159	-494	167	130	124	-86
Urology	121	-436	-154	266	130	73
Total	2,469	-8,496	951	4,625	2,348	-1,897

Table I.15 Difference in supply for base model and ideal situation

Supply	Berkel	Gasthuis	Haven	Maassluis	Oog	Vlietland
Cardiology	39	-196	-1	65	49	45
Dermatology	29	-66	23	27	23	-36
ENT	15	-30	-39	40	46	-31
Gastroenterology	14	-56	21	41	29	-49
General surgery	114	-280	74	165	76	-149
Geriatrics	8	-40	2	40	4	-14
Gynaecology	32	-163	29	68	39	-5
Internal medicine	66	-307	67	135	-12	53
Neurology	63	-242	48	104	50	-22
Ophthalmology	29	-38	9	32	7	-39
Orthopaedics	21	-90	25	62	22	-40
Paediatrics	55	-159	43	77	37	-52
Pulmonary medicine	26	-189	-31	80	67	47
Rheumatology	48	-132	46	33	35	-31
Urology	32	-119	-40	67	34	26
Total	589	-2,108	274	1,038	506	-298

I.4. Scenarios

This section contains the outcomes of waiting time per specialty for every scenarios. Furthermore, the patient growth used in scenario is presented and subsequently the outcomes for supply and demand for scenario 3.

I.4.1. Waiting times scenarios

Table I.16 shows that the waiting times per specialty are affected by the scenarios, despite the fact that overall average is not changed.

Table I.16 Average waiting time per specialty per scenario

	Base	1.1	1.2	2.Opth	2.ENT	2.CAR	2.RAD	3
Cardiology	16.7	16.6	16.7	16.7	16.7	16.7	16.6	16.7
Dermatology	20.8	20.4	20.7	20.8	20.8	20.8	20.8	21.0
ENT	20.6	20.8	20.6	20.6	20.3	20.6	20.6	20.8
Gastroenterology	19.4	19.6	19.5	19.4	19.4	19.4	19.4	19.9
General surgery	16.3	17.1	16.7	16.3	16.3	16.3	16.7	16.2
Geriatrics	19.6	19.6	19.6	19.6	19.6	19.6	19.6	18.7
Gynaecology	21.7	21.6	21.7	21.7	21.7	21.7	21.7	21.9
Internal medicine	16.8	16.4	16.5	16.5	16.5	16.5	16.5	16.6
Neurology	19.9	20.0	20.2	19.9	19.9	19.9	19.9	20.1
Ophthalmology	19.3	18.5	18.8	18.9	19.3	19.3	19.3	19.8
Orthopaedics	22.2	22.6	22.6	22.6	22.6	22.6	22.6	22.9
Paediatrics	18.5	17.9	18.5	18.5	18.5	18.5	18.5	18.8
Pulmonary medicine	22.4	22.7	22.6	22.4	22.4	22.4	22.7	22.6
Rheumatology	20.0	19.8	19.9	20.0	20.0	20.0	20.0	20.2
Urology	22.6	23.1	22.8	22.6	22.6	22.6	22.6	22.4
Overall average	19.18	19.18	19.18	19.18	19.18	19.18	19.18	19.18

I.4.2. Scenario 3

The patient growth as shown in Table I.17 is based on the expected population growth of every town in the Care area of Franciscus.

Table I.17 Patient growth per city for scenario 3

City	Current number of patients	Population growth (%)	Expected number of patients	% of total patients
Schiedam	6593	1	6659	16,27%
Vlaardingen	6732	1	6799	16,61%
Rotterdam	17663	3	18193	43,58%
Lansingerland	4006	7	4286	9,88%
Maassluis	2777	1	2805	6,85%
Westland	326	5	342	0,80%
Midden-Delftland	196	1	198	0,48%
Nissewaard	597	1	603	1,47%
Albrandsewaard	472	-2	463	1,16%
Capelle aan den IJssel	815	2	831	2,01%
Pijnacker-Nootdorp	354	5	372	0,87%

Table I.18 and Table I.19 present the supply and demand for every year in the coming five years. These are the distributions of the supply and demand considering the same capacity constraints as in the base model.

Table I.18 Patient flow for scenario 3

Patient flow	Base	2020	2021	2022	2023	2024	2025
Berkel	1,982	1,985	2,031	2,033	2,095	2,106	2,107
Gasthuis	18,209	18,269	18,471	18,576	18,703	18,873	18,860
Haven	1,680	1,686	1,661	1,661	1,667	1,673	1,674
Maassluis	1,630	1,649	1,709	1,707	1,769	1,773	17,76
Oog	378	377	385	379	386	388	389
Vlietland	16,613	16,602	16,649	16,607	16,663	16,687	16,710
Total	40,494	40,568	40,906	40,963	41,283	41,500	41,516

Table I.19 Supply for scenario 3

Supply	Base	2020	2021	2022	2023	2024	2025
Berkel	107	111	115	115	119	119	119
Gasthuis	1,417	1,416	1,433	1,438	1,450	1,464	1,464
Haven	105	105	102	103	103	103	103
Maassluis	81	85	89	89	93	93	93
Oog	28	28	28	28	28	28	28
Vlietland	1,122	1,121	1,128	1,126	1,133	1,135	1,135
Total	2,859	2,866	2,895	2,899	2,925	2,942	2,943

J. Appendix – Scientific article

Optimisation of elective care patient allocation over multiple locations based on patient preferences

A case study for Franciscus Gasthuis & Vlietland

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Abstract
There is an increasing pressure on quality, access and cost of healthcare since the implementation of the "Zorgverzekeringswet" (ZVW). Therefore, hospitals focus on the service for patients. They have set up external outpatient clinic (EOCs) to provide care closer to the patients home. EOCs conduct in initiatives as "The right care at the right place" and can alleviate the pressure on hospital locations, as patients can be distributed over multiple locations. This can only be achieved when patients are correctly scheduled over the available locations. Therefore, an optimisation model for the allocation of elective care patients of different specialties over multiple locations is designed. This model determines the optimal allocation by optimising the service for patients, defined by waiting time and travel time. A case study for Franciscus Gasthuis & Vlietland is applied to test the designed model. There is a mismatch between supply of consultation hours and demand of patients at her locations, which causes a lack of performance at her EOC locations. Scenarios are set up to analyse the effect of measure on the performance of EOC and therefore the service for patients. These outcomes of this analysis have provided Franciscus with possible measures to improve the performance of her EOCs. The model designed in this research is a first version, further research could most certainly increase the quality of the design.

Keywords Patient planning optimisation, Linear programming, service for patients, external outpatient clinics

1. Introduction

Since the implementation of the "Zorgverzekeringswet" (ZVW), the Dutch healthcare system changed from a supply-driven to a demand-driven system. Healthcare organisations, as hospitals, now focuses on the service for patients. Therefore, there is an increasing pressure on quality, access and cost of healthcare and hospitals aim to find an optimal balance between these three components. Access of healthcare is defined by affordable and available healthcare for everyone in need of care. Besides, access is also meant in a geographical way, patients prefer hospital locations close to their homes (NVZ, 2016; Delaronde, 2019; Ministerie van VWS, 2016).

In context of accessible healthcare, care parties have setup an initiative: The right care in the right place (JZOJP). This initiative is headed by the Ministry of Health, Welfare and Sport. It aims to shift the perspective of healthcare providers from their interests and what they have to offer, to what people need from them to live independently as long as possible. The development of transmural care is one of the means that help to achieve this goal. Transmural care is care supplied by healthcare providers, for example General Practitioners and medical specialists, to fulfil the needs of a patient in an optimum way (Taskforce Zorg op de Juiste Plek, 2018; Medical Groep, 2019).

One way in which hospitals can contribute to this initiative, is to set up external outpatient clinics (EOCs). These clinics are set up to offer care closer to the home of the patient. Furthermore, hospitals aim to enlarge their care area by setting up these EOCs (Runia, 2017; Sonneveld & Heida, 2014).

There is an increasing pressure on hospital locations due to shortage of personnel and the increasing number of patients. This causes long waiting times for patients, which effects the service for patients (Vermeeren, 2019). The use of EOCs can alleviate the pressure on hospital locations, as patients can be distributed over multiple locations. Moreover, it is hypothesised that EOCs can improve the service for patients, because they offer care closer to the patients and could cause a reduction in waiting time (Runia, 2017). This can only be achieved when patients are correctly scheduled over the available locations. Therefore, an optimisation model for the allocation of elective care patients of different specialties over multiple locations is proposed. This model determines the optimal allocation by optimising the service for patients.

The remainder of this paper is structured as follows. Section 2 summarises a literature review on previous research of patient scheduling. Furthermore, previous research on patients planning optimisation is discussed.. In Section 3, the methodology is elaborated. In this section, the case study of Franciscus Gasthuis & Vlietland (Franciscus) is introduced and the design of the model is presented. Then, the model is applied for the case study of Franciscus. The results are shown in section 4. Section 5 contains the discussion on the designed model. In the final Section, Section 6, the conclusions and recommendations for future research are presented.

2. Literature

To optimise the service for patients, an definition for service for patients needs to be defined. The model focuses on the allocation of patients over multiple locations, therefore factors that influence the hospital location choice for patients are used to define the service for patients.

The decision-making process considering location choice of patients is a well-known topic in the literature. Research is executed in a wide range of countries all over the world (Smith et al, 2018; Varkevisser & Geest, 2006). Based on a literature review an overview is created, presented in Table 1.

This research focus on the allocation of patients over multiple locations of the same hospital organisation. Therefore, not all factors are considered. Quality of service is equal for every locations, as every locations has the same resources and care is offered by the same specialists. The same accounts for influence of the general practitioner and advice of family in friends. These are irrelevant, since all locations are part of the same hospital. Furthermore, availability of resources is only relevant for clinical patients, this model is designed for polyclinical patients. Therefore, the service for patients is defined by:

- Waiting time. This is the time between scheduling an appointment the moment of the appointment itself.
- Travel time. This the time a patient to travel from their origin to the involved Franciscus location.

Table 1. Literature review on factors influencing location choice of patients

Factor	Results
Travel time	- Varkevisser & Geest (2006) - Beukers, Kemp, & Marco (2014) - Birk & Henriksen (2012) - Smith et al (2018) - Cruppé & Geraedts (2017)
Waiting time	- Sivey (2012) - Varkevisser & Geest (2006) - Beukers, Kemp, & Marco (2014) - Birk & Henriksen (2012) - Smith et al (2018) - Birk, Gut, & Henriksen (2011)
Quality of service	- Beukers, Kemp, & Marco, (2014) - Birk & Henriksen (2012)
Availability of facilities	- Smith et al (2018)
Influence of General Practitioner	- Beckert (2017) - Wiedenhöfer & Keppler (2014) - Cruppé & Geraedts, (2017)
Advice of family and friends	- Wiedenhöfer & Keppler (2014) - Cruppé & Geraedts, (2017)

Subsequently, an literature review is carried out on previous research on patient planning optimisation models. Previous research is often focused on one specific department of a hospital (Min & Yih, 2010; Baril, Gascon, & Cartier, 2014). Models are designed to either measure performances or improve performance (Reitsema, 2017; Strahl, 2015).

Furthermore, models are designed for the allocation of hospital locations or resources (Kritchanchai & Hoeur, 2018; Hulshof & al., 2011). These before mentioned research focus either on one department or the allocation of hospital location. This model focuses on the allocation of patients over multiple locations.

Azadeh, et al. (2015) have conducted a research in minimising the waiting time of patients in emergency department laboratories. The model designed in this research has similarities with the model designed for this research: it considers multiple location, different activities and different types of appointments. However, the research of Azadeh et al. (2015) focuses on the waitng time at the location, the waiting time from moment of arrival till the moment a patitens is treated. This model focuses on the waiting time before an appoitment.

Therefore, the model created in this research is a first design and have not been applied or reviewed by researchers before. Hence, the outcomes of the application of the model should be considered as a explorative study. In the next section, the model is elaborated.

3. Methodology

The different steps of this study are discussed in this chapter. As presented in the previous chapter, a literature study is done. Afterwards, a case study of Franciscus is introduced. Subsequently, a linear programming model is designed. Lastly, the model is applied for the case study.

Case study

A case study is used to gather insight in the current use of EOCs. With an analysis of the current performance of the EOCs, bottlenecks are determined. The effects of the bottlenecks are quantified by means of performance indicators and KPIs. Subsequently, the model is applied for the case study to evaluate measures that could improve the performance of EOCs to increase the service for patients. The case study used in the research is Franciscus Gasthuis & Vlietland.

Franciscus is a hospital group in the area of Rotterdam, the Netherlands. Franciscus has six locations. The main locations in Rotterdam and Schiedam, two EOCs in Berkel and Maassluis, several polyclinics in Haven and an polyclinic in Oogziekenhuis Rotterdam (Franciscus Gasthuis & Vlietland, 2019)

A first analysis on the performance of the EOCs have shown that the locations are not optimally used. There often empty rooms and employees with lack of work during opening hours. Moreover, the occupancy rate of scheduled consultation hours is beneath 80%. Which is considered low by Franciscus (Korthorst & Stelt, 2019). Furthermore, as explained in the introduction, there is an increasing pressure on the main locations. Based on these observations, Franciscus determined that the performance of the EOC should be increased.

Therefore, further analysis is done to determine the bottlenecks that causes this inefficiency at the EOCs and the effect of the bottlenecks are quantified based on KPIs. The KPIs used in this research are:

- Average costs per consults;
- Average waiting time per patient;
- Average travel time per patient.

Three components are researched: the stakeholders, the customer journey and the data. This is done by interviews, observations and data-analysis.

Linear programming model

The decision-making factors for the choice of hospital location for a patient are determined in the literature review in chapter 2. Subsequently, the bottlenecks that influence the performance of EOCs are determined and the effect is quantified in the case study in chapter 3. Based on these findings, a patient planning optimisation model is designed. This model minimises the total inconvenience cost for patients by allocating all appointments over all locations. The inconvenience costs are calculated by a combination of waiting time and travel time, the factors that influence the service for patients.

Waiting time is taken into account as the time between the moment an appointment is scheduled and the moment of the appointment takes. Travel time is defined as the relative travel time towards the preference location. The location that is the closest to the origin of the patient is assumed to be the preference location of that patient. Each other location causes the patient extra travel time. This extra travel time is taken into account as travel time in the model. Furthermore, the allocation is optimised considering the location capacity, capacity of specialties at a location and utilisation of the latter capacity.

The mathematical model is formulated as described by Martinich (1997) and Hiller & Lieberman (2014).

The objective function of this LP model is:

$$\text{MIN } \alpha_1 \sum_{a \in A} \sum_{j \in J} T_{p_a j}(X_{aj}^L + X_{aj}^M + X_{aj}^H) + \alpha_2 \sum_{a \in A} \sum_{j \in J} (W^L X_{aj}^L + W^M X_{aj}^M + W^H X_{aj}^H) \tag{1}$$

The objective function (1) minimises the inconvenience costs for all appointments over all locations. Weight factors α_1 and α_2 determine the influence of the factors on the total cost. The first part of the objective functions sums up all travel times for each appointment travelling to the assigned location for all appointment for all locations. The second part sums up all appointments times the assigned waiting time for all appointments for all locations. The waiting time is determined by the utilisation rate of a specialty on a location.

The objective function is subject to the following constraints:

Functional constraints:

$$\sum_{i \in I} \sum_{a \in A} \sum_{k \in K} q_{ik}(X_{aj}^L + X_{aj}^M + X_{aj}^H) \leq c_j \qquad \forall\, j \in J \tag{2}$$

$$\sum_{i \in I} \sum_{a \in A} q_{ik} X_{aj}^L \leq 0{,}2 u_{kj} Y_{kj} \qquad \forall\, k \in K, j \in J \tag{3}$$

$$\sum_{i \in I} \sum_{a \in A} q_{ik} X_{aj}^M \leq (0.7 - 0{,}2) u_{kj} Y_{kj} \qquad \forall\, k \in K, j \in J \tag{4}$$

$$\sum_{i \in I} \sum_{a \in A} q_{ik} X_{aj}^H \leq (1 - 0.7) u_{kj} Y_{kj} \qquad \forall\, k \in K, j \in J \tag{5}$$

$$\sum_{j \in J} (X_{aj}^L + X_{aj}^M + X_{aj}^H) = 1 \qquad \forall\, a \in A \tag{6}$$

Constraint (2) defines the capacity restriction for each location; the sum of all appointments on a location times the duration of these appointments is smaller or equal to the maximum capacity for that location. Constraints (3), (4) and (5) define the capacity constraint of specialties on a location; the sum of all appointments assigned to a location for a specialty in the [low, medium, high] utilisation range times the duration of these appointments is equal or lower than the capacity of that specialty on that location if that specialty is available on that location. Constraint (3) defines the low utilisation range, (4) the medium, and (5) the high utilisation range. Constraint (6) ensures that every appointment is assigned to one and only one location.

Other constraints

$$X_{aj}^{L} = \{0,1\} \qquad \forall\, a \in A, j \in J \qquad (7)$$

$$X_{aj}^{M} = \{0,1\} \qquad \forall\, a \in A, j \in J \qquad (8)$$

$$X_{aj}^{H} = \{0,1\} \qquad \forall\, a \in A, j \in J \qquad (9)$$

$$Y_{kj} = \{0,1\} \qquad \forall\, k \in K, j \in J \qquad (10)$$

$$T_{Pj} \geq 0 \qquad \forall\, p \in P, j \in J \qquad (11)$$

The constraints presented above define the characteristics of the variables. The first four constraints (7-10) are binary, whereas the other constraints (11-12) define an integer variable.

The model elaborated in this section is applied to the case study, which is explained in the next Section.

Model application

The LP model explained in the previous section is applied for the case study Franciscus. The model is used to analyse the effect of suggested measures on the performance of EOCs and the service for patients. The data used for the application of the model is provided by the Business Intelligence department of Franciscus. The model is calibrated to set valid values for estimated parameters. Subsequently, the model is verified and validated.

After calibration, verification en validation, a base model is created. This base model represents the real distribution of patients for March 2019. Moreover, an ideal model is designed that represents the allocation of patients in the ideal world, without any capacity constraint or waiting time. In this model every appointment is assigned to its preference location according to their travel time.

Based the current state analysis, literature study and the comparison the base model and ideal situation, measures are determined. This measures are analysed based on scenarios. These scenarios are run in the model. For each scenario, KPIs are calculated to determine the effect on service for patients.
The measures that are analysed are:

- A shift in consultation hours of specialties over the locations;
- Investments on the resources for one of the EOC locations.

Four different investments are tested:

- Ophthalmology equipment for EOC Berkel;
- Audio booth for EOC Berkel;
- Home trainer for EOC Maassluis;
- Radiology equipment for EOC Maassluis.

For scenario two an additionally cost/benefit analysis is performed to check whether the investment is beneficial considering the costs of investment and the additional number of appointments the investment yields.

Furthermore, a forecast scenario is created for the years 2020-2025 to determine whether the current supply of consultation hours is sufficient given the patient growth. Besides, the scenario is also used to analyse the effect patient growth on the service for patients.

4. Results

In the current state analysis for Franciscus, several bottlenecks have been established:

- The schedule of EOC locations are based on the planning of specialists. The demand of patient is not considered;
- The importance of EOC locations are underestimated by the main locations.
- Lack of communications between the main locations and the EOC locations.
- Franciscus has an inefficient appointment system that differs per location.

These bottlenecks cause a mismatch between the demand of patients and the supply of consultation hours at the Franciscus locations. This causes a lack of performance at the EOCs and therefore a lack of service for patients. Waiting time of specialties exceed the Treeknorm (28 days) and the average travel time per patient is longer than necessary.

Model application for Franciscus Gasthuis & Vlietland

The model is applied for Franciscus. From the verification and validation can be concluded that the model slightly overestimates the number of appointments for the EOC locations, therefore the average costs per consult. This is taken into account while analysing the outcomes of the scenarios. Conclusion are drawn on the effect of the measures, the actual values are not considered. Subsequently, the scenarios are run to analyses the effect of the measures on the service for patients.

A shift in consultation hours has a positive effect on the service for patients. one extra consultation hour of each specialty at both locations already has a positive effect on the service for patients. The average utilisation rate of the EOCs is increased by 15% and the average cost per consult decreases by 2 euro per patient. Besides, the average travel time patient is decreased by 1 minute. Due to the functioning of the model, waiting time remains equal. The average waiting time is only affected by a change in number of appointments.

The analysis of scenario two shows that only the investment of Radiology equipment would be a beneficial investment. These devices have rather high investment costs, but the costs are covered within three years. This is concluded from cost/benefit analysis The average utilisation rate of the EOCs are increased by 12% and the average cost per consult is decreased by 1 euro. Nevertheless, the service for patients as determined for the model does not improve much due to this investment. The travel time is only slightly decreased.

From the forecast scenario is concluded that the location capacity of the Franciscus locations would be sufficient. However, the capacity of some specialties is going to fall short. This concern the specialties Geriatrics, Urology and Neurology. These specialties need to increase their supply of consultation hours with a minimum of four consultation hours a week, to cope with the patient growth in the coming five years.

Based on the resulted obtained from this model applications, an advice is given on the improvement of EOCs to increase the service for patients at Franciscus in section 6. First, the next section present a discussion of the designed model and results.

5. Discussion

The discussion refers to the design of the LP model.

The model that is created for this study is a first design for the optimisation of the allocation of patients for multiple specialties over multiple hospital locations. Therefore, the model is not yet applied or reviewed by other researchers. The model must be considered as a first design, reviews and adjustments by other researchers will be beneficial for the quality of the model. Furthermore, this model is a simplified design and does not consider all constraints involved in the allocation of patients. For example, preferences of specialists, opening hours and availability of resources are excluded. Therefore, the model only be used as explorative study. Before a decision is made on analysed measures, further research is required.

Furthermore, the method used for the design of this model is Linear Programming. This model can only be used in case both objective function and constraints are linear. Therefore, waiting time is considered as linear variable. However, waiting time is actually a non-linear dynamic variable that changes over time. This causes deficiency of validation of the model, effecting the usability of the model. In hindsight, a different method for the design of the model could have provided a more accurate model. For example, discrete event simulation. This method can include dynamic variables as waiting time. With dynamic waiting time, more valid and therefore reliable outcomes could be simulated. However, discrete event simulation is less suitable for calibration and sensitivity analysis, due to long running times. In this study, calibration is used to find values for estimated parameters to validate the model. With discrete event modelling, this could not have been carried out, which could cause a lack of validation.

The model is applied to a case study. Verification has shown that the model functions correctly. The results of the model applications is based on estimated value for parameters, which results in uncertainty of the outcomes of the model. Further research is advised to obtain more reliable results.

Based on the results and discussion, conclusions are drawn. This conclusion is presented in section 6. Furthermore, recommendations are provided for future research.

6. Conclusion and recommendations

The main objective of this research was to design a model that optimises the allocation of patients of multiple specialties over multiple locations to optimise the service for patients. The model is tested by a case study. The case study that is used the situation of Franciscus. Franciscus has six locations and seeks to find measures to improve the performance of her EOC locations to increase the service for patients. Therefore, scenarios have been created to analyse the effect of several measures on the service for patients.

The main result concluded from the application of the designed model is that a shift in consultation hours towards the EOC locations would improve the performance of EOCs. The improvement performance of the EOC causes an increase in service for patients, since the average travel time per patient is decreased. Furthermore, this measure leads to less consultation hours the main location, therefore the pressure on the main locations is decreased. Besides, the average costs per consult, regardless of the location, is decreased. Nevertheless, the implementation of this measure can only be achieved by the cooperation of several stakeholders. Changes in the organisation of Franciscus are necessary to achieve an increase in service for patients. Examples of these changes are, increasing awareness of the demand of patients at EOC locations and scheduling patients based on their origin considering all Franciscus locations.

A second measure that can improve the performance of EOCs is the investment of Radiology equipment at the EOC Maassluis. This measure does not necessarily increase the service for patients as defined by the KPIs, but it does improve the accessibility for patients and therefore the service for patients. This investment increases the attractiveness for patients and for specialists, as a complete diagnosis can now be carried out at once on the same location.

The model designed in this study is the first version of a model that allocates elective care patients over multiple locations including multiple specialties. Therefore, the model is not applied or reviewed by other researchers. Considering the results of this study, some recommendations for future research are:

Usage of different modelling methods. Models that include waiting time as dynamic variable that changes over time.

Inclusion of other constraints in the LP model than only capacity constraints. For example, constraint of resources and FTEs, preferences of specialists and opening hours of locations.

Extend the definition of service for patients. Further exploration of other factors that define the service for patients. This design is limited to travel time and waiting time, influence of other factors are possible.

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