UNIVERSITY OF TWENTE.

MASTER THESIS

Determining the balance between general and specialist care of Internal Medicine practitioners based on patient demand

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This thesis is written as part of the graduation assignment of the master programme of Industrial Engineering & Management at the University of Twente.

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Determining the balance between general and specialist care by doctors based on patient demand

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This thesis is intended for Isala Ziekenhuis Zwolle and the supervisors from the University of Twente involved in the research. In his public version, some original values are altered and some parts are moved to a confidential appendix.

Preface

This report is the result of my graduation project at the Isala hospital in Zwolle, which I executed for the final part of my Industrial Engineering & Management master programme. In this programme, I got many opportunities to develop myself, not only academically, but also professionally. I am grateful for the privilege of studying at the University of Twente, a place that has provided me with an enriching environment for personal development.

I am thankful that I could perform my graduation project at Isala. I was always eager to understand what it is like to work in the healthcare sector, and with this project I was able to gain real-world experience. Specifically, I want to thank Ton, who offered great support in the entire project. You helped me to always think critically, you gave very helpful feedback and supported me beyond this project. I will never forget the weekly meetings on Monday, together with my fellow graduation students Ruben and Jur where we could brainstorm and be critical on our projects. If I compare my guidance with those from other students, I am sure I got very lucky. And even without comparing, I know that this guidance was of exceptional quality. Thank you for that.

Furthermore, I want to thank my supervisors from the University of Twente, Gréanne, Sebastian and Jedidja. Sebastian, you provided me with multiple ideas and a research paper which helped me to tackle the problem in this research. Gréanne, you always tried to make time even though you're very busy, and I appreciate that very much. Your feedback made sense was always to the point. Jedidja, your input during the weekly meetings was always very useful.

Finally, I want to thank my fellow students, roommates, friends and family for supporting met the past six years. In especially Elise, who was all of the aforementioned for me. Except for family although it felt like it. Together with Elise I did not only make all my master assignments, I also understood them thanks to her. I have learned a lot in these years about operations research and even more about myself. I am looking forward to what the future will bring!

Stan van der Wel

Enschede, December 2023

Management Summary

Problem Definition

The Internal Healthcare Department of Isala Hospital in Zwolle's objective is to have T-shaped specialists among its internists. T-shaped specialists are characterized by an equitable distribution of their time towards the treatment of general patients and patients that require specialist care. However, currently there exists a substantial disparity in the allocation of time dedicated to general patients among the internists. The time spent on general patients per internist fluctuates from 1% to 56%. As a result, we have formulated the following research question:

''How can the internal medicine department at Isala allocate their internists such that the balance between executing deep expertise and cross-domain treatments is optimized?''

Optimized in this context means striving for a similar percentage of time dedicated to general and expertise patients for all internists, while having an equitable distribution of overtime across internists.

Methodology

We formulated a quadratic optimization model to determine the allocation of patients, considering the specific patient demand and the availability of internists within the department. The patient demand was categorized based on Diagnosis-Related Groups (DRGs), each associated with a DRG type that signifies preferences, sometimes one two or even three.

In addition, we developed an Excel-based tool, utilizing a heuristic approach for optimizing patient distribution. We classified and ranked the DRG types from rigid to flexible in planning. For example, a DRG type that can only be seen by 1 specialty is less flexible than the DRG type for general patients, which can be seen by multiple specialties. We start with allocating the least flexible and end with the most flexible DRG types to ensure that DRG's will be allocated as much as possible to their preferred specialties.

Experiment design

In total 4 experiments were executed for the patient demand of 2022 and the forecasted patient demand of 2030. This forecasting element was included to provide recommendations not only for short-term considerations but also for long-term planning.

The first experiment allocates all appointments as optimal as possible. The second experiment researched which specialty was needed most if an infectiologist would retire. The third experiment focused on which specialty would be the best for an additional internist. Lastly, the fourth experiment was designed to establish the optimal allocation when considerations of overtime and availability were disregarded.

Results

In the actual situation we found that a lot of patients were not treated by the preferred specialty. In the actual situation 15.3% of the appointments were not placed at their preferred specialty and overtime per internist fluctuated from -2.0% to 108.1%. The amount of time spent on general patients per internist fluctuated from 1.3% to 48.2%. Our optimized allocation allowed overtime allocation from 0.2% to 19.2% per internist and made sure that only 1% of the appointments were not placed at their preferred specialty. The experiment was executed with both the model and the heuristic, which yielded similar results. Only 0.8% of the total appointments were placed worse in the

heuristic than in the model. The allowed overtime percentages and resulting T-shaped specialist percentages are shown in Table 1.

Table 1: Overtime and T-shaped specialist percentages for optimized appointment allocation of 2022

Specialty	% General	% Overtime
Endocrinology	0.0%	12.5%
Haematology	0.0%	19.2%
Infectiology	71.0%	12.5%
Nephrology	12.6%	12.5%
Oncology	0.0%	0.2%
Elderly	23.0%	12.5%
Vascular	0.0%	12.5%

The result of the experiment on which internist to hire to replace an infectiologist is interesting for Isala as an infectiologist will be retiring soon. The results for the patient demand of 2030 is the most interesting as hiring an internist is most often a long term decision. The allowed overtime percentages and resulting T-shaped specialist percentages are shown in Table 2.

Table 2: Overtime and T-shaped specialist percentages when replacing an infectiologist based on the demand for 2030

Replacement		END	HAE	INF	NEP	ONC	ELD	VAS
Endocrinologist	%Overtime	12,5%	19,2%	12,5%	12,5%	0,2%	12,5%	12,5%
Haematologist	%Overtime	17,5%	4,3%	17,5%	17,5%	-0,1%	17,5%	17,5%
Infectiologist	%Overtime	12,5%	19,2%	12,5%	12,5%	0,2%	12,5%	12,5%
Nephrologist	%Overtime	12,5%	19,2%	12,5%	12,5%	0,2%	12,5%	12,5%
Oncologist	%Overtime	18,0%	19,2%	18,0%	18,0%	-11,5%	18,0%	18,0%
Elderly healthcare	%Overtime	12,5%	19,2%	12,5%	12,5%	0,2%	12,5%	12,5%
Vascular internist	%Overtime	12,5%	19,2%	12,5%	12,5%	0,2%	12,5%	12,5%

We value the reduction of the maximum overtime across specialties more important than an equitable distribution of general patients. Based on the predicted patient demand in 2030 the best replacements for the infectiologist that will soon retire are ranked from 1 (most favourable) to 7 (least favourable). The ranking is similar for the addition of an internist.

1. Haematologist
2. Endocrinologist
3. Oncologist
4. Vascular internist
5. Nephrologist
6. Elderly healthcare internist
7. Infectiologist

From experiment four we learn that each specialty, except infectiology, at least 1 additional internist is needed in the future. Isala would need to hire about 3 endocrinologists, 2 haematologists, 1 nephrologist, 2 oncologists, 1 elderly healthcare internist and 1 vascular internist for 2030.

Practical And Scientific Contribution

The practical significance of this research lies in its immediate applicability for Isala Hospital, particularly in the context of the forthcoming retirement of an infectiologist. The insights derived from this study can assist Isala in making informed decisions regarding the recruitment of a replacement. Furthermore, the user-friendly and readily accessible Excel tool developed in this research enables Isala to perform swift sensitivity analyses, allowing them to investigate the potential impacts of varying compositions of internists on appointment allocation.

From a scientific standpoint, this research stresses the efficacy of quadratic programming optimization techniques for strategic healthcare optimization decision making. By utilizing mathematical and programming tools, we have demonstrated the capability to address a complex problem with relative ease. This scientific contribution highlights the potential for mathematical and computational approaches to resolve intricate issues effectively, while also showing that heuristics can achieve similar results and that this is sometimes a more practical option.

Table of Contents

1. Problem Introduction

This chapter introduces the problem that this research concerns. Section 1.1 discusses the company background and the motivation of this research. Section 1.2 describes the research plan, including the problem description, scope and research questions.

1.1 Company Background & Research Motivation

Section 1.1.1 introduces the hospital, Isala and the department where this research is focussed on. Section 1.1.2 gives the motivation of this research, and Section 1.1.3 provides the context of the analysed problem.

1.1.1 The internal medicine department at Isala Ziekenhuis Zwolle

Isala is an hospital organization in the Netherlands with five locations in Zwolle, Meppel, Steenwijk, Kampen and Heerde. Under the motto 'close if possible, further away if necessary', they jointly guarantee the supply of basic and top care in Southwest Drenthe and Northwest Overijssel. At the location in Zwolle, the hospital is divided into several departments, including the internal medicine department. This research will be done for this department at the Zwolle location.

Internists work in the Department of Internal Medicine. They are engaged in the prevention, investigation and treatment of diseases of the internal organs. In the treatment of diseases, an internist can prescribe medication, recommend lifestyle changes or refer to another specialty. Within the team of internists, each internist has his own specialization, such as:

- Elderly medicine
- Dialysis and nephrology
- Endocrinology (i.e., diabetes)
- Haematology
- Infectious diseases
- Oncology
- Vascular medicine
- Acute healthcare

We name all the specialties together the ‘department’. If we exclude oncology and haematology, we say ‘general’ internal medicine.

1.1.2 Research Motivation

In Isala, the internists are considered as T-shaped specialists, characterized by their possession of in-depth knowledge and cross-domain skills and attitudes. This concept is visually depicted in Figure 1. Specifically, this implies for example that an endocrinologist at Isala possesses significant expertise in endocrinology, enabling the treatment of all oncology patients. Additionally, the endocrinologist also possesses sufficient knowledge about other medical areas, such as diabetes, to enable the treatment of some diabetes patients.

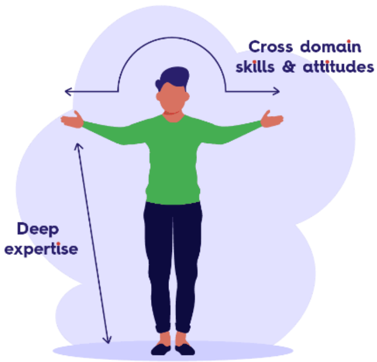

Figure 1: T-shaped specialist[1]

The balance between in-depth knowledge and cross-domain skill is important to Isala as an internist should maintain their specialty while also exhibiting broad orientation. The goal of this research is to improve the current balances across all internists. We define the balance as follows:

$$\text{T-shaped specialist balance} = \frac{Amount\ of\ time\ spent\ on\ treating\ general\ patients\ by\ internist}{Amount\ of\ time\ spent\ in\ total\ on\ patients\ by\ internist}$$

[1] = https://agilescrumgroup.nl/t-shaped/

1.1.3 Problem Context

For effective monitoring of balances, it is essential to classify the patients among the specializations. Section 1.1.3.1 provides a detailed explanation of how DRG (Diagnosis Related Group) codes can serve as a useful tool in achieving this objective. Lastly, the allocation of patients to internists is a critical aspect. Therefore, the composition of the internist team plays a vital role in striving for specific balances. The responsibility of recruiting internists lies with the "Medisch Specialistisch Bedrijf" (MSB), as outlined in Section 1.1.3.2.

1.1.3.1 DRG

The term 'Diagnosis Related Groups' (DRG) signifies a nine-digit code that conveys information about the content of healthcare activities. Therefore, a DRG provides information regarding the entire care trajectory and all procedures involved. It forms the basis of a hospital invoice (healthcare bill). As a DRG indicates the procedures it encompasses, conversely, we can identify under which DRG an appointment falls. By linking DRGs, in consultation with internists, to a specialty, we can subsequently determine the most appropriate type of internist for conducting or having conducted the appointment.

1.1.3.2 MSB

A Medical Specialist Association (MSB) is an organization comprising medical specialists who practice in private practice. This association has entered into a collaboration agreement with the board of directors of a general hospital. There are approximately 70 MSBs in the Netherlands. Through MSBs, boards of directors have a single clear point of contact. Among other things, boards of directors negotiate with MSBs regarding the provision of healthcare and budget allocation.

Isala also operates with an MSB. Among their responsibilities is the recruitment of new internists for the Department of Internal Medicine. For instance, when an internist retires, they initiate a vacancy announcement to secure a replacement. However, expanding the department of internal medicine by hiring additional personnel is not a straightforward process. The growth of this department is subject to specific constraints outlined in the "integrated care agreement." Therefore, it is of paramount importance that the available hours are optimally allocated with the appropriate internists.

1.2 Research Plan

Section 1.2.1 shows different planning levels and helps to demarcate the problem of this research. Section 1.2.2 discusses the perceived problem and the root causes of this problem. Section 1.2.3 gives the scope and objective of this research, and Section 1.2.4 describes the research design. Section 1.2.5 provides the outline of this thesis corresponding to the research design.

1.2.1 Hierarchical framework for healthcare planning and control

Organizations employ planning and control decisions to establish and manage their operational processes. These decisions are made for long-term, medium-term, and short-term purposes. To address the complexity of planning and control in the healthcare sector, Hans et al.(2012) have proposed a hierarchical framework in the existing body of literature. This framework serves to structure and deconstruct the planning and control functions within healthcare organizations. Moreover, the framework can be utilized to identify planning issues that may arise within an organization. Figure 2 visualises the hierarchical framework for healthcare planning and control.

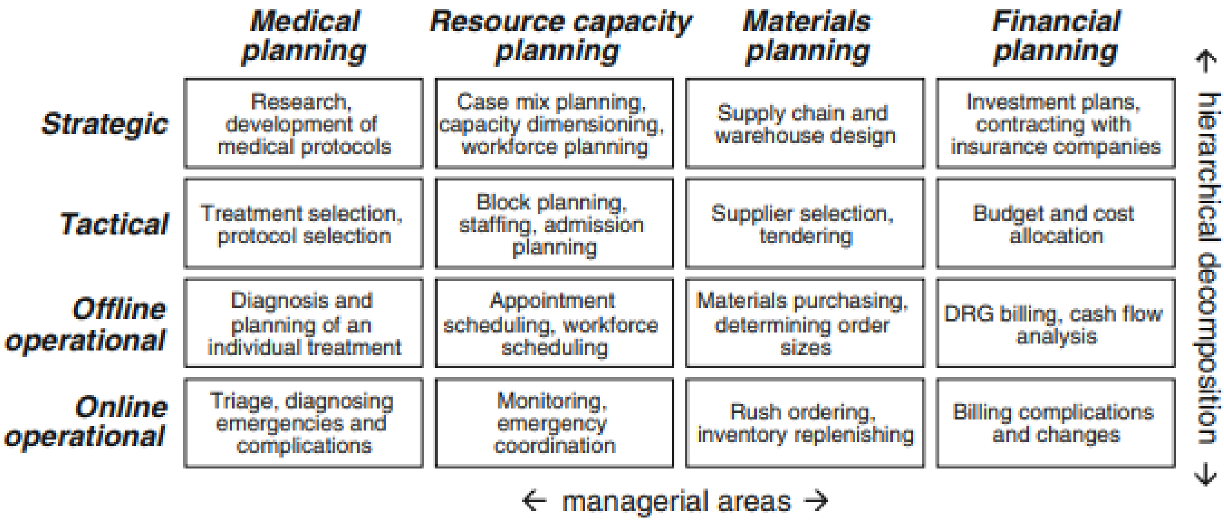

Figure 2: Hierarchical framework for healthcare planning and control (Hans et al. 2012)

The planning and control framework contains four key managerial areas: medical planning, resource capacity planning, materials planning, and financial planning. Medical planning entails decision-making by clinicians, including protocols, triage, diagnoses, and treatments. Clinicians are granted increased autonomy as processes become more complex. Resource capacity planning concerns renewable resources and primarily involves their planning, scheduling, monitoring, and control. Renewable resources are equipment, facilities, and staff. Materials planning focuses on consumable resources and materials, such as blood, bandages, and food. This managerial area involves considerations of storage, distribution, and retrieval, often requiring knowledge of warehouse design, inventory management, and purchasing. Financial planning, the final managerial area, centers on managing costs and revenues for both present and future purposes. It has a big influence on the way processes are organized and managed (Hans et al., 2012).
The framework's horizontal axis positions the hierarchical dimensions. As time progresses, more information typically becomes available. Therefore, the framework differentiates between strategic, tactical, and operational planning levels. The operational level is further subdivided into offline and online components. In this research we are dealing with a strategic resource capacity planning problem, which is further explained in the upcoming Sections.

1.2.2 Problem Description

As described in Heerkens & Van Winden (2021), anything or any situation that is not how you want it to be is an action problem. It is the discrepancy between norm and reality, as perceived by the problem owner. In this case, the problem owner is the internal medicine department within Isala. The norm aspired to is the equitable distribution of deep expertise and cross-domain treatments among all internists, while the current reality deviates from this equilibrium.

This action problem is viewed on the right in the problem cluster below. This problem is perceived at Isala. The problem cluster shows how other problems cause the action problem. On the left, the root cause of all these problem can be found: no steering information. This means that there is no data visualization of how much time each internist spends on deep expertise and cross-domain treatments.

This action problem is situated on the right within the problem cluster illustrated below. This issue is perceived within the Isala institution, and the problem cluster shows how various interconnected issues contribute to the emergence of this action problem. On the left-hand side, the root cause underlying all these problems can be found: the absence of steering information. This implies the lack of comprehensive data visualization regarding the allocation of time by each internist between deep expertise and cross-domain treatments.

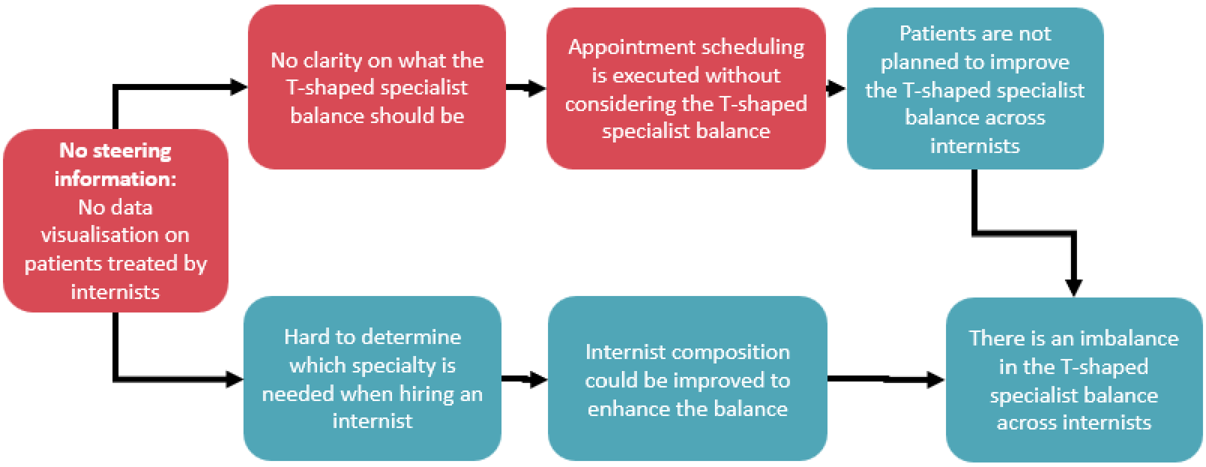

Figure 3: Problem cluster

Primarily, this issue gives rise to the problem of lacking visibility into the total number of general and specialty appointments. Consequently, the division of these appointments, and how it could be optimally allocated, remains unknown. In essence, the ideal distribution remains unknown. It becomes infeasible for receptionists to pursue a more equitable allocation when they lack clarity on the target balance. The receptionists need guidance when aiming for a better allocation.

Furthermore, the absence of steering information presents challenges in determining the most needed specialization when recruiting a new internist. The compound of internists is paramount for optimizing allocation. For instance, if all nephrologists are fully occupied with nephrology appointments, it would be imprudent to allocate general appointments to them. The objective is to avoid overtime and ensure that nephrology patients receive treatment from nephrologists. In such a scenario, the addition of another nephrologist would facilitate a more equitable distribution of nephrology patients and enable a greater allocation of general appointments to each internist.

In the problem cluster, there are some red-highlighted boxes, which represent the issues focused on this research. By addressing these problems, we expect to naturally solve the action problem that the Internal Medicine Department at Isala is facing.

1.2.3 Research Objective & Scope

The objective of this research is to improve the balance between in-depth knowledge and cross-domain skills and attitudes among internists. In practice, achieving an identical balance for every internist is infeasible, given the unpredictability of patient types. Nonetheless, it may be possible to reduce differences in this balance across internists.

By analysing available data, a comprehensive overview of personnel, patient types, and their volumes can be obtained. Based on this overview, it should be feasible to match the appropriate internist with each patient, thus minimizing differences in the balance of in-depth knowledge and cross-domain skills and attitudes across internists.

After the overview is realised and visualised, this research will provide some advice on how the department should allocate their staff and patients based on this overview. The final step will be to provide recommendations for the future by incorporating data such as the aging population in the Netherlands. The last two steps of the methodology can aid Isala in their decision-making process regarding the recruitment of new staff by providing them with data on patient demand, which can enable them to select the most suitable internist for the job. In this context, the term "the most suitable internist for the job" encompasses the selection of internists who ensure that the balance between deep expertise and cross-domain skills for each internist is not significantly disturbed at Isala.

In Section 1.2.1 different levels were discussed such as strategic, tactical and operational. Solving the core problem is a work force planning problem, which is on a strategic level. After resolving this issue, it should be possible to use this as input for creating a block planning schedule. A block schedule gives guidance to the receptionist planning the patients. This solves the second red-highlighted problem in the problem cluster from Section 1.2.2. On a tactical level, when the block planning is created, we need to determine some planning rules such that the receptionist will optimally make use of the block planning. Planning rules are used on an operation level. Planning rules will solve the final red-highlighted box.

This research is exclusively focused on the internal medicine department of Isala , and thus, other departments of Isala will not be considered. Within this department, for simplicity, we only consider the internists and no other medical specialist that could treat certain patients. We try to make the developed models as generalized as possible, such that they could be applied to other departments with T-shaped professionals.

The study will consider all patient data within the internal medicine department of Zwolle to ensure that decisions are based on a complete set of information, rather than solely focusing on a subset of patients. Furthermore, the workload of the research will not be significantly reduced by limiting the number of patients since all data can be incorporated into a single file and loaded accordingly.

The research will assume that Isala's current rules and procedures are followed. For example, the study will not explore how to determine or predict the duration of a specific treatment. Instead, the research will solely examine how patients can be assigned to internists to maintain a balance between deep expertise and cross-domain treatments for each internist as effectively as possible.

1.2.4 Research Design

To achieve the research objective, we pose the following main research question:

How can the internal medicine department at Isala allocate their internists such that the balance between executing deep expertise and cross-domain treatments is optimized?

Seven sub-questions are defined to help answer the main research question:

1. *What is the current process for assigning internists to patients?*
   The objective of this question is to gain comprehension of the current procedures. Prior to giving advice, it is important to have a certain understanding. Otherwise, the advice might not fit with the given context. We will answer this question by interviewing and observing the personnel at the internal healthcare department.
2. *What are the available treatments and which internists are qualified to perform them?*
   In order to appropriately assign a cross-domain treatment to a qualified internist, it is necessary to have knowledge of the specific treatments that can be executed by each internist, and whether a qualified treatment is a deep expertise or cross domain treatment. Failure to do so could result in scheduling appointments between patients and doctors who lack the necessary expertise to effectively address the patient's needs. In cooperation with the internal medicine department, we will assign Diagnosis-Related Group (DRG) codes to various medical specialties. Through the integration of DRG codes with appointments and data analysis, we aim to gain insights into the distribution of an internist's time across different medical specialties
3. *What is the targeted balance between specialized expertise and interdisciplinary healthcare provision?*
   Upon obtaining information regarding the treatments that can be performed by each internist, it is possible to determine, by data analysis, the number of internists within each specialization that are employed at Isala. In that way we theoretically determine what the optimal balances are given the current combination of internists.
4. *How to allocate patients to internists to obtain this balance?*
   By reviewing relevant literature, we will develop a model that helps us attain the targeted balance.
5. *What are scenarios of future patient demand that impact the internist balance in the future?*
   Isala desires to ascertain the means by which an optimal combination can be maintained in the future. By executing a data analysis to explore trend in demand, recommendations for the future can also be given.
6. *What would be the optimal composition of internists for Isala Hospital to achieve a balanced distribution of specialized and interdisciplinary care provision in 2030?*
   Utilizing the outcomes of the previous questions, we will determine the optimal combination of internists for Isala Hospital.
7. *Which recommendations can we give to Isala based on the results of this research?*
   A comparison between the optimal and the current situation may be made in order to identify the necessary modifications required to attain a better configuration. This can help Isala in their decision process for acquiring new specialists.

1.2.5 Outline Thesis

This thesis follows the outline as shown in Figure 4. Chapter 2 focuses on the current situation of Isala and its performance, by answering the first four research questions from Section 1.2.3. Chapter 3 gives a theoretical framework for this research and discusses alternative solutions that are found in literature. These solutions are then analysed and the knowledge gained is used to set up a model in Chapter 4. Chapter 5 presents the results from applying the found model. Chapter 6 concludes this research with a recommendation for Isala and a conclusion and discussion on the methodology of this research.

Figure 4: Outline thesis

2 Current Situation

In the context of this research, the calendar year 2022 is designated as the reference point for our investigation, herein referred to as the 'current situation.' Section 2.1 shows the prevailing methodology for scheduling patient appointments. Subsequently, Section 2.2 describes details concerning the internists active during the year 2022. Lastly, in Section 2.3, an explanation is provided on the allocation of appointments among internists through data filtration techniques, accompanied by an exploration of an optimal distribution strategy.

2.1 Planning process

Within the internal healthcare department of Isala, new patients are referred through various channels, including general practitioners, other departments within the hospital, or external healthcare facilities. Upon arrival, these patients undergo an initial triage process overseen by an internist responsible for triage duties at that specific point in time. The triaging internist is tasked with determining the appropriate internist for the patient's subsequent care. Subsequently, the internist responsible for triage communicates their decision to the scheduling office, which is responsible for arranging the patient's appointment with the designated internist.

Once a new patient undergoes treatment, the attending internist initiates a Diagnosis-Related Group (DRG) code. This process is facilitated by the internist's increased understanding of the patient's condition and medical history, gathered during the clinical encounter. Following the treatment session, a follow-up appointment is scheduled, if thought necessary, by the department's secretary. At this point, the patient transitions from the classification of a 'new patient' to that of a 'control patient.' The schematic representation of this sequential process involving new patients is presented in Figure 5.

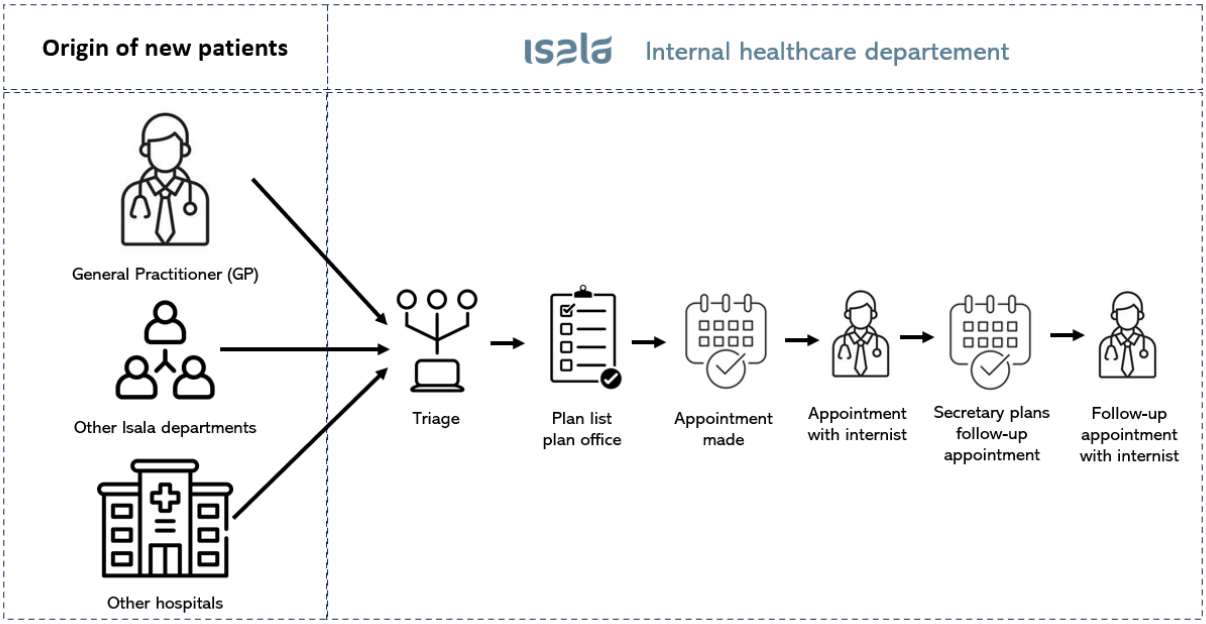

Figure 5: Patient flow internal healthcare department Isala

As a general categorization, appointments within the healthcare system fall under two primary classifications, namely, those designated for new patients and control patients. It is important to note, however, that within each of these overarching categories, there exist various subtypes of appointments, each characterized by distinct attributes, including differing durations allocated during clinic hours. The comprehensive scope of this classification encompasses a total of 66 unique appointment types. To provide a representative overview, a selection of these appointment types is presented in Table 3 for illustrative purposes. For a comprehensive list detailing all 66 appointment types, please refer to Appendix A.

Table 3: Appointment types

Appointment type	Label	Duration (minutes)
New Patient	NP	30
Control Patient	CP	15
…		…
Telephone consult	TC	5

2.2 Staff

As indicated in Section 1.2.2, this research specifically focuses on internists within the internal medicine department. In 2022, a total of 42 internists were present, each with a distinct specialization. In rare instances, a doctor may possess expertise in two specialties, in which case their available time is divided between the two areas.

The term "full-time equivalent" (FTE) is used to measure employed individuals or students in a manner that allows for comparability, regardless of the variation in the number of hours worked or studied per week. It is important to note that not all internists have the same FTE value, typically ranging between 0.7 and 1. However, there are exceptional cases where the FTE can be even lower. Various factors contribute to these differences, such as a doctor's desire to allocate less time to work in order to spend more time with their children, among other reasons.

When an internist has an FTE of 1, they are expected to dedicate 17 hours of their workweek to patient treatment in the outpatient clinic (referred to as "poli"). Consequently, an internist with an FTE of 0.5 would allocate 8.5 hours to poli. Some doctors may have additional specialized tasks that allow them to subtract a portion of their expected poli hours. We consider these hours per week to be the availability of each internist.

Typically, doctors are assumed to work for 44 weeks per year. However, there are situations where doctors may purchase an extra week of holiday, resulting in fewer than 44 working weeks. Moreover, certain special circumstances, such as pregnancy, may also lead to doctors working fewer than 44 weeks in a year. In Table 4, all internists of 2022 are listed with their specialty and their expected availability in 2022.

Table 4: Internist, their specialty and expected availability in 2022

Internist	Specialty	Expected availability 2022 (minutes)
Internist 1	Endocrinology	39260
Internist 2	Endocrinology	37133
Internist 3	Endocrinology	35664
Internist 4	Endocrinology	30353
Internist 5	Endocrinology	30966
Internist 6	Haematology	21120
Internist 7	Haematology	28380

Internist 8	Haematology	24552
Internist 9	Haematology	36960
Internist 10	Haematology	31680
Internist 11	Haematology	9000
Internist 12	Haematology	27192
Internist 13	Infectiology	29040
Internist 14	Infectiology	30996
Internist 15	Infectiology	30065
Internist 16	Nephrology	26131
Internist 17	Nephrology	12275
Internist 18	Nephrology	19892
Internist 19	Nephrology	26183
Internist 20	Nephrology	30420
Internist 21	Nephrology	23758
Internist 22	Nephrology	3120
Internist 23	Oncology	23436
Internist 24	Oncology	26400
Internist 25	Oncology	19032
Internist 26	Oncology	29832
Internist 27	Oncology	34320
Internist 28	Oncology	25200
Internist 29	Oncology	26400
Internist 30	Oncology	13200
Internist 31	Oncology	2160
Internist 32	Oncology	24420
Internist 33	Elderly healthcare	33496
Internist 34	Elderly healthcare	17398
Internist 35	Elderly healthcare	19394
Internist 36	Elderly healthcare	29909
Internist 37	Elderly healthcare	22620
Internist 38	Elderly healthcare / Vascular	33208
Internist 39	Vascular	3600
Internist 40	Vascular	35697
Internist 41	Vascular	31200

2.3 Data Analysis

2.3.1 Filtering the data

The dataset utilized in this research, sourced from Isala, encompasses appointment-related information for patients, spanning from the 1st of January 2018 to the 14th of July 2023. This dataset encompasses a total of 413,299 appointments. Notably, the data has been pseudonymized, as it pertains to the context of this study, with personal information being deemed irrelevant. All patient data has been extracted from the CTcue environment within Isala, spanning multiple years to facilitate the identification of potential patterns, seasonality, and the isolation of COVID-19-related effects, as elaborated upon in Chapter 5.

Each appointment is characterized by a Diagnosis-Related Group (DRG) status, which can assume one of the following designations:

1. Invoiced
2. Opened
3. Parked
4. Closed
5. Not declared
6. Not invoiced
7. Expired

We found that the definition of the "parked" status lacked clarity within the department. Given that only 82 out of the total 413,299 appointments fell under this categorydecided, in consultation with the department manager, to exclude these appointments from consideration. The "expired" status signified appointments that did not transpire, totalling 7,599 such appointments, which were likewise excluded from the analysis. Consequently, a dataset comprising 405,618 appointments was retained, as it was assumed that appointments bearing the remaining statuses had happended as intended in practice.

For the purpose of this study, the calendar year 2022 was designated as the reference point for the “current situation”. After filtering out appointments that fell outside of the year 2022, a dataset consisting of 74,133 appointments within that calendar year was obtained. Subsequently, appointments executed exclusively by internists, as detailed in Section 2.2, were selected, yielding a total of 73,890 appointments. Finally, specific appointment types such as “administration work” were omitted, resulting in a dataset comprising 70,288 appointments. Appendix B provides a comprehensive list of the retained appointment types. The entire filtering process is visually represented in Figure 6.

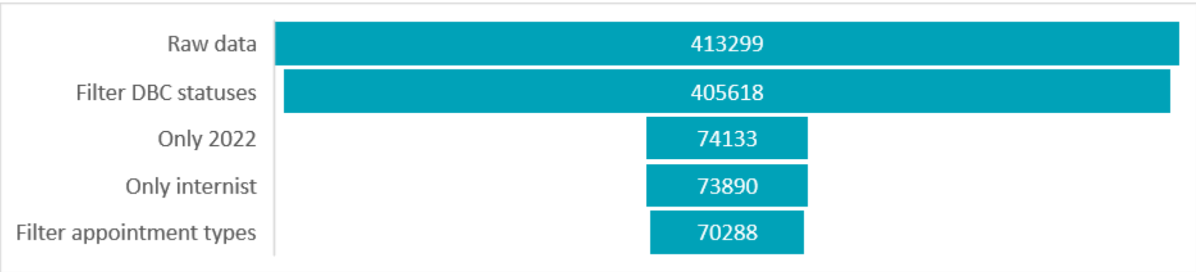

Figure 6: Filtering process of the appointment data

2.3.2 DRG division

Upon associating appointments with Diagnosis-Related Group (DRG) codes within the dataset, the subsequent task involved aligning these DRG codes with specific medical specializations. This process, however, presented a certain degree of complexity, as the categorization of DRG codes in this context is somewhat subjective. For instance, certain internists might designate a particular DRG code to the field of nephrology, while others might classify it as infectiology. We arrived at a consensus, regarding DRG code allocation that most internists would concur, in the following way. To establish a foundational framework, we initially adopted the DRG categorization provided by the Dutch Healthcare Authority (NZA). NZA had previously devised a classification scheme for DRG codes prevalent in internal healthcare departments throughout the Netherlands. It is worth noting that some categories within this NZA list did not align precisely with the specialties at the internal healthcare department of Isala. For example, NZA included a category named 'system diseases,' which was not a recognized specialization at Isala. Nonetheless, DRG codes associated with systemic diseases were indeed treated within the internal healthcare department at Isala.

Thereafter, we executed a quantitative analysis of the treatment patterns associated with all DRG codes, taking into account both the frequency of treatment and the internist responsible for each case. Using this empirical data in conjunction with the NZA's DRG classification, we devised a preliminary conceptual framework. Subsequently, we had meetings with internists specializing in each respective field. They provided feedback on this framework, which was incorporated and processed. The final iteration of this framework underwent inspection by another internist, leading to minor adjustments. The resulting DRG classification, which can be referenced in Appendix C, excluded DRG codes with a total appointment count in 2022 of less than 10, as their contribution was insignificant.

Our analysis led us to a categorization of DRG codes based on the ideal specialization for their handling. These categorizations can be summarized as follows:

1. **Exclusive Specialty:** Certain DRG codes are best suited for treatment by a particular specialization and should be exclusively managed by that specialization.
2. **General Availability:** Conversely, some DRG codes can be accommodated by any specialized internist, with no exclusive association to a particular specialization.
3. **Single Preference:** There exist DRG codes that are ideally managed by a specific specialization but are also permissible for treatment by another specialization without significant deviation from optimal care.
4. **Dual Specialization:** Certain DRG codes warrant treatment by only two distinct specializations, and no others.
5. **Preference with Alternatives:** Lastly, some DRG codes exhibit a primary preference for a specific specialization but are amenable to treatment by a secondary preference specialization if the former is not feasible.

The complete set of unique DRG classifications is presented in Table 5. It is essential to note the distinction between 'General' and 'Department' classifications, where 'Department' encompasses the entirety of the internal healthcare department, while 'General' encompasses all departments except for oncology and haematology. The notation '80/20,' in the context of Infectiology/Haematology, signifies that 80% of cases are ideally entrusted to an infectiologist, while the remaining 20% are considered suitable for management by a haematologist.

Table 5: Internist specialty preference possibilities per DRG type

Type	1st Preference	2nd Preference	3rd Preference
1	General		
2	Endocrinology		
3	Endocrinology	General	
4	Endocrinology/Elderly	General	
5	Endocrinology/Vascular		
6	Endocrinology/Vascular	General	
7	Endocrinology/Haematology (80/20)		
8	Endocrinology/Oncology		
9	Haematology		
10	Haematology	General	
11	Haematology	Vascular	
12	Infectiology		
13	Infectiology	General	
14	Infectiology	Department	
15	Infectiology/Haematology (80/20)		
16	Nephrology		
17	Nephrology	General	
18	Oncology		
19	Elderly healthcare		
20	Elderly healthcare	General	
21	Vascular		
22	Vascular	General	
23	Vascular	Nephrology	General
24	Department		

2.3.3 Patient Type distribution

Now that we have filtered the data for the year 2022, linked DRG codes to their corresponding appointments, and determined the appropriate specialization for each DRG, we can construct an overview detailing how the DRG specializations were distributed among the internists in 2022.

This Overview is depicted in Figure 7, with an enlarged version provided in Appendix D. Figure 8 shows the same data, but in a 100% stack column to better visualize the difference in time spent on general patients across internists.

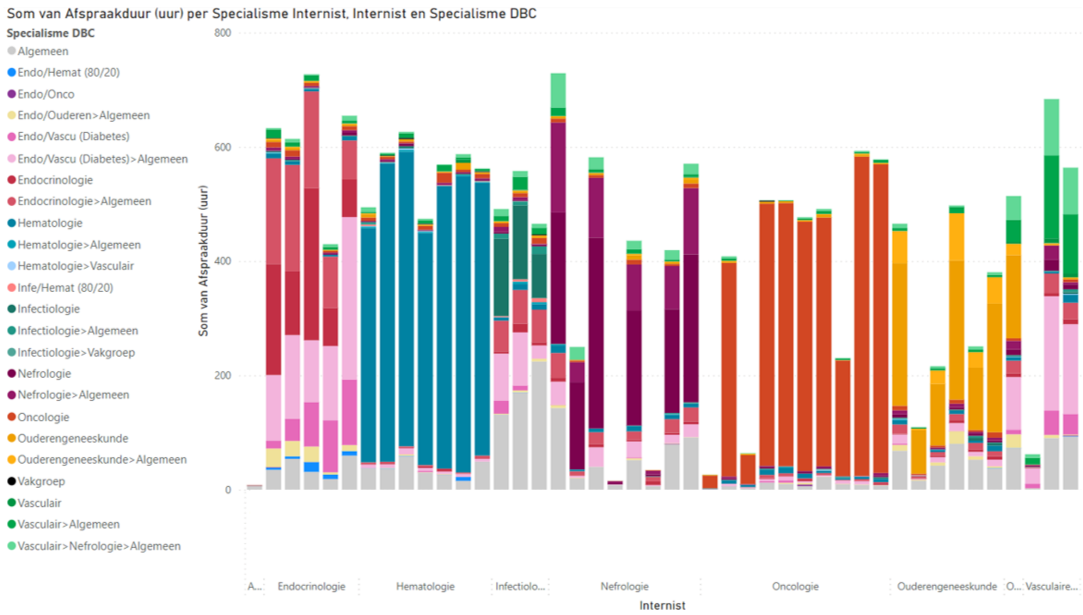

Figure 7: DRG specialty division over internists in 2022, stack column

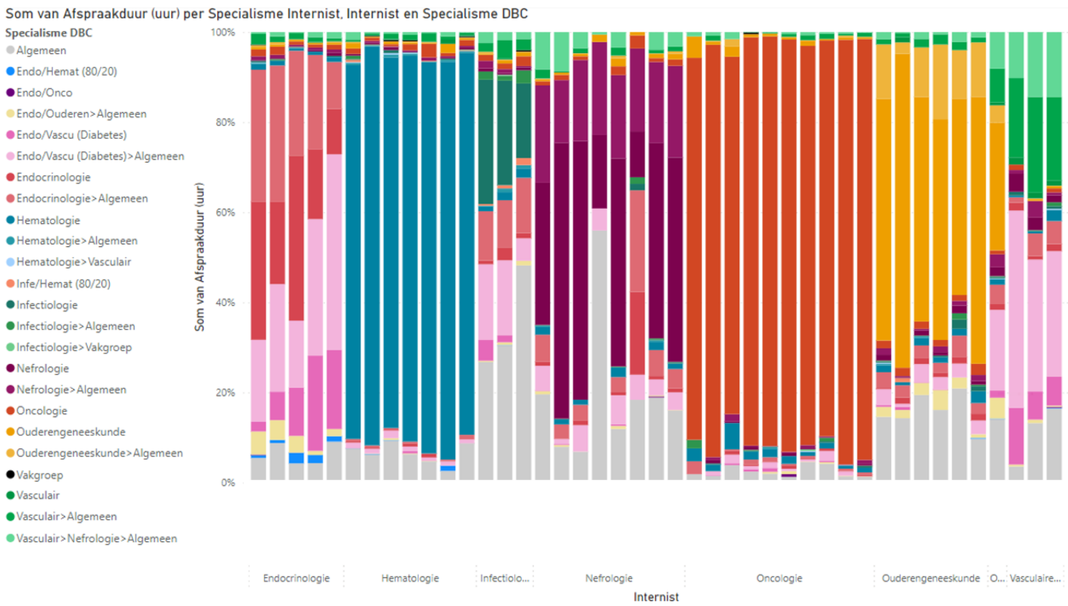

Figure 8: DRG specialty division over internist in 2022, 100% stack column

In Figure 7 and 8, it is evident that the distribution of general patients among various medical specialties is not uniform. To illustrate, the infectiologists (internists 13, 14, and 15) have attended to a significantly higher number of general patients compared to other specialties. The maximum percentage spent on general patients is 48.2%, while the lowest is percentage is 2.0% within the general section of the department. We see that haematologist and oncologists are also treating general patients, while this should not be the case. Additionally, the number of hours worked by each internist exhibits substantial variability across the group. Overtime fluctuates from -2% to 108%, where -2% indicates that an internist did not use all the minutes of the predetermined availability. We found that 15.3% of the appointments were not placed at their preferred specialty.

2.3.4 Targeted balance

In Figure 7 and 8 it becomes evident that there exists an unequal distribution of the 'T-shaped specialist' balance among the internists. For instance, a noticeable inequality emerges where infectiologists allocate a lesser portion of their time to their specialized field while devoting a comparatively larger portion to general healthcare, as opposed to endocrinologists.

We define specialized care as encompassing treatments falling within the designated specialization of an internist. For instance, infectiology DRG codes represent specialized expertise for infectiologists. Conversely, all other DRG codes can be regarded as constituting interdisciplinary healthcare within the domain of infectiologists. In an ideal scenario, interdisciplinary care should exclusively comprise general or department DRG codes. This alignment would signify that all specialty-specific DRG codes are being managed by an internist possessing the required specialization. Consequently, the calculation of the targeted balance is formulated as follows:

$$Targeted\ balance = \frac{Total\ duration\ appointments\ with\ general\ or\ department\ DRG\ codes}{Total\ duration\ of\ all\ appointments}$$

Isala also is wondering what the targeted balance would be if you would treat the specialties oncology and haematology differently. They are both specialized in such a way, that the T-shaped specialist makes less sense there. The formula for the targeted balance is not valid anymore in this case, so the targeted balance is calculated with the allocation tool described in Appendix I. The rest of this research mainly focuses on treating the specialties haematology and oncology different.

When considering all specialties, the targeted balance is equal to 0.099, implying that internists should allocate 9.9% of their time to general or departmental appointments. However, when we exclude oncology and haematology, the targeted balance shifts to 0.174, indicating that internists should dedicate 17.4% of their time to general or departmental appointments.

2.4 Conclusion

We conclude that there is a disbalance of general care relative to the total care for the current situation in the internal medicine department of Isala, with some specialists spending more percent of their time on general care than other (e.g., ranging from 4% up to 52% general care versus 96% up to 48% specialty specific appointments). We observe that there is potential to improve this balance, through rearranging appointments. The potential balance, which we named the targeted balance, is equal to 0.174. The question now is: how do we attain this targeted balance? This question is answered in Chapters 3 and 4. Chapter 3, reviews different relevant literature sources and Chapter 4 shows how this literature is used for a model for our case. With the aid of this model, we endeavour to approach the targeted balance more closely.

3. Literature

This chapter discusses literature to this research. Section 3.1 explains resource capacity based on relevant literature. Section 3.2 describes how linear programming is a fitting technique for our problem. Section 3.3 show how the outcomes of our model can be put into practice. Finally, Section 3.4 summarizes the chapter.

3.1 Resource capacity planning

Capacity planning is the process by which organizations determine the broad level of resources they make available for the delivery of a service or a set of services. Specifically we define capacity planning to be ‘‘deciding on the amount of beds, staff, consulting rooms, equipment, etc. sufficient to enable an organization to meet demand for one or more packages of care while achieving specified service standards’’ (Utley et al. 2012). The resources that we are dimensioning in this research are the internists of the internal healthcare department. The goal is to achieve a service standard where we divide patients over internists such that the T-shaped specialist balance discussed in Chapter 1 will be more in balance.

In healthcare there are different planning techniques for different type of patients. The internal healthcare department treats outpatients, or said different: ambulant patients. Gupta and Wang (2011) discussed patient appointments in ambulatory care. They say that clinics use a two-step process to manage appointments. In the first step, which they refer to as the clinic profile setup problem, service providers’ daily clinic time is divided into appointment slots. In the second step, which they refer to as the appointment booking problem, physicians’ offices decide which available slots to book for each incoming request for an appointment.

The amount of slots are based on the care providers’ availability and workload. Providers’ (i.e. physicians, physician’s assistants and nurse practitioners) workloads in the primary-care setting are often described in terms of their panel sizes. A panel is a group of patients for whom the same provider is the preferred service provider. The panel provider is also called the preferred care provider (PCP) (Gupta and Wang, 2011). We will base the PCP on the DRG linked to the patients. For example, a patient from which the DRG is seen as a ‘nephrology-DRG’, all the nephrologists are this patient’s PCP. Appointment booking procedures must strive to match patients with their PCPs. This ensures continuity of care (Doescher et al. 2004), and allows physicians to provide more value-added services to their patients (O’Hare et al. 2004).

Primary care clinics tend to divide available provider time into equal length time slots such that, by and large, patients’ needs can be accommodated in a standard appointment slot. Unlike a primary care environment where most services can be performed within a fixed-length appointment slot, specialists’ appointment lengths can be highly variable and diagnosis dependent. **(**Gupta & Denton 2008). Although we are dealing with specialists’ appointments lengths in our research, we are using a mid-way approach. We are using multiple standard appointment slots. Through the years, Isala came with different appointment types (NP, CP, etc.) that have different durations. We assume that these durations are empirically chosen such that the variability is well taken into account as well. Copying the appointment types of the current system has the advantage that the solution of this research is easier to implement for Isala. Next to that, due to the state of information systems in health care, crucial information is often not available (Carter 2002). In our case, there is no available data on actual durations of the appointments which makes it hard to determine ‘perfect’ appointment durations.

3.2 Mathematical modelling

Scheduling methods rely on operations research techniques, including forecasting, mathematical modelling and optimization, queue models and stochastic processes. These techniques are used in many ways, including setting appointments, scheduling staff, planning surgeries and managing the flow of patients through health care systems (Hall 2012). As we are ignoring queues, uncertainty and looking for a long term planning in our research, therefore we believe that mathematical modelling is the best way to tackle the problem in this research.

Blake & Carter (2002) introduced a goal programming approach for strategic resource allocation in acute care hospitals. In our research, we are dealing with an internal medicine department instead of an acute care hospital. Nonetheless, their work is very applicable to our setting. For example, they make use of objective function weights such that they can incorporate multiple objectives but all with a different magnitude in influence. This is useful for our research as we are dealing with four objectives:

1. Minimizing overtime of internists and among internists
2. Minimizing idle time of internists
3. Minimizing the amount of patients that are not treated by one of their PCP's
4. Minimizing the disbalances in general and specialty treatments among internist

Next to that, Blake & Carter (2002) make use of a vector p, which represents the preferred mix of cases. We could use a similar technique to make sure that patients will be scheduled at the preferred internist.

Guo and Bard (2022) are one of the many examples in literature where overtime minimization incorporated in a mathematical programming model. The difference with other sources is that Guo & Bard (2022) also propose an algorithm that does approximately the same as the mathematical programming model. This is interesting, as algorithms are most often easier to implement than mathematical programming models.

3.3 Block planning and blueprint scheduling

A claim for ''more capacity'' is the universal panacea for many health care managers. It is, however, often overlooked that instead of such drastic strategic measures, tactically allocating and organizing the available resources may be more effective and cheaper. **(**Hans et al. 2012) More capacity could be a solution for the internal healthcare department of Isala. In chapter 2 we saw that not all patients were treated by the an internist with the preferred specialty. Increasing the availability of the internists would give the receptionists more space to place patients at the preferred internist. However, as explained in Section 1.1.3.3, increasing capacity is not so easy to do. With a technique like linear programming, we can show that by dividing the patients differently, more patients will be treated by an internist with the preferred specialty. It gives us an optimal division of patients, but how do we make sure that this optimal division will be attained in practice?

Consider for example a ''master schedule'' or ''block plan'', which is the tactical allocation of blocks of resource time (e.g. operating theatres, or CT-scanners) to specialties and/or patient categories during a week. Such a block plan should be periodically revised to react to variations in supply and demand. (Hans et al. 2012) The determined optimal division of patients could be translated into blocks of resource time for every internist.

The block planning gives the receptionist information on when and at which internist to plan a certain type of patient. Type here means the specialty that is linked to the DRG of a patient. However, the types explained at Section 2.1 (NP, CP, …) are not incorporated yet. It is useful to do so, as otherwise receptionists might plan too much new patients at once for example. That could result in a too big accumulation of patients that have to come back as a control patient. Thus, it is better to divide these appointment types over time. Blueprint scheduling could be a solution for this. A blueprint schedule in the healthcare environment is the amount of capacity on a set time can be used for specific patient types in the operational planning (Leeftink et al., 2020).

3.3 Conclusion

From all techniques in scheduling methods, we choose to go for linear programming. We use Blake & Carter (2002) and Gua & Bard (2022) as a starting point four our model in Chapter 4.

The programming model must have an optimal division of patients over the internist as outcome. Based on this division we will make a block schedule for all internist, to make sure the derived balances by the mathematical model will be attained in practice. Each block is meant for a certain group of patients, nephrology patients for example. The blocks are then filled with appointment type slots (NP, CP, etc.) such that the receptionist know when to plan which type of patient. Thus, a blueprint for every internist is developed.

4. Model

Section 4.1 provides a brief overview of the model's objectives. The model itself is introduced in Section 4.2 and explained in Section 4.3. Section 4.4 explains the heuristic that is inspired by the model. Section 4.5 shows the Excel tool that is based on this heuristic. The chapter ends with a conclusion in Section 4.6.

4.1 Model introduction

The objective of this model is to determine an allocation of appointment minutes that improves the balance between general and specialty specific appointments, while making sure that appointments are placed as much as possible at their preferred specialty. So, the two objectives are as follows:

1. Minimize the number of patients that are not treated by one of their PCP's.
2. Minimize the disbalances between general and specialty treatments among specialists.

The weighting of each objective is done by adjusting a weight in the objective function. The model is shown and further explained in Section 4.2. The model is a quadratic model, as we want to minimize the differences across specialists for the T-shaped specialist balance. By taking the square of the differences to the target balances and penalizing these quadratic differences, we make sure that the model aims for balances for each specialist that are as close as possible to the target balances.

The two goals, ''Minimizing overtime of specialists and among'' and ''Minimizing idle time of specialist'' described in Section 3.2 are not ignored. They are covered by predetermining availability and overtime or idle time per specialist and using this as input. We predetermine in such a way that overtime and idle time across specialists are as equally distributed as possible. This is further explained in Section 4.2.

4.2 Mathematical model

4.2.1 Indices

i	*specialist I*
t	*DRG type t* *(See Table 5 in chapter 2 for the types)*

4.2.2 Parameters

TTD(t)	*Total time to divide of DRG type t*
Capacity(i)	*Time that specialist i is available plus overtime or minus idle time per year*
TargetBalance(i)	*Targeted balance for T-shaped specialist balance for specialist i* *(Check Section 2.3.4 for the calculation)*
Y(i,t)	*Weight for placing t minutes at specialist i*

4.2.3 Variables

X(i ,t)	*Time spent by specialist i on DRG appointment type t*

4.1.1 Objective

$$Min\ z = \sum_i (\left(\frac{X_{i,1}}{Capacity(i)} - Targetbalance(i)\right)\hat{}2) \qquad \text{(T-shaped specialist)}$$

$+ \sum_{(i,t)} (X(i,t) * Y(i,t) * -1)$ (DRG at preferred specialist) (1)

4.1.1 Constraints

$\sum_i X_{i,t} = TTD_t$ $\forall t$ *(Total appointment durations divided)* (2)

$\sum_t X_{i,t} = Capacity_i$ $\forall i$ *(Overtime/Idle time specialist)* (3)

$X_{i,t} \geq 0$ $\forall i, t$ (4)

In the first part of equation 1 we aim for an equitable distribution of general patients, by comparing with the parameter TargetBalance. Based on the parameters TTD(t) and Capacity(i), we are able to determine the ideal balance for each specialist. By minimizing the square of the differences between the actual balances and the target balances, we make sure that the model aims for minimal differences and thus be as close to the target balance as possible.

Moving on to second part of equation 1, it contains the variable "Y(i,t)," which represents a table of weights. These weights are assigned as follows: a weight of 3 if DRG type t is the first preference for specialist I and a weight of 1 if it is the third preference. Conversely, a weight of -1 is assigned if the DRG type should not be allocated to the specialist. A negative value multiplied with the -1 in the objective will result in a positive value, which is not wished for as the model is minimizing. If there are three preferences, then the second preference gets a weight of 2. That means that all weights for a general preference are equal to 1, allowing the first part of the objective in equation 1 to shuffle appointment minutes around to strive for the best possible T-shape specialist balances across specialists.

Equations 2, 3, and 4 represent the model's constraints. equation 2 ensures that all appointment minutes are allocated to an specialist, equation 3 enforces the fulfilment of specialists' capacity, and equation 4 prevents the model from allocating negative minutes.

4.3 Heuristic

While a heuristic method may entail a degree of approximation, it possesses the advantage of seamless integration into Microsoft Excel in contrary to the model. This heuristic works for every department that have specialists with different specialties and a set of patients that can be treated as general patients, meaning that they can be treated by all specialists or at least multiple specialists. The heuristic exists out of the following 12 steps:

1. Determine the capacity of each specialist.
2. Assign appointment minutes exclusive to a single specialty.
3. Allocate appointment minutes designated for two specialties.
4. Allocate minutes that are preferred at one specialty but are also allowed at one other single specialty.
5. Allocate appointment minutes meant for a single specialty but can be deemed as general.
6. Allocate minutes that are preferred at one specialty, secondly preferably placed at another single specialty and otherwise deemed as general.
7. Distribute appointment minutes intended for two specialties but considered as general.
8. Assign appointment minutes meant for a single specialty but categorized as department-specific.
9. Allocate general appointment minutes.
10. Distribute the remaining minutes from steps 5, 6, 7 and 8.
11. Allocate department-specific appointments.

12. Allocate the remainder of step 9 and 10.

The overarching concept is to first divide the more rigid DRG types and end with dividing the most flexible ones.

Step 1: Determine the capacity of each specialist

The first step involves the determination of whether each specialist should work overtime or experience idle time. This assessment is facilitated through the use of a compact Excel tool that is provided as an attachment to this research. A more comprehensive explanation of its functionality can be found in Appendix I.

Once the overtime or idle time has been established for each specialist, the calculation of the capacity of each specialist is done as outlined below:

Capacity(i) = Availability(i) + Overtime (i) – Idle time (i)

Step 2: Divide appointment minutes that can only be placed at 1 specialty

Having computed the capacity for each specialist, we are now prepared to initiate the allocation of appointment minutes. Our initial focus lies in the allocation of appointment minutes dedicated exclusively to a single specialty. In this regard, we introduce an additional index, denoted as "specialty s," which distinguishes the heuristic from the model. This index can encompass a range of specialties, such as endocrinology or vascular care. For the sake of general reference, we denote these specialties as "s1," "s2," "s3," and so forth.

Specialty minutes (s,i) = Total specialty(s) minutes * Capacity (endocrinologist i) / Total capacity specialty(s)

Subsequently, the remaining capacity for each specialist is calculated:

Remaining capacity (i) = Start capacity (i) – Specialty minutes (s,i)

It is possible that the quantity of minutes of a certain specialty that has to be divided, may surpass the capacity of that specialty. This has a consequence that the remaining capacity, for the specialist with that specialty, becomes negative. A negative capacity is infeasible, so in that case we set the remaining capacity to zero. This will ensure that no other minutes will be allocated to these specialists.

Step 3: Divide appointment minutes that can only be placed at 2 specialties

Now that Step 2 has been successfully executed, we proceed to the allocation of DRG types that are suitable for assignment to two distinct specialties. These DRG types, due to their duality in applicability, offer a higher degree of flexibility compared to the DRG types distributed in Step 1.

For instance, let us consider a scenario where a DRG type needs to be assigned to an specialist specializing in either "s1" or "s2." We determine the number of minutes allotted to each specialist, but only if that specialist possesses one of these two specified specialties. If the specialist does not have either of these specialties, the allocated minutes are equal to zero. The calculation is outlined as follows:

DRG minutes (s1 or s2) (i) = Remaining capacity previous step (i) / Total remaining capacity of specialists with specialty s1 or s2 after previous step * total minutes to be divided

Again, the remaining capacity for each specialist is calculated:

Remaining capacity (i) = Remaining capacity previous step (i) – DRG minutes (s1 or s2)(i)

We do the same for every other DRG type that can be placed at two specialties. Note that the sequence of how these types are allocated, can influence the end result. Imagine that there would also be a DRG type that can only be allocated to s2 and s3. This has overlap with the DRG type that can only be placed at s1 and s2. Allocating the DRG type that can only be placed at s1 or s2 first, might cause that there is not enough space left for the DRG type that can be placed at s2 or s3 among specialists with s2. An illustrative example of this situation can be found in chapter 6.

Step 4: Allocate minutes that are preferred at one specialty but are also allowed at one other single specialty

Let us consider the scenario where we have a DRG type that prefers allocation to an specialist with specialization "s1." However, if there is insufficient capacity available within this specialization, we may allocate the minutes to an specialist with specialization "s2." In this context, our allocation process unfolds as follows.

Firstly, we make an attempt to allocate all the minutes meant for specialists with specialization "s1." This allocation is based on the proportion of the total remaining capacity of specialists specializing in "s1." When it is not possible to allocate all the minutes to "s1" specialists, we distribute the remaining minutes in a similar manner to specialists with specialization "s2."

Step 5: Divide appointment minutes that should only be placed at 1 specialty, but otherwise can be considered as general

Similar to step 10, but in this step we prevent overbooking the capacity of the specialists. Our aim is to allocate as any minutes as possible and remember the remaining minutes which will be allocated in step 9. To illustrate this, we will consider two cases for a DRG type that prefers to be allocated to specialists with s1 but can otherwise be placed at specialists that belong to the general part of the department.

In the first case, when the total minutes to be allocated are lower than the total remaining capacity of specialists with "s1," we can straightforwardly assign all the minutes to specialists with "s1." This allocation is carried out in proportion to their respective shares of the remaining capacity.

In the second case, when the total minutes to be allocated exceed the total remaining capacity of specialists with "s1," we allocate as much as possible based on their shares in the remaining capacity. The minutes that cannot be allocated are deferred to be distributed to the remaining general section of the department in Step 10. This is postponed to a later stage, as the entire general section of the department is regarded as more flexible than a single specialized specialty.

Step 6: Allocate minutes that are preferred at one specialty, secondly preferably placed at another single specialty and otherwise deemed as general

As an illustrative example, consider a scenario involving a DRG type that is ideally assigned to specialists with specialization "s1." If there is insufficient capacity within "s1," the allocation process proceeds to specialists with "s2." In the case of "s2" also lacking adequate capacity, the allocation continues to the remaining general section of the department.

Step 6 can be viewed as an amalgamation of both Step 4 and Step 5. It closely mirrors the methodology of Step 4, where the initial focus is on allocating all available minutes to the preferred specialty, which, in this case, is "s1." Subsequently, any remaining minutes are directed toward the second preferred specialty, "s2." However, should there be any minutes that remain unallocated after this step, they will be recorded for later distribution in Step 10.

Step 7: Divide appointment minutes that should only be placed at 2 specialties, but otherwise can be considered as general

This step closely resembles the process in Step 3. However, it is important to note a crucial difference: unlike in Step 3, this step does not afford the opportunity to override the initial capacities. Here, the allocation of all appointment minutes is executed, following a distribution ratio based on each specialist's individual capacity in relation to the total capacity. If the available capacity is insufficient to accommodate the allocation, any remaining minutes are noted and allocated in Step 10.

Step 8: Divide appointment minutes that should only be placed at 1 specialty, but otherwise can be considered as department

This step essentially replicates the process outlined in Step 5, with one notable difference: the remaining minutes can be allocated to the entire department, rather than exclusively to the 'general' segment of the department. Any remaining minutes will be allocated in Step 10.

Step 9: Divide general appointment minutes

These appointment minutes are open for allocation to any specialist within the general part of the department. In accordance with the T-shaped professional principle, our objective is to allocate these minutes in proportion to the remaining capacities.

Step 10: Divide the remaining of steps 5, 6, 7 and 8

The distribution of the remainders from Step 5, 6, and 7 follows the same methodology as that in Step 9. The allocation of the remainder from Step 8 differs slightly. In Step 8, we do not exclusively allocate appointments to the 'general' Section of the department but distribute them across the entire department.

Step 11: Divide department appointments

Similar to step 8, with the distinction that the allocation of appointments does not exclusively target the 'general' segment of the department but extends to the entire department.

Step 12: Divide final rests

The minutes that could not be allocated during Step 9 or Step 10 due to capacity constraints are aggregated and denoted as "remainder" or "rest." These minutes are subsequently distributed among the specialists in accordance with their respective shares of the remaining availability. In this step, there is the possibility that DRG types that should be allocated to the general part of the department are also allocated to the non-general part of the department.

4.4 Conclusion

In this chapter, we have introduced our mathematical model, which is designed to allocate appointment minutes such that they are assigned to the preferred specialties, with the additional objective of achieving an optimal T-shaped specialist balance. Subsequently, we elaborated on our heuristic approach, which is based on the model and closely aligns with its principles. We chose to develop this heuristic as it offers a more practical integration within Microsoft Excel, a widely utilized tool by Isala personnel. The implementation of this heuristic in an Excel-based tool for Isala is shown in Chapter 5.

Chapter 6 outlines a series of experiments conducted using both the mathematical model and the heuristic. These experiments serve to provide a comprehensive analysis of their respective performance characteristics. Chapter 7 is dedicated to evaluating the results of these experiments, facilitating an assessment of the heuristic's and the model's performance.

5. Excel tool

Given that Excel enjoys widespread accessibility and proficiency among the personnel at Isala, the practical implementation of this research is simplified. Figure 8 shows the main page of the dashboard in the Excel file in which the algorithm is implemented.

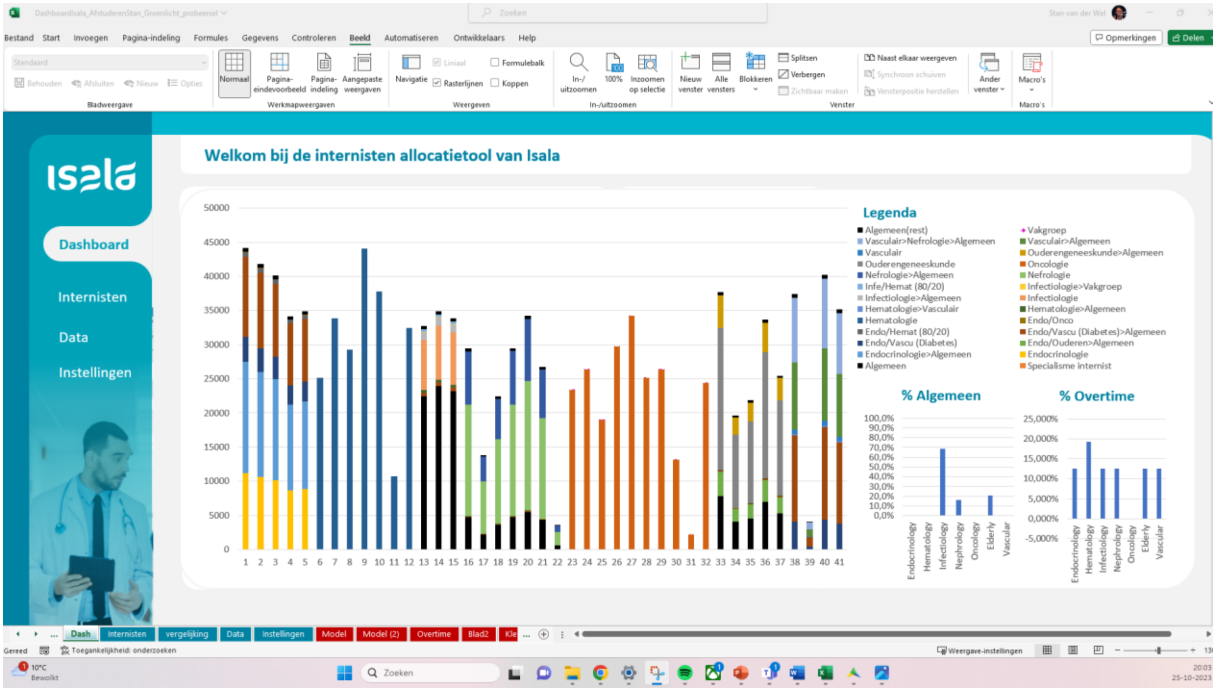

Figure 9: Main page Excel dashboard

The dashboard interface provides navigation options, under which 'Internisten' and 'Data,' situated on the left side. In the 'Internisten' Section, users are given the opportunity to specify the availability of internists, the duration of their availability, and the respective medical specialties they possess.

In cases where an internist holds dual specialties, it is important that the user inputs their information twice, exemplified by the case of internist Internist 38, who is proficient in both elderly healthcare and vascular specialties, as depicted in Figure 9.

When navigating to the 'Data' Section, users can specify the distribution of each Diagnosis-Related Group (DRG) type among the internists. These DRG types were determined and explained in Chapter 2. It is essential to note that the quantities are to be expressed in terms of minutes. Figure 10 provides an illustrative representation of the 'Data' page for reference.

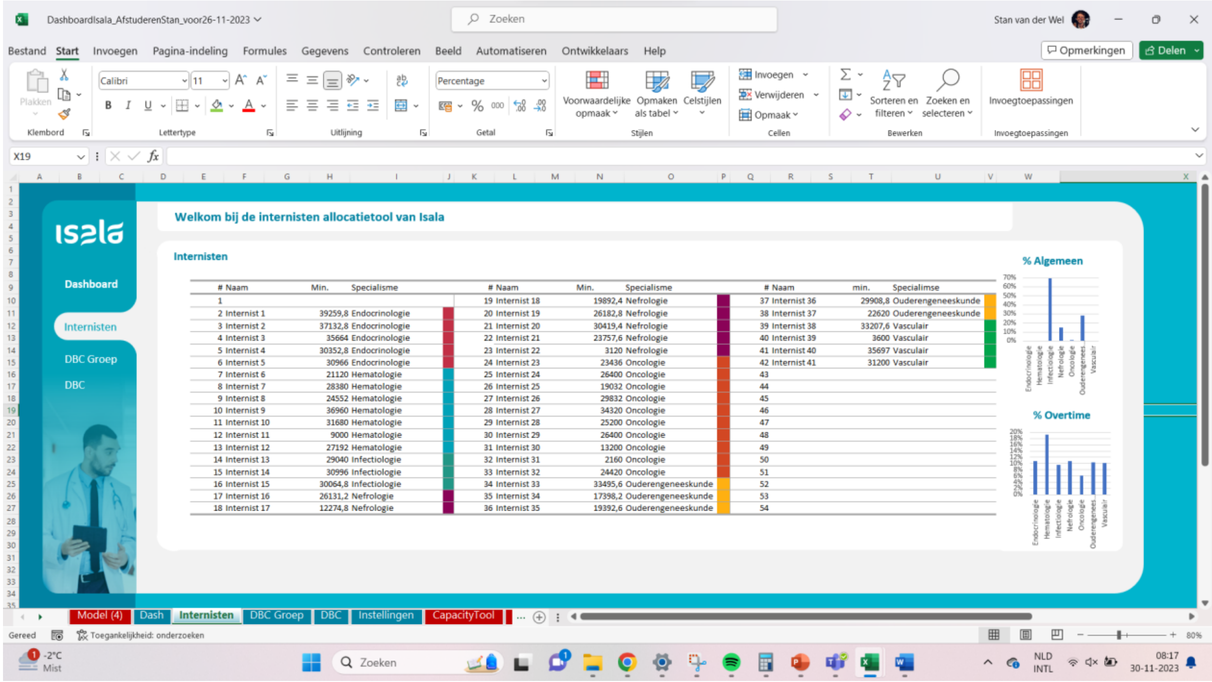

Figure 10: Internist input page Excel dashboard

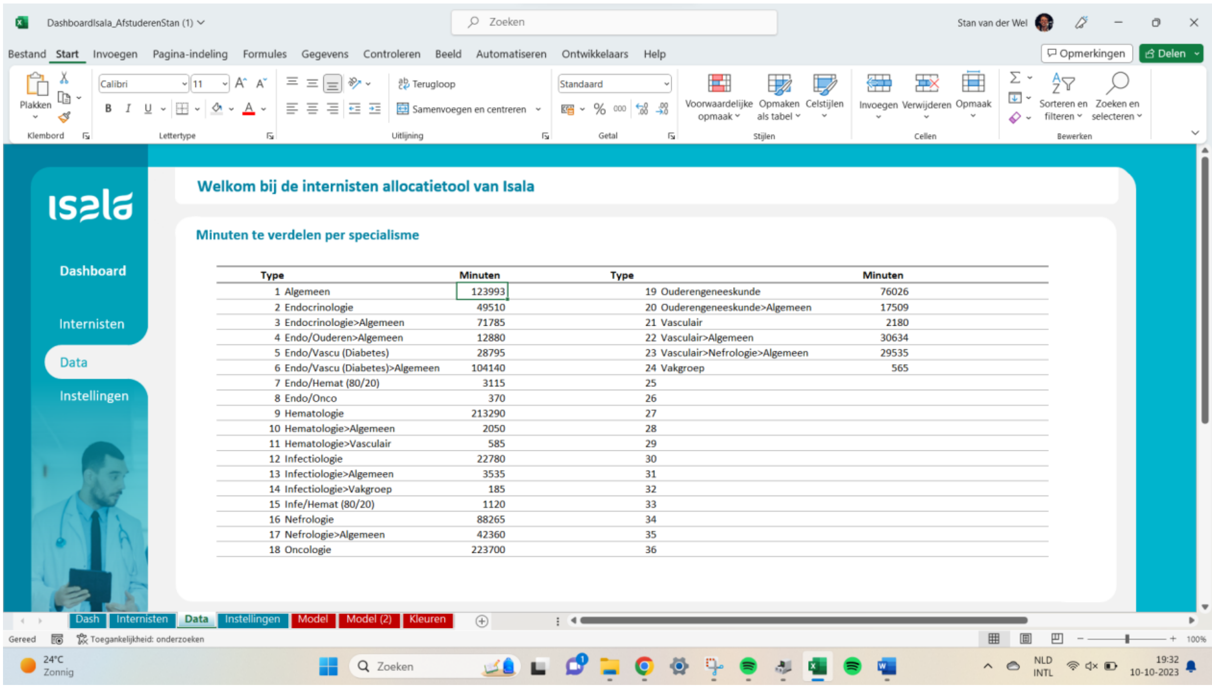

Figure 11: Data input page Excel dashboard

Once the user has entered the relevant data for the internists and appointments, they return to the main interface. At this page, two graphical representations are presented: a stacked chart and a pair of bar charts. The stacked chart visualizes the recommended allocation of time that each internist should devote to various Diagnosis-Related Group (DRG) types, based on the user's input data.

The left bar chart displays the distribution of time among medical specialties for general patient care in terms of percentages. In contrast, the right bar chart shows the percentage of overtime attributed to each specialty. Adjusting internist allocations based on the insights provided by these bar charts ensures that a greater number of patients receive treatment from internists specializing in their desired areas. Simultaneously, this approach aligns with the overarching objective of creating T-shaped specialists while maintaining an equitable distribution of overtime.

6. Experiment design

This chapter describes the two instances, the current situation instance and experiment settings in Section 6.1, and the future patient demand instance and experiment settings in Section 6.2. Section 6.3 presents the conclusion of this chapter.

6.1 Current situation

For the current situation, 4 experiments were set up. First we want to know what the optimal division of appointments would be with the data input for 2022. This experiment set-up is shown in Section 6.1.1. Then, in Section 6.1.2, we change the input slightly compared to Section 6.1.1 by replacing one of the infectiologists as an infectiologist will be retiring soon at the Isala internal healthcare department. In the third experiment, we want to find out what the effects would be if we added an extra internist to the current internist personnel. This experiment is elaborated on in Section 6.1.3. The fourth experiment, in Section 6.1.4, researches the impact of having variable capacity input.

6.1.1 Optimal appointment division current situation

In total, there are two indices and four parameters that require determination for each individual experiment, as outlined in Chapter 4. Commencing with the indices, the total number of internists denoted as "i" and the DRG types labeled as "t." As explicated in Chapter 2, we are confronted with a dataset comprising 41 internists and 24 distinct DRG types.

Subsequently, we need input values for the following 4 parameters;

1. TTD(t); Total minutes to divide of DRG type t
2. Capacity(i); Minutes that internist I is available per year
3. TargetBalance(i); the optimal T-shape specialist balance for each internist
4. Y(i,t); Weight for allocating minutes of DRG type t to internist i

The values for TTD(t) are shown in Table 6 and the values for Capacity(i) are shown in Table 7. The formula for calculating Capacity(i) is:

Capacity(i) = Availability (i) + Overtime (i) – Idle time (i)

In Section 4.3 we explained that we use the capacity tool to determine the overtime or idle time per internist. The availability, overtime and idle time per internist is also shown in Table 7.

Table 6: DRG types

Type	1st Preference	2nd Preference	3rd Preference	Demand (min)
1	General			123,993
2	Endocrinology			49,510
3	Endocrinology	General		71785
4	Endocrinology/Elderly			12,880
5	Endocrinology/Vascular			28,795
6	Endocrinology/Vascular	General		104,140
7	Endocrinology/Haematology (80/20)			3,115
8	Endocrinology/Oncology			370

9	Haematology			213,290
10	Haematology	General		2,050
11	Haematology	Vascular		585
12	Infectiology			22,780
13	Infectiology	General		3,535
14	Infectiology	Department		185
15	Infectiology/Haematology (80/20)			1,120
16	Nephrology			88,265
17	Nephrology	General		42,360
18	Oncology			223,700
19	Elderly healthcare			76,026
20	Elderly healthcare	General		17,509
21	Vascular			2,180
22	Vascular	General		30,634
23	Vascular	Nephrology	General	29,535
24	Department			565
	Total			**1,148,907**

The TargetBalance is determined by the following formula:

TargetBalance = $\frac{Total\ general\ appointment\ minutes}{Total\ capacity\ general\ part\ of\ the\ internal\ healthcare\ department} = \frac{123{,}993}{631{,}774} = 0.196$

The final parameter, denoted as Y(i,t), is a set of weights. For this experiment, the weights are displayed in Table 8. Notably, for DRG type 1, representing general appointments, the weight assigned to every internist is 1, with the exception of the haematologists and the oncologists, who receive a weight of -1. This is because of the fact that general appointments should exclusively be scheduled within the general part of the department.

With these input values, we can proceed with our first experiment. The objective of this experiment is to enhance the allocation of appointments compared to the actual allocation in 2022 while maintaining the same availabilities and patient demand, as presented in Chapter 2. Enhancing here meaning that we will strive for a more equitable distribution of overtime across the internists, as well as allocating more appointments to their preferred specialty and have a better division of general care across the general department.

Table 7: Capacities 2022, experiment Section 7.1.1

Internist	Specialty	Availability	Overtime	Idle	Capacity
Internist 1	Endocrinology	39,260	4,907	0	44,167
Internist 2	Endocrinology	37,133	4,642	0	41,774
Internist 3	Endocrinology	35,664	4,458	0	40,122
Internist 4	Endocrinology	30,353	3,794	0	34,147
Internist 5	Endocrinology	30,966	3,871	0	34,837
Internist 6	Haematology	21,120	4,055	0	25,175
Internist 7	Haematology	28,380	5,449	0	33,829
Internist 8	Haematology	24,552	4,714	0	29,266
Internist 9	Haematology	36,960	7,096	0	44,056
Internist 10	Haematology	31,680	6,083	0	37,763
Internist 11	Haematology	9,000	1,728	0	10,728
Internist 12	Haematology	27,192	5,221	0	32,413
Internist 13	Infectiology	29,040	3,630	0	32,670
Internist 14	Infectiology	30,996	3,875	0	34,871
Internist 15	Infectiology	30,065	3,758	0	33,823
Internist 16	Nephrology	26,132	3,266	0	29,398
Internist 17	Nephrology	12,275	1,534	0	13,809
Internist 18	Nephrology	19,892	2,487	0	22,379
Internist 19	Nephrology	26,183	3,273	0	29,456
Internist 20	Nephrology	30,419	3,802	0	34,222
Internist 21	Nephrology	23,758	2,970	0	26,727
Internist 22	Nephrology	3,120	390	0	3,510
Internist 23	Oncology	23,436	47	0	23,483
Internist 24	Oncology	26,400	53	0	26,453
Internist 25	Oncology	19,032	38	0	19,070
Internist 26	Oncology	29,832	60	0	29,892
Internist 27	Oncology	34,320	69	0	34,389
Internist 28	Oncology	25,200	50	0	25,250
Internist 29	Oncology	26,400	53	0	26,453
Internist 30	Oncology	13,200	26	0	13,226
Internist 31	Oncology	2,160	4	0	2,164
Internist 32	Oncology	24,420	49	0	24,469
Internist 33	Elderly healthcare	33,496	4,187	0	37,683
Internist 34	Elderly healthcare	17,398	2,175	0	19,573
Internist 35	Elderly healthcare	19,393	2,424	0	21,817
Internist 36	Elderly healthcare	29,909	3,739	0	33,647
Internist 37	Elderly healthcare	22,620	2,828	0	25,448
Internist 38	Vascular	33,209	4,151	0	37,359
Internist 39	Vascular	3,600	450	0	4,050
Internist 40	Vascular	35,697	4,462	0	40,159
Internist 41	Vascular	31,200	4,907	0	35,100
Total		**1,035,458**			**1,148,825**

Table 8: Weights Y(i,t) current situation

Y(i,t)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Internist 1	1	3	3	3	3	3	3	3	-1	1	-1	-1	1	1	-1	-1	1	-1	-1	1	-1	1	1	1
Internist 2	1	3	3	3	3	3	3	3	-1	1	-1	-1	1	1	-1	-1	1	-1	-1	1	-1	1	1	1
Internist 3	1	3	3	3	3	3	3	3	-1	1	-1	-1	1	1	-1	-1	1	-1	-1	1	-1	1	1	1
Internist 4	1	3	3	3	3	3	3	3	-1	1	-1	-1	1	1	-1	-1	1	-1	-1	1	-1	1	1	1
Internist 5	1	3	3	3	3	3	3	3	-1	1	-1	-1	1	1	-1	-1	1	-1	-1	1	-1	1	1	1
Internist 6	-1	-1	-1	-1	-1	-1	3	-1	3	3	3	-1	-1	-1	3	-1	-1	-1	-1	-1	-1	-1	-1	1
Internist 7	-1	-1	-1	-1	-1	-1	3	-1	3	3	3	-1	-1	-1	3	-1	-1	-1	-1	-1	-1	-1	-1	1
Internist 8	-1	-1	-1	-1	-1	-1	3	-1	3	3	3	-1	-1	-1	3	-1	-1	-1	-1	-1	-1	-1	-1	1
Internist 9	-1	-1	-1	-1	-1	-1	3	-1	3	3	3	-1	-1	-1	3	-1	-1	-1	-1	-1	-1	-1	-1	1
Internist 10	-1	-1	-1	-1	-1	-1	3	-1	3	3	3	-1	-1	-1	3	-1	-1	-1	-1	-1	-1	-1	-1	1
Internist 11	-1	-1	-1	-1	-1	-1	3	-1	3	3	3	-1	-1	-1	3	-1	-1	-1	-1	-1	-1	-1	-1	1
Internist 12	-1	-1	-1	-1	-1	-1	3	-1	3	3	3	-1	-1	-1	3	-1	-1	-1	-1	-1	-1	-1	-1	1
Internist 13	1	-1	1	1	-1	1	-1	-1	-1	1	-1	3	3	3	3	-1	1	-1	-1	1	-1	1	1	1
Internist 14	1	-1	1	1	-1	1	-1	-1	-1	1	-1	3	3	3	3	-1	1	-1	-1	1	-1	1	1	1
Internist 15	1	-1	1	1	-1	1	-1	-1	-1	1	-1	3	3	3	3	-1	1	-1	-1	1	-1	1	1	1
Internist 16	1	-1	1	1	-1	1	-1	-1	-1	1	-1	-1	1	1	-1	3	3	-1	-1	1	-1	1	2	1
Internist 17	1	-1	1	1	-1	1	-1	-1	-1	1	-1	-1	1	1	-1	3	3	-1	-1	1	-1	1	2	1
Internist 18	1	-1	1	1	-1	1	-1	-1	-1	1	-1	-1	1	1	-1	3	3	-1	-1	1	-1	1	2	1
Internist 19	1	-1	1	1	-1	1	-1	-1	-1	1	-1	-1	1	1	-1	3	3	-1	-1	1	-1	1	2	1
Internist 20	1	-1	1	1	-1	1	-1	-1	-1	1	-1	-1	1	1	-1	3	3	-1	-1	1	-1	1	2	1
Internist 21	1	-1	1	1	-1	1	-1	-1	-1	1	-1	-1	1	1	-1	3	3	-1	-1	1	-1	1	2	1
Internist 22	1	-1	1	1	-1	1	-1	-1	-1	1	-1	-1	1	1	-1	3	3	-1	-1	1	-1	1	2	1
Internist 23	-1	-1	-1	-1	-1	-1	-1	3	-1	-1	-1	-1	-1	1	-1	-1	-1	3	-1	-1	-1	-1	-1	1
Internist 24	-1	-1	-1	-1	-1	-1	-1	3	-1	-1	-1	-1	-1	1	-1	-1	-1	3	-1	-1	-1	-1	-1	1
Internist 25	-1	-1	-1	-1	-1	-1	-1	3	-1	-1	-1	-1	-1	1	-1	-1	-1	3	-1	-1	-1	-1	-1	1
Internist 26	-1	-1	-1	-1	-1	-1	-1	3	-1	-1	-1	-1	-1	1	-1	-1	-1	3	-1	-1	-1	-1	-1	1
Internist 27	-1	-1	-1	-1	-1	-1	-1	3	-1	-1	-1	-1	-1	1	-1	-1	-1	3	-1	-1	-1	-1	-1	1
Internist 28	-1	-1	-1	-1	-1	-1	-1	3	-1	-1	-1	-1	-1	1	-1	-1	-1	3	-1	-1	-1	-1	-1	1
Internist 29	-1	-1	-1	-1	-1	-1	-1	3	-1	-1	-1	-1	-1	1	-1	-1	-1	3	-1	-1	-1	-1	-1	1
Internist 30	-1	-1	-1	-1	-1	-1	-1	3	-1	-1	-1	-1	-1	1	-1	-1	-1	3	-1	-1	-1	-1	-1	1
Internist 31	-1	-1	-1	-1	-1	-1	-1	3	-1	-1	-1	-1	-1	1	-1	-1	-1	3	-1	-1	-1	-1	-1	1
Internist 32	-1	-1	-1	-1	-1	-1	-1	3	-1	-1	-1	-1	-1	1	-1	-1	-1	3	-1	-1	-1	-1	-1	1
Internist 33	1	-1	1	3	-1	1	-1	-1	-1	1	-1	-1	1	1	-1	-1	1	-1	3	3	-1	1	1	1
Internist 34	1	-1	1	3	-1	1	-1	-1	-1	1	-1	-1	1	1	-1	-1	1	-1	3	3	-1	1	1	1
Internist 35	1	-1	1	3	-1	1	-1	-1	-1	1	-1	-1	1	1	-1	-1	1	-1	3	3	-1	1	1	1
Internist 36	1	-1	1	3	-1	1	-1	-1	-1	1	-1	-1	1	1	-1	-1	1	-1	3	3	-1	1	1	1
Internist 37	1	-1	1	3	-1	1	-1	-1	-1	1	-1	-1	1	1	-1	-1	1	-1	3	3	-1	1	1	1
Internist 38	1	-1	1	3	3	3	-1	-1	-1	1	2	-1	1	1	-1	-1	1	-1	3	3	3	3	3	1
Internist 39	1	-1	1	1	3	3	-1	-1	-1	1	2	-1	1	1	-1	-1	1	-1	-1	1	3	3	3	1
Internist 40	1	-1	1	1	3	3	-1	-1	-1	1	2	-1	1	1	-1	-1	1	-1	-1	1	3	3	3	1
Internist 41	1	-1	1	1	3	3	-1	-1	-1	1	2	-1	1	1	-1	-1	1	-1	-1	1	3	3	3	1

6.1.2 Optimal appointment division current situation when replacing an infectiologist

In this experiment, we introduce a single modification when compared to the experiment outlined in Section 6.1.1. We change the specialty of internist 13 and, consequently, the corresponding weights of Y(13,t) within the model. Internist 13, who specializes in infectious diseases, is on the verge of retirement. Isala faces the decision of determining whether it is most optimal to adhere to their longstanding practice of replacing him with a new infectious disease specialist or, alternatively, to select an internist with a another specialty. This experiment aims to show the effects associated with the recruitment of internists from diverse specialties. The weighting coefficients for each specialty in Y(I,t) are presented in Table 9.

Table 9: Weights Y(i,t) per specialty internist

Y(i,t)	1	2	3	4	5	6	7	8	9	10	11	12
Endocrinologist	1	3	3	3	3	3	3	3	-1	1	-1	-1
Haematologist	-1	-1	-1	-1	-1	-1	3	-1	3	3	3	-1
Infectiologist	1	-1	1	1	-1	1	-1	-1	-1	1	-1	3
Nephrologist	1	-1	1	1	-1	1	-1	-1	-1	1	-1	-1
Oncologist	-1	-1	-1	-1	-1	-1	-1	3	-1	-1	-1	-1
Elderly healthcare internist	1	-1	1	3	-1	1	-1	-1	-1	1	-1	-1
Vascular internist	1	-1	1	1	3	3	-1	-1	-1	1	2	-1
Y(i,t)	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Endocrinologist	1	1	-1	-1	1	-1	-1	1	-1	1	1	1
Haematologist	-1	-1	3	-1	-1	-1	-1	-1	-1	-1	-1	1
Infectiologist	3	3	3	-1	1	-1	-1	1	-1	1	1	1
Nephrologist	1	1	-1	3	3	-1	-1	1	-1	1	2	1
Oncologist	-1	1	-1	-1	-1	3	-1	-1	-1	-1	-1	1
Elderly healthcare internist	1	1	-1	-1	1	-1	3	3	-1	1	1	1
Vascular internist	1	1	-1	-1	1	-1	-1	1	3	3	3	1

When adding a haematologist or an oncologist to the department, the overall capacity of the general section of the department will decrease, resulting in a change in the target balance. This balance can be calculated as follows:

$$\text{Target balance} = \frac{\textit{Total general appointment minutes}}{\textit{Total capacity general part of the internal healthcare department}} = \frac{123{,}993}{602{,}734} = 0.206$$

Table 10 shows the overtime percentages per specialty per replacement option. The resulting capacities can be calculated as follows. For example, in case of an endocrinologist, we multiply the availability of the endocrinologist with 1 + the overtime percentage for endocrinologists. So, if the replacement for the infectiologist would be an haematologist, the capacity of an endocrinologist would be availability endocrinologist * 1.175.

Table 10: Overtime input percentages experiment when replacing an infectiologist in 2022

Replacement		END	HAE	INF	NEP	ONC	ELD	VAS
Endocrinologist	%Overtime	12,5%	19,2%	12,5%	12,5%	0,2%	12,5%	12,5%
Haematologist	%Overtime	17,5%	4,3%	17,5%	17,5%	-0,1%	17,5%	17,5%
Infectiologist	%Overtime	12,5%	19,2%	12,5%	12,5%	0,2%	12,5%	12,5%
Nephrologist	%Overtime	12,5%	19,2%	12,5%	12,5%	0,2%	12,5%	12,5%
Oncologist	%Overtime	18,0%	19,2%	18,0%	18,0%	-11,5%	18,0%	18,0%
Elderly healthcare internist	%Overtime	12,5%	19,2%	12,5%	12,5%	0,2%	12,5%	12,5%
Vascular internist	%Overtime	12,5%	19,2%	12,5%	12,5%	0,2%	12,5%	12,5%

6.1.3 Optimal appointment division current situation when adding an extra internist

For this experiment, we will employ the same set of input data utilized in the experiment detailed in Section 6.1.1, with the only exception being the number of internists. We increase this with one internist, going from 41 to 42 internists in total. We will research the effects of adding each type of internist. We continue to use the weighting coefficients for Y(i,t) as shown in Table 9.

In Chapter 2 we concluded that about every internist made overtime. Therefore hiring an extra internist might make sense. We assume an availability of 30.000 minutes for the extra internist, as this is about the amount of minutes a fulltime internist is available per year.

The new TargetBalance is 123,993 / 661,774 = 0.187 when adding a specialty that belong to the general section of the department. The new TargetBalance is 123,993 / 632,734 = 0.196 when adding an oncologist or haematologist. The overtime percentage per addition are shown in Table 11.

Table 11: Overtime input percentage when adding an internist to the current situation

addition 2022		END	HAE	INF	NEP	ONC	ELD	VAS
Endocrinologist	%Overtime	7,41%	11,75%	7,41%	7,41%	12,42%	7,41%	7,41%
Haematologist	%Overtime	19,23%	4,42%	19,23%	19,23%	19,23%	19,23%	19,23%
Infectiologist	%Overtime	7,41%	11,75%	7,41%	7,41%	12,42%	7,41%	7,41%
Nephrologist	%Overtime	7,41%	11,75%	7,41%	7,41%	12,42%	7,41%	7,41%
Oncologist	%Overtime	0,10%	0,10%	0,10%	0,10%	-11,47%	0,10%	0,10%
Elderly healthcare	%Overtime	7,41%	11,74%	7,41%	7,41%	12,42%	7,41%	7,41%
Vascular internist	%Overtime	7,41%	11,75%	7,41%	7,41%	12,42%	7,41%	7,41%

6.1.4 Optimal appointment division current situation when allowing differences in overtime

In the preceding experiments, we incorporated the parameter of capacity (defined as Availability + Overtime – Idle time) to ensure a relatively equitable distribution of overtime and idle time among internists. In this experiment, we ignore this input to see how the appointments would be divided if overtime, idle time or availability was not a constraint by using it as input. We expect that this will show which specialties are understaffed and which are overstaffed.

6.2 Patient demand 2030

In order to offer advice on the optimal specialty to recruit for at Isala, it is important to consider the future landscape. Given the typical tenure of internists at Isala, recruitment decisions are inherently long-term in nature. It is possible that patient demand will exhibit significant alterations over an eight-year horizon. We will again execute 5 experiments.

First we want to know how the current situation would deal with the patient demand of 2030. This experiment set-up is shown in Section 6.2.1. Then, in Section 6.2.2, we change the input slightly compared to Section 6.2.1 by replacing one of the infectiologists as an infectiologist will be retiring soon at the Isala internal healthcare department. In the third experiment, we want to find out what the effects would be if we added an extra internist to the current internist personnel. This experiment is elaborated on in Section 6.2.3. The fourth experiment, in Section 6.2.4 researches the impact of ignoring the capacity input for 2030.

6.2.1 Optimal appointment division current situation

Consulting firm X conducted a research study for Isala, aimed at forecasting future patient demand. Utilizing the year 2019 as a basis, X provided annual percentage growth projections for each DRG. The data of this research can be found in Appendix J.

To estimate the anticipated demand for the year 2030, we extrapolated the demand for each DRG in 2022 by applying a compounded growth factor, represented as (1 + the yearly percentage increase) to the power of eight, accounting for the eight-year time span to 2030. This projection is grounded in the assumption that the "current" year corresponds to the year of reference within the preceding Chapter 2, which was 2022. The resulting demand forecast for the year 2030 is presented in Table 12.

We use this demand forecast instead of the actual demand forecast in the experiment of Section 6.1.1. The rest of the input values are the same as in the experiment of Section 6.1.1. The goal of this experiment is to see how the current composition of internists would deal with future patient demand when applying our model and heuristic. We do this to check whether there are problems in the future when the composition is kept the same as it is in the current situation.

Table 12: DRG demand per DRG type forecasted for 2030

DRG Type	Demand	DRG Type	Demand	DRG Type	Demand
1	131620	9	250975	17	45387
2	49966	10	2061	18	281967
3	72820	11	586	19	97755
4	13080	12	23485	20	21009
5	116383	13	4321	21	2182
6	35259	14	185	22	31083
7	3136	15	1123	23	31382
8	370	16	104520	24	566

Utilizing the tool described in Section 4.3, we compute the capacity for each internist, which in turn allows us to calculate the potential overtime for each specialty. Table 13 presents the respective overtime percentages for each specialty, while Table 14 provides the capacity for each internist. The weights in Y(i,t) are the same as in the experiment of Section 6.1.1. The target balance, however, changes to 131,620 / 632,774 = 0.208

Table 13: Overtime percentages for 2030

Specialty	Endocrinology	Haematology	Infectiology	Nephrology	Oncology	Elderly	Vascular
% Overtime	24,8%	40,3%	24,8%	24,8%	25,7%	24,8%	24,8%

Table 14: Needed capacities 2030

Internist	Capacity	Internist	Capacity
INTERNIST 1	48986	INTERNIST 22	3893
INTERNIST 2	46332	INTERNIST 23	29448
INTERNIST 3	44499	INTERNIST 24	33173
INTERNIST 4	37872	INTERNIST 25	23914
INTERNIST 5	38637	INTERNIST 26	37485
INTERNIST 6	29631	INTERNIST 27	43124
INTERNIST 7	39817	INTERNIST 28	31665
INTERNIST 8	34447	INTERNIST 29	33173
INTERNIST 9	51855	INTERNIST 30	16586
INTERNIST 10	44447	INTERNIST 31	2714
INTERNIST 11	12627	INTERNIST 32	30685
INTERNIST 12	38150	INTERNIST 33	41793
INTERNIST 13	36234	INTERNIST 34	21708
INTERNIST 14	38674	INTERNIST 35	24197
INTERNIST 15	37512	INTERNIST 36	37318
INTERNIST 16	32604	INTERNIST 37	28223
INTERNIST 17	15315	INTERNIST 38	41434
INTERNIST 18	24820	INTERNIST 39	4492
INTERNIST 19	32669	INTERNIST 40	44540
INTERNIST 20	37955	INTERNIST 41	38929
INTERNIST 21	29643		

6.2.2 Optimal appointment division future situation when replacing an infectiologist

This experiment replicates the conditions outlined in Section 6.2.1, with the only exception being the patient demand, which is the same as that of Section 6.2.2. The purpose of conducting this experiment is not solely to provide short-term recommendations to Isala regarding the choice of a replacement for the retiring infectiologist but also to offer insight into long-term considerations.

When an infectiologist is replaced with either an oncologist or a haematologist, the target balance is adjusted from 0.208 to 131,620 / 602,734 = 0.218. Additionally, the alteration in the replacement has an impact on overtime levels, resulting in modified overtime percentages as detailed in Table 15.

Table 15: Overtime input percentages when replacing an infectiologist for 2030 patient demand

		END	HAE	INF	NEP	ONC	ELD	VAS
Endocrinologist	%Overtime	24,77%	40,30%	24,77%	24,77%	25,65%	24,77%	24,77%
Haematologist	%Overtime	29,86%	23,40%	29,86%	29,86%	25,65%	29,86%	29,86%
Infectiologist	%Overtime	24,77%	40,30%	24,77%	24,77%	25,65%	24,77%	24,77%
Nephrologist	%Overtime	24,77%	40,30%	24,77%	24,77%	25,65%	24,77%	24,77%
Oncologist	%Overtime	30,60%	40,30%	30,60%	30,60%	11,70%	30,60%	30,60%
Elderly healthcare	%Overtime	24,77%	40,30%	24,77%	24,77%	25,65%	24,77%	24,77%
Vascular internist	%Overtime	24,77%	40,30%	24,77%	24,77%	25,65%	24,77%	24,77%

6.2.3 Optimal appointment division future situation when adding an extra internist
This experiment is similar to the experiment discussed in Section 6.1.3. The difference with that experiment is that we take the forecasted patient demand instead of the demand in the current situation. Just like Section 6.2.2, the reason for this experiment is that we want to give Isala advice on the long term as well as on the short term. We assume an availability of 30,000 minutes for the extra internist.

When adding endocrinologist, infectiologist, nephrologist, elderly healthcare or vascular internist, the target balance changes to 131,620 / 662,774 = 0.199. If we add an haematologist or oncologist, the target balance stays 131,620 / 632,774 = 0.208.

Table 16: Overtime input percentages when adding an internist for 2030 patient demand

		END	HAE	INF	NEP	ONC	ELD	VAS
Endocrinologist	%Overtime	19,12%	23,89%	19,12%	19,12%	24,59%	19,12%	19,12%
Haematologist	%Overtime	40,30%	22,83%	40,30%	40,30%	40,30%	40,30%	40,30%
Infectiologist	%Overtime	19,12%	23,89%	19,12%	19,12%	24,59%	19,12%	19,12%
Nephrologist	%Overtime	19,12%	23,89%	19,12%	19,12%	24,59%	19,12%	19,12%
Oncologist	%Overtime	25,65%	25,65%	25,65%	25,65%	11,28%	25,65%	25,65%
Elderly healthcare	%Overtime	19,12%	23,89%	19,12%	19,12%	24,59%	19,12%	19,12%
Vascular internist	%Overtime	19,12%	23,89%	19,12%	19,12%	24,59%	19,12%	19,12%

6.2.4 Optimal appointment division future situation when allowing differences in overtime
In the experiment of Section 6.1.4 we wanted to allow unlimited capacity to see how the appointments would be divided if overtime, idle time or availability are not constraining the output by using it as input. We expect that this will show which specialties are understaffed and which are overstaffed.

6.3 Conclusion
In this chapter we discussed several experiments that we will execute with both the model and heuristic that were described in Chapter 4. Experiments are executed for both the current situation and the future situation in 2030. The results and findings of these experiments are discussed in Chapter 7.

7. Results

In this chapter, we discuss the results of the experiments that were stated in Chapter 6. In Section 7.1 we discuss the results of experiments that were conducted for the current situation. Section 7.2 discusses the results of the experiments that were conducted for 2030. The current and future situation are compared in Section 7.3 We conclude this chapter with Section 7.4.

7.1 Current situation

For the current situation, a series of five experiments was conducted to investigate various aspects. Initially, our objective was to determine the optimal distribution of appointments based on the data input for the year 2022. The outcomes of this experiment are detailed in Section 7.1.1. Subsequently, in Section 7.1.2, we analyse the results of an experiment where a slight modification was introduced to the input by replacing one of the infectiologists. The third experiment aimed to assess the effects of introducing an additional internist to the existing personnel, and the findings of this experiment are in Section 6.1.3. The fourth experiment researched the impact of ignoring the overtime, idle time or availability input. The results of this experiment are shown in Section 7.1.4.

7.1.1 Optimal appointment current situation

In this section we present and discuss the results of the experiment that was introduced in Section 6.1.1. The experiment is executed with both the model and the heuristic. The goal of this experiment was to get a better division of appointments than the actual division of 2022, while having the same input values.

Mathematical Model

Given that all internists, with the exception of Internist 38, are each associated with a single specialty, we proceed to allocate minutes on a per-specialty basis. Within the mathematical model, Internist 38 is possibly allocated appointment minutes from the specialty of elderly healthcare. However, he exclusively receives vascular appointment minutes due to the higher demand of this specialty. Furthermore, the allocation of minutes per individual specialty is detailed in Table 17, while Figure 11 visually represents this distribution. We get an objective value of -3.184.022.

Table 17: Allocation of DRG type minutes to specialties for 2022 with the mathematical model

Specialty\DRG type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Endocrinology	0	49510	71785	0	0	70667	3115	0
Haematology	0	0	0	0	0	0	0	0
Infectiology	71887	0	0	0	0	0	0	0
Nephrology	20351	0	0	0	0	0	0	0
Oncology	0	0	0	0	0	0	0	370
Elderly	31755	0	0	12880	0	0	0	0
Vascular	0	0	0	0	28795	33473	0	0
Specialty\DRG type	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Endocrinology	0	0	0	0	0	0	0	0
Haematology	213290	0	0	0	0	0	0	0
Infectiology	0	2050	0	22780	3535	0	1120	0
Nephrology	0	0	0	0	0	0	0	88265
Oncology	0	0	0	0	0	185	0	0

Elderly	0	0	0	0	0	0	0	0
Vascular	0	0	585	0	0	0	0	0

Specialty\DRG type	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Endocrinology	0	0	0	0	0	0	0	0
Haematology	0	0	0	0	0	0	0	0
Infectiology	0	0	0	0	0	0	0	0
Nephrology	42360	0	0	0	0	0	8528	0
Oncology	0	223700	0	0	0	0	0	565
Elderly	0	0	76026	17509	0	0	0	0
Vascular	0	0	0	0	2180	30634	21007	0

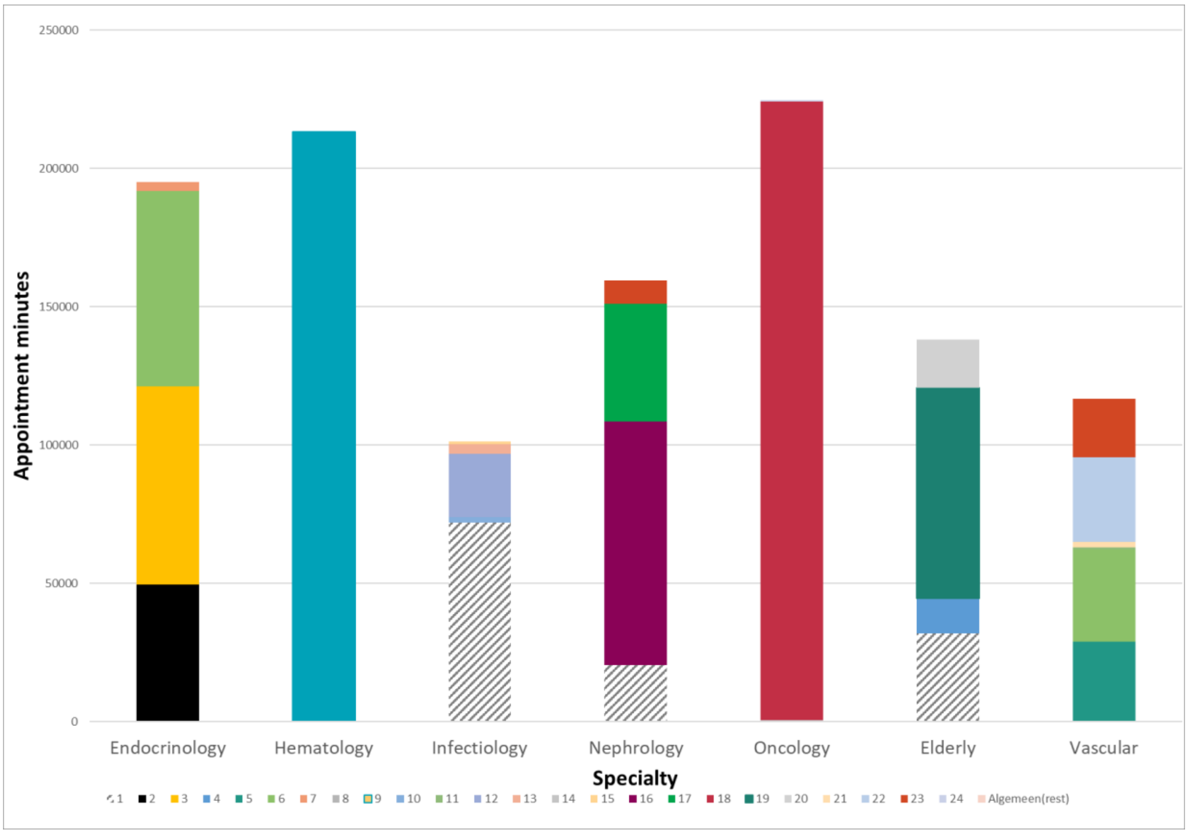

Figure 12: Optimal division 2022 by model

Within Figure 11, the areas characterized by gray-and-white stripes correspond to the allocation of general minutes. We see that the specialties endocrinology and vascular did not get any general appointments assigned, while those specialties are part of the general section of the department. They are too busy with appointment types that are preferred to be treated by those specialties. Table 18 provides a breakdown of the percentage of time devoted by each specialty to general patients.

Table 18: General patients percentage for 2022 based on the results of the mathematical model

Specialty	% General
Endocrinology	0,0%
Haematology	0,0%
Infectiology	71,0%
Nephrology	12,6%
Oncology	0,0%
Elderly	23,0%
Vascular	0,0%

Heuristic

We will now replicate the same analysis using the heuristic, instead of the mathematical model. Table 19 provides an overview of the manner in which the heuristic distributes the appointment minutes, utilizing the same example as outlined in Section 6.1.1. Figure 12 offers a graphical representation of these results. We get an objective value of -3.174.578.

Table 19: Allocation of DRG type minutes to specialties for 2022 by the heuristic

Specialty\DRG type	1	2	3	4	5	6	7	8
Endocrinology	0	49510	71785	0	16118	54182	3115	367
Haematology	0	0	0	0	0	0	0	0
Infectiology	68048	0	0	0	0	4579	0	0
Nephrology	26646	0	0	0	0	1793	0	0
Oncology	0	0	0	0	0	0	0	3
Elderly	29299	0	0	12880	0	1972	0	0
Vascular	0	0	0	0	12677	41063	0	0

Specialty\DRG type	9	10	11	12	13	14	15	16
Endocrinology	0	0	0	0	0	0	0	0
Haematology	213290	0	0	0	0	0	0	0
Infectiology	0	1125	0	22780	3535	185	1120	0
Nephrology	0	441	0	0	0	0	0	88265
Oncology	0	0	0	0	0	0	0	0
Elderly	0	484	0	0	0	0	0	0
Vascular	0	0	585	0	0	0	0	0

Specialty\DRG type	17	18	19	20	21	22	23	24	Rest
Endocrinology	0	0	0	0	0	0	0	0	0
Haematology	0	0	0	0	0	0	0	0	0
Infectiology	0	0	0	0	0	0	0	0	0
Nephrology	42360	0	0	0	0	0	0	0	0
Oncology	0	223700	0	0	0	0	0	565	552
Elderly	0	0	76026	17509	0	0	0	0	0
Vascular	0	0	0	0	2180	30634	29535	0	0

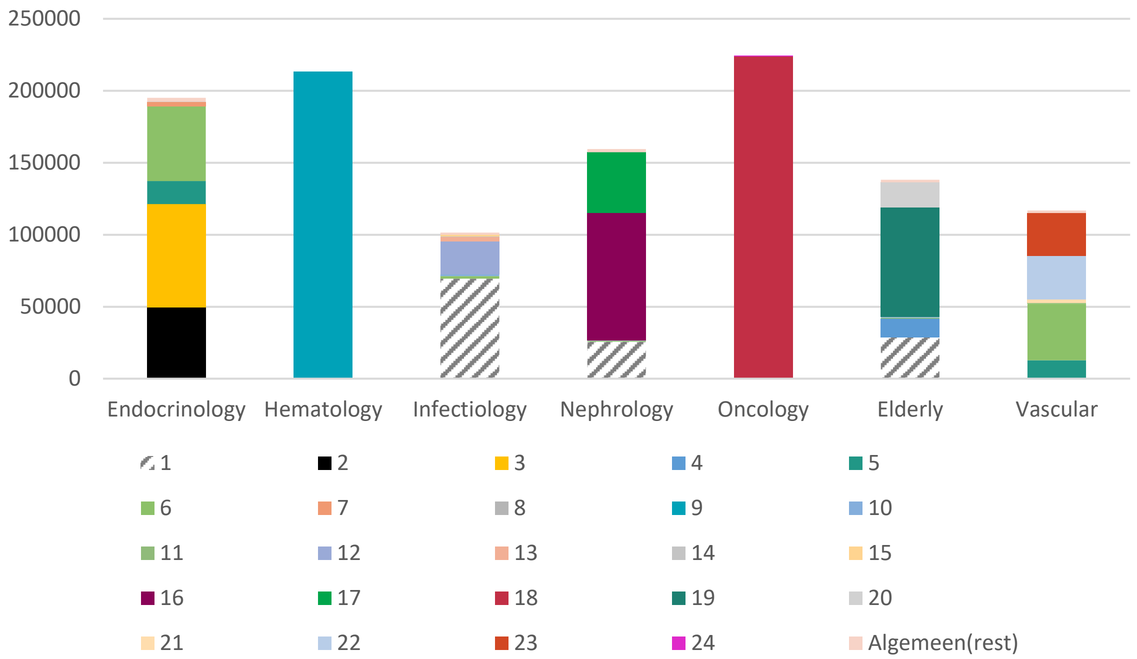

Figure 13: Optimal division 2022 by heuristic

Within Figure 12, the gray-white striped area represents the allocation of general minutes. Table 20 offers a breakdown of the percentage of time dedicated by each specialty to the care of general patients. We see that that the heuristic provides a more equitable distribution of general patients across the general section of the department. However, this is made possible due to the worse allocation of appointments to the preferred specialty as explained in the comparison below.

Table 20: Overtime and general percentage for 2022 by heuristic

	% General
Endocrinology	0.0%
Haematology	0.0%
Infectiology	67.1%
Nephrology	16.7%
Oncology	0,0%
Elderly	21.2%
Vascular	0.0%

Comparison model and heuristic

There is a difference of 9814 in the objective values. The model attains a lower value, meaning that the model performs better than the heuristic as we want to minimize.

Table 21: Difference in model and heuristic output

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Rest
Endocrinology	1	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Haematology	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Infectiology	0	1	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
Nephrology	0	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
Oncology	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0
Elderly	0	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Vascular	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1

Table 21 shows if there is a difference in the assigned minutes per specialty and DRG type between using the heuristic or the model. DRG type 1 stands for all the general appointments. The differences for DRG type 1 are neglectable, as these appointment minutes for infectiology, nephrology and elderly healthcare are interchangeable as all three are part of the general section of the department. The same goes for the differences for DRG types 5, 8 and 10. The differences for DRG types 6, 14 and 23 cause the difference in objective values for the model and heuristic.

For DRG type 6, the heuristic allocates 552 less minutes in total compared to the model. These 552 minutes can be found back at oncology under "rest". The heuristic allocates 8895 minutes less to endocrinology or vascular medicine, the two preferred specialties of this DRG type. So, 8895 minutes will get a weight of 1, instead of 3 in the objective function. That results in a difference of (3-1) * 8895 = 17790 in the objective value.

For DRG type 14, the heuristic allocated 185 minutes to the preferred specialty; infectiology. The model allocated these minutes to oncology. Meaning a difference of (3-1) * 185 = -370 in the objective value.

For DRG type 23, the heuristic allocates all the 29535 minutes to the first preferred specialty; vascular medicine. The model allocated allocates only 21007 minutes to vascular medicine and assign 8528 minutes to the second preferred specialty; nephrology. This causes a difference of (3-2) * 8528 = -8528 in the objective values.

We sum the differences in objective values due to DRG types 6, 14 and 23: 17790 – 370 - 8528 = 8892. The difference in objective values is 9444. So, this leaves us still with a difference of 9444 – 8892 = 552. This 552 difference exists due to the 552 minutes assigned to "rest" in the heuristic. In the model, these minutes are assigned to a specialty with weight 1.

The smallest difference in the weights of y(i,t) is 1. So the difference of 9444 in the objective values corresponds maximally to a difference of 9444 / 1 = 9444 minutes. So, in this instance, the heuristic maximally allocates 9444 worse than the model. The total demand in minutes is 1,148,907 minutes. So, that means that we are talking about 9444 / 1,148,907 * 100% = 0.8% of the total demand that is placed worse compared to the model.

7.1.2 Optimal appointment division current situation when replacing an infectiologist

In evaluating various replacement options with the model, we have assessed the generated overtime and the proportion of general healthcare provided by each specialty. All are detailed in Table 22, to facilitate comparison. A closer examination of the overtime percentages reveals that the acquisition of a new internist, whether with expertise in endocrinology, infectiology, nephrology, elderly care, or vascular medicine, would not impact the distribution of overtime. However, the addition of an oncologist would worsen the overtime situation. While hiring a haematologist could alleviate the overtime situation within the haematology specialty, it would concurrently elevate overtime commitments for all other specialties, except oncology. Acquiring an haematologist would decrease the maximum overtime across specialties.

Considering the distribution of general healthcare by specialty, the acquisition of an infectiologist appears to be the least favourable option, leading to a disproportionate concentration of general appointments within a single specialty, thereby causing an imbalance. Conversely, every other replacement option contributes to improving the balance. In particular, the hiring of an endocrinologist or a vascular internist enhances the T-shaped balance among internists, as it creates space for both endocrinology and vascular healthcare to treat general patients.

Based on this analysis, although the decision to add a haematologist could increase overtime for other specialties, with the exception of oncology, we recommend this option. It mitigates the maximum overtime across specialties and prioritizes an equitable distribution of overtime over the even distribution of general patients.

We rank the best replacement options from best to worse. In this ranking, a more equitable distribution of overtime is considered to be more important than the equitable distribution of general patients.

1. Haematologist
2. Endocrinologist
3. Vascular internist
4. Elderly healthcare internist
5. Nephrologist
6. Infectiologist
7. Oncologist

Note that this intermediate conclusion is based on a short-term time-window. For an informed decision, the long-term trends should be taken into account, as considered in Section 7.2. All allocations based on the different replacement options are shown in graphs in Appendix G.

Table 22: Overtime and general percentage per replacement option

Replacement		END	HAE	INF	NEP	ONC	ELD	VAS
Endocrinologist	% General	5,7%	0,0%	59,8%	18,2%	0,0%	25,2%	6,9%
Haematologist	% General	0,0%	0,0%	56,4%	16,1%	0,0%	20,7%	0,0%
Infectiologist	% General	0,0%	0,0%	68,6%	16,1%	0,0%	20,8%	0,0%
Nephrologist	% General	0,0%	0,0%	56,1%	29,5%	0,0%	20,8%	0,0%
Oncologist	% General	0,0%	0,0%	55,7%	16,0%	0,0%	20,6%	0,0%
Elderly healthcare	% General	0,0%	0,0%	56,1%	16,1%	0,0%	34,9%	0,0%
Vascular internist	% General	3,2%	0,0%	58,4%	16,8%	0,0%	23,1%	7,3%

Endocrinologist	%Overtime	12,5%	19,2%	12,5%	12,5%	0,2%	12,5%	12,5%
Haematologist	%Overtime	17,5%	4,3%	17,5%	17,5%	-0,1%	17,5%	17,5%
Infectiologist	%Overtime	12,5%	19,2%	12,5%	12,5%	0,2%	12,5%	12,5%
Nephrologist	%Overtime	12,5%	19,2%	12,5%	12,5%	0,2%	12,5%	12,5%
Oncologist	%Overtime	18,0%	19,2%	18,0%	18,0%	-11,5%	18,0%	18,0%
Elderly healthcare	%Overtime	12,5%	19,2%	12,5%	12,5%	0,2%	12,5%	12,5%
Vascular internist	%Overtime	12,5%	19,2%	12,5%	12,5%	0,2%	12,5%	12,5%

7.1.3 Optimal appointment division current situation when adding an extra internist

In this experiment we wanted to show the impact of adding an extra internist to the workforce. The overtime input percentages and the resulting percentages for time to spend on general patients is shown in Table 23 per specialty. In most cases, we see that all internists still have to make overtime to treat all the patients. As we value an equal workload more important than the T-shaped specialist balance, we conclude that adding an oncologists is the worst option as it will not decrease the maximum overtime and will increase the overtime of the general section of the department. Adding an haematologist, on the other hand, will decrease the maximum overtime across the department. Therefore we consider this to be the best option for adding an internist.

Table 23: Overtime and T-shaped specialist percentages when adding an extra internist in the current situation

Addition 2022		**END**	**HAE**	**INF**	**NEP**	**ONC**	**ELD**	**VAS**
Endocrinologist	%Overtime	7,4%	19,2%	7,4%	7,4%	0,1%	7,4%	7,4%
Haematologist	%Overtime	11,7%	4,4%	11,7%	11,7%	0,1%	11,7%	11,7%
Infectiologist	%Overtime	7,4%	19,2%	7,4%	7,4%	0,1%	7,4%	7,4%
Nephrologist	%Overtime	7,4%	19,2%	7,4%	7,4%	0,1%	7,4%	7,4%
Oncologist	%Overtime	12,4%	19,2%	12,4%	12,4%	-11,5%	12,4%	12,4%
Elderly healthcare	%Overtime	7,4%	19,2%	7,4%	7,4%	0,1%	7,4%	7,4%
Vascular internist	%Overtime	7,4%	19,2%	7,4%	7,4%	0,1%	7,4%	7,4%
Addition 2022		**END**	**HAE**	**INF**	**NEP**	**ONC**	**ELD**	**VAS**
Endocrinologist	%General	2,0%	0,0%	70,2%	14,0%	0,0%	20,4%	2,7%
Haematologist	%General	0,0%	0,0%	67,2%	16,5%	0,0%	21,0%	0,0%
Infectiologist	%General	0,0%	0,0%	65,2%	11,9%	0,0%	16,1%	0,0%
Nephrologist	%General	0,0%	0,0%	59,3%	24,3%	0,0%	16,1%	0,0%
Oncologist	%General	0,0%	0,0%	66,7%	16,6%	0,0%	21,1%	0,0%
Elderly healthcare	%General	0,0%	0,0%	59,3%	11,9%	0,0%	29,3%	0,0%
Vascular internist	%General	1,4%	0,0%	70,2%	14,0%	0,0%	19,9%	3,7%

When adding an internist with a general specialty, we see that the overtime is the same for every option. The allocation of general patients, however, is different. Adding an endocrinologist or vascular internist makes sure that the whole general section of the department will have time for general patients. Adding a nephrologist or an elderly healthcare internist provide similar results. Adding an infectiologist causes the worst distribution of general patients and is there for considered the worst option after adding an oncologist.

7.1.4 Optimal appointment division current situation when ignoring overtime, idle time and availability

In this experiment we ignored the capacity input. We used the model to have capacity as a variable instead of a parameter input. This experiment is not executed with the heuristic as it does not work without the capacity input.

By ignoring capacity as parameter input, we give the model the freedom to place all the DRG types at their preferred specialty. Figure 13 shows the optimal allocation of appointments. Optimal meaning that the whole department makes the same percentual amount of overtime and every specialty of the general section of the department spends the same percentual share of their time on general patients. The resulting percentages are shown in Table 24, as well as the needed availability per specialty. We compare the availabilities with the actual availabilities in Section 7.3.

Table 24: Needed availabilities and overtime for optimal composition of internists in the current situation

	% General	% Overtime	Availability (min)
Endocrinology	17,%	11%	246,687
Haematology	0%	11%	196,104
Infectiology	17%	11%	29,168
Nephrology	17%	11%	142,759
Oncology	0%	11%	201,646
Elderly	17%	11%	106,470
Vascular	17%	11%	112,224

The difference with the actual situation is that all the specialties have the same percentual share of their time available for general patients, while also all DRG types are allocated to their preferred specialty. For example, DRG type 10 is not seen by its preferred specialty in the division at Section 7.1.1 while it is only seen by its preferred specialty in the division of this experiment. The total appointments treated by infectiology way less than it is in the actual situation, while endocrinology treat a lot more patients. This leaves more space for dividing the general appointment equally over the general section of the department. In the actual situation, general appointments are only allocated to infectiology, nephrology and elderly healthcare while in the division of this experiment general appointments are allocate to the whole general section of the department.

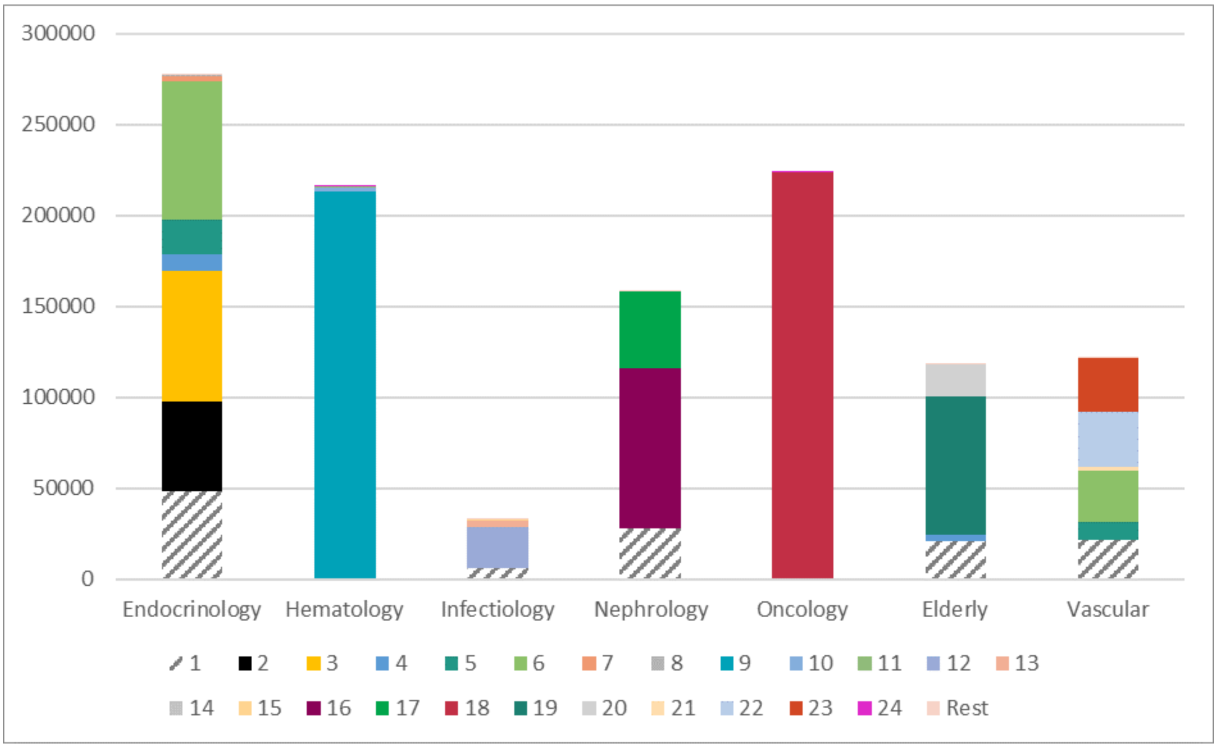

Figure 143: Optimal composition of internists in 2022 by heuristic

7.2 Future situation

For the future situation, 4 similar experiments were conducted as for the current situation. First we wanted to know what the optimal division of appointments would be with the forecasted demand input for 2030. This experiment's results are shown in Section 7.2.1. Then, in Section 7.2.2, we discuss the results of the experiment where we changed the input slightly compared to Section 7.2.1 by replacing one of the infectiologists. In the third experiment, we wanted to find out what the effects would be if we added an extra internist to the current internist personnel. This experiment's results are elaborated on in Section 7.2.3. The fourth experiment researched the impact of ignoring the overtime input. The results of this experiment are shown in Section 7.2.4. The experiment discussed in Section 7.2.5 looked for the perfect allocation of appointments when the availability per specialty perfectly matches the future patient demand.

7.2.1 Optimal appointment current situation

In this section we present and discuss the results of the experiment that was introduced in Section 6.2.1. The experiment is executed with both the model and the heuristic to compare their performance. The goal of the experiment is to find an optimal allocation of appointments based on future demand, while having the same composition of internists of the current situation.

Mathematical model

Given that all internist, with the exception of Internist 38, are associated with a single specialty, we proceed to delineate the allocation of minutes on a per-specialty basis. Internist 38 has two specialties: vascular and elderly medicine. However, the demand for vascular internist is so much higher than the demand for elderly medicine internist, that we can assume Internist 38 to be only a vascular internist. The allocation of minutes per specialty is shown in Figure 14. We get an objective value of -3.694.581.

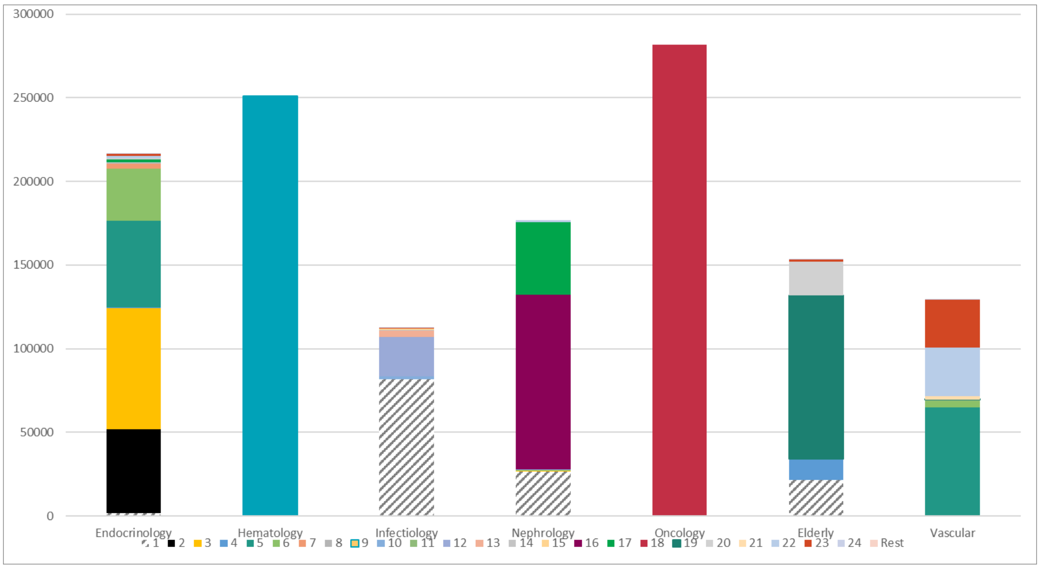

Figure 1415: Optimal division 2030 by model

The model allocated 0.5%, 0.0%, 72.9%, 15.2%, 0.0%, 13.4% and 0.9% general appointments to respectively endocrinologists, haematologists, infectiologists, nephrologists, oncologists, elderly healthcare internists and vascular internists. An interesting fact is that oncology can have nearly the same amount of overtime input as the rest of the specialties, which was not possible for 2022. This indicates that the demand of oncology is growing faster than the rest.

Heuristic

When conducting this experiment with the heuristic, we also get an objective value of -3.694.581. Table 25 displays the corresponding values for overtime and the proportion of general care for each specialty, while Figure 15 visually represents the allocation of appointment types.

Table 25: Overtime and general percentage 2030 based on the heuristic outcomes

	Endocrinology	Haematology	Infectiology	Nephrology	Oncology	Elderly	Vascular
% General	0,8%	0,0%	72,6%	15,1%	0,0%	14,0%	0,0%

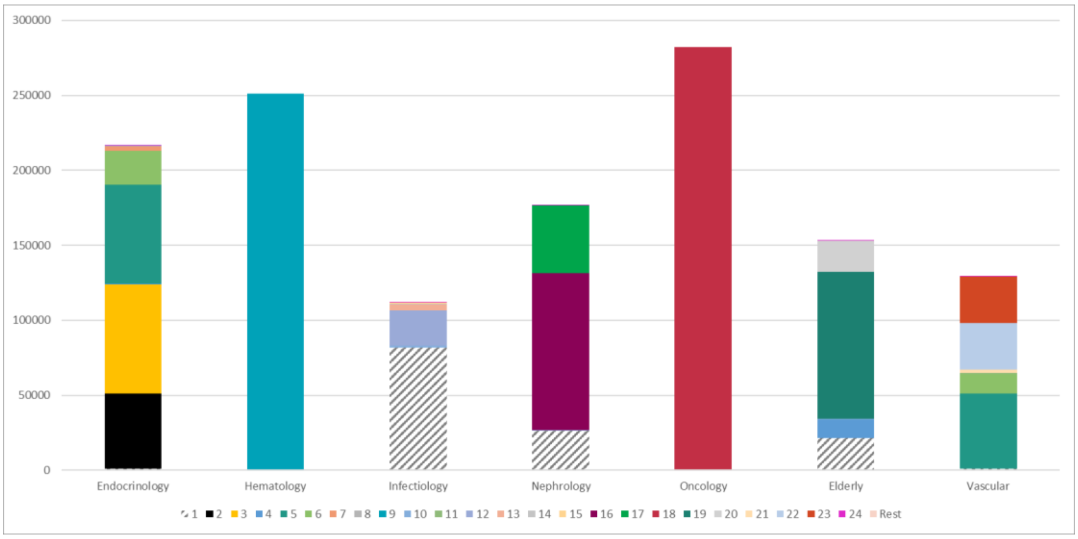

Figure 15: Optimal division 2030 by heuristic

Comparison model and heuristic

In both the heuristic and the model, the overtime and idle time for each internist remain consistent as these values were predetermined. The allocation of general patients to specialties is identical between the two approaches, showcasing comparable performance in this regard. Also, the objective value is the same for both the heuristic and the model. This indicates that both solutions are from the same quality.

When we compare the allocation of minutes for each DRG type to their respective specialties in both the heuristic and the model, discrepancies become evident. Table 26 provides a visual representation of this analysis. To signify equal values, we denote them as '1,' while any disparities are marked as '0.' For instance, we observe differences in the allocation of DRG type 5 between the model and the heuristic. This discrepancy is reasonable since DRG type 5 must either be placed in the endocrinology or vascular medicine specialty and is not permitted in any other specialty. The disparities in this DRG type allocation are confined to the designated specialties, implying that they contribute equally to the objective value. These differences all arise from the concept of interchangeability, which explains how different allocations can yield the same objective value.

Table 26: Difference in allocated minutes for 2030 by heuristic and model

Comparison	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	REST
Endocrinology	0	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
Haematology	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Infectiology	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
Nephrology	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
Oncology	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Elderly	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
Vascular	0	1	1	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1

7.2.2 Optimal appointment division current situation when replacing an infectiologist

In evaluating various replacement options for 2030 with the model, we have assessed the generated overtime and the proportion of general healthcare provided by each specialty. All are detailed in Table 27, to facilitate comparison. A closer examination of the overtime percentages reveals that the acquisition of a new internist, whether with expertise in endocrinology, infectiology, nephrology, elderly care, or vascular medicine, would not impact the distribution of overtime. However, the addition of an oncologist would worsen the overtime situation. While hiring a haematologist could alleviate the overtime situation within the haematology specialty, it would concurrently elevate overtime commitments for all other specialties, except oncology. Acquiring an haematologist would decrease the maximum overtime across specialties.

Considering the distribution of general healthcare by specialty, the acquisition of an infectiologist appears to be the least favourable option, leading to a disproportionate concentration of general appointments within a single specialty, thereby causing an imbalance. Conversely, every other replacement option contributes to improving the balance. In particular, the hiring of an endocrinologist or a vascular internist enhances the T-shaped balance among internists, as it creates space for both endocrinology and vascular healthcare to treat general patients.

Based on this analysis, although the decision to add a haematologist could increase overtime for other specialties, with the exception of oncology, we recommend this option. It mitigates the maximum overtime across specialties and prioritizes an equitable distribution of overtime over the even distribution of general patients.

We rank the best replacement options from best to worse. In this ranking, a more equitable distribution of overtime is considered to be more important than the equitable distribution of general patients.

1. Haematologist
2. Endocrinologist
3. Vascular internist
4. Elderly healthcare internist
5. Nephrologist
6. Infectiologist
7. Oncologist

Table 27: Overtime and T-shaped specialist percentages when replacing an infectiologist for 2030 patient demand

Replacement 2030		**END**	**HAE**	**INF**	**NEP**	**ONC**	**ELD**	**VAS**
Endocrinologist	%Overtime	24,8%	40,3%	24,8%	24,8%	25,7%	24,8%	24,8%
Haematologist	%Overtime	29,8%	23,0%	29,8%	29,8%	26,2%	29,8%	29,8%
Infectiologist	%Overtime	24,8%	40,3%	24,8%	24,8%	25,7%	24,8%	24,8%
Nephrologist	%Overtime	24,8%	40,3%	24,8%	24,8%	25,7%	24,8%	24,8%
Oncologist	%Overtime	30,6%	40,3%	30,6%	30,6%	11,7%	30,6%	30,6%
Elderly healthcare	%Overtime	24,8%	40,3%	24,8%	24,8%	25,7%	24,8%	24,8%
Vascular internist	%Overtime	24,8%	40,3%	24,8%	24,8%	25,7%	24,8%	24,8%
Replacement 2030		**END**	**HAE**	**INF**	**NEP**	**ONC**	**ELD**	**VAS**
Endocrinologist	%General	8,8%	0,0%	60,6%	15,0%	0,0%	17,5%	7,6%
Haematologist	%General	0,8%	0,0%	62,4%	15,3%	0,0%	14,6%	1,1%
Infectiologist	%General	0,5%	0,0%	72,7%	15,0%	0,0%	14,1%	0,7%
Nephrologist	%General	0,0%	0,0%	41,9%	35,7%	0,0%	14,0%	0,0%
Oncologist	%General	0,5%	0,0%	60,6%	29,1%	0,0%	14,1%	0,7%
Elderly healthcare	%General	0,6%	0,0%	60,6%	15,0%	0,0%	30,0%	0,7%
Vascular internist	%General	5,5%	0,0%	60,6%	15,0%	0,0%	16,4%	13,2%

7.2.3 Optimal appointment division future situation when adding an extra internist

In this experiment we wanted to research how adding an extra internist with different specialties would affect the allocation of appointments. From the input, we could see that only an haematologist would bring down the overtime of haematologists, which is the maximum overtime across internists. In that sense, adding an haematologist would be the best option. Adding an haematologist does not improve the division of general appointments.

Adding an internist with a general specialty would decrease the overtime of the general specialties and also improve the division of general appointments. Except for adding an infectiologists, which is the second worst option. The worst option is adding an oncologist. It will not bring down the maximum overtime percentage across internists and will not improve the division of general appointments.

Table 28: Overtime and T-shaped specialist percentages when adding an internist for 2030 patient demand

addition 2030		END	HAE	INF	NEP	ONC	ELD	VAS
Endocrinologist	%Overtime	19,1%	40,3%	19,1%	19,1%	25,7%	19,1%	19,1%
Haematologist	%Overtime	23,9%	22,8%	23,9%	23,9%	25,7%	23,9%	23,9%
Infectiologist	%Overtime	19,1%	40,3%	19,1%	19,1%	25,7%	19,1%	19,1%
Nephrologist	%Overtime	19,1%	40,3%	19,1%	19,1%	25,7%	19,1%	19,1%
Oncologist	%Overtime	24,6%	40,3%	24,6%	24,6%	11,3%	24,6%	24,6%
Elderly healthcare	%Overtime	19,1%	40,3%	19,1%	19,1%	25,7%	19,1%	19,1%
Vascular internist	%Overtime	19,1%	40,3%	19,1%	19,1%	25,7%	19,1%	19,1%
addition 2030		**END**	**HAE**	**INF**	**NEP**	**ONC**	**ELD**	**VAS**
Endocrinologist	%General	5,0%	0,0%	71,4%	11,0%	0,0%	13,1%	4,1%
Haematologist	%General	0,2%	0,0%	74,0%	14,7%	0,0%	13,5%	0,2%
Infectiologist	%General	0,0%	0,0%	75,4%	12,0%	0,0%	10,9%	0,0%
Nephrologist	%General	0,0%	0,0%	68,3%	24,9%	0,0%	10,9%	0,0%
Oncologist	%General	0,4%	0,0%	72,9%	14,9%	0,0%	13,9%	0,6%
Elderly healthcare	%General	0,0%	0,0%	68,3%	12,0%	0,0%	25,6%	0,0%
Vascular internist	%General	2,6%	0,0%	71,4%	11,0%	0,0%	11,8%	8,6%

7.2.4 Optimal appointment division future situation when ignoring overtime, idle time and availability

By ignoring capacity as parameter input, we give the model the freedom to place all the DRG types at their preferred specialty. Figure 16 shows the optimal allocation of appointments. Optimal meaning that the whole department makes the same percentual amount of overtime, all DRG types are allocated to their preferred specialty and every specialty of the general section of the department spends the same percentual share of their time on general patients. The resulting percentages are shown in Table 29, as well as the needed availability per specialty. We compare the availabilities with the actual availabilities and the optimal availabilities for the current situation in Section 7.3.

Table 29: Needed overtime and availabilities for optimal composition of internists for 2030 patient demand

Specialty	% General	% Overtime	Availability (min)
Endocrinology	14,5%	27,6%	270555
Haematology	0,0%	27,6%	280887
Infectiology	14,5%	27,6%	33211
Nephrology	14,5%	27,6%	176089
Oncology	0,0%	27,6%	277564
Elderly	14,5%	27,6%	144886
Vascular	14,5%	27,6%	141308

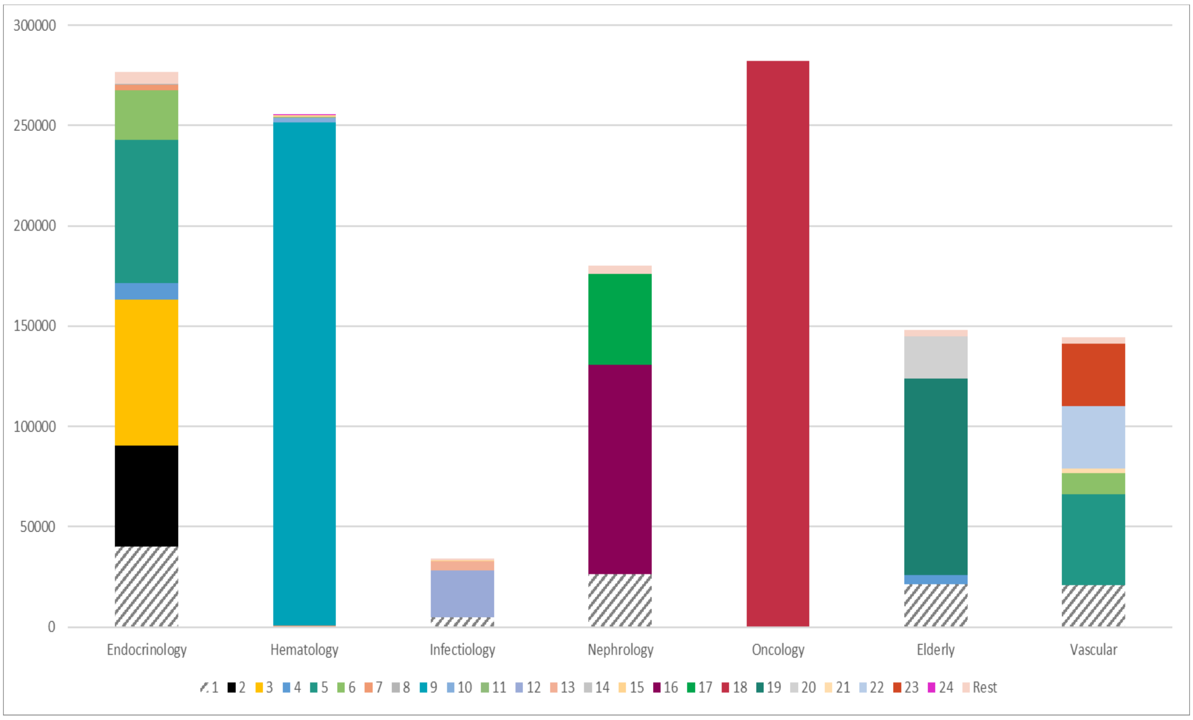

Figure 16: Optimal composition of internist in 2030 by heuristic

7.3 Comparison 2022 and 2030

Table 30 displays the actual availability for the year 2022, alongside the optimal availabilities for both 2022 and 2030, categorized by specialty. It also shows a comparison between this optimal availability of 2022 and 2030 with the actual availability of 2022. In this context, "optimal" implies that the overtime is equitably distributed across all specialties and the percentage of general patients is equal within the general segment of the department.

Based on a quick interpretation of the data in table 30, we can conclude that constructing an ideal balance requires increased capacity in all specialties, except for infectiology. This means that, when internists make 30.000 minutes a year without over time, Isala would need to hire about three additional endocrinologists, three haematologists, one nephrologist, two oncologists, one elderly healthcare internist and one vascular internist for 2030. In addition, three infectiologists are no longer needed for an optimal balance.

Table 30: Comparison real, optimal 2022 and optimal 2030 availabilities

	1 Real 2022	2 Optimal 2022	3 Optimal 2030	2-1	3-1
Endocrinology	173,375	246,687	270555	73,312	97,180
Haematology	178,884	196,104	280887	17,220	102,003
Infectiology	90,100	29,168	33211	-60,933	-56,890
Nephrology	141,778	142,759	176089	981	34,311
Oncology	224,400	201,646	277564	-22,754	53,164
Elderly	122,815	106,470	144886	-16,345	22,071
Vascular	103,705	112,224	141308	8,519	37,603

A more in depth view of the data reveals that for optimal availability in 2022 and 2030, there is an excess of infectiologists. In contrast, the specialty that requires the most additional capacity varies between the two time frames. For 2022, the most favourable course of action seems to be the replacement of an infectiologist with an endocrinologist. However, section 7.1.2 already explained that it is actually more ideal to replace an infectiologist with a haematologist, thus not an endocrinologist. This is because endocrinology patients can also be seen by other specialties, while haematology patients can only be seen by haematologists. These internists already have the highest overtime percentage. Adding an endocrinologist would therefore not bring this percentage down. This conclusion of adding haematologists is in line with the data for 2030, but reorganizing the internist allocation should still not be based solely on this data.

7.4 Conclusion

In Sections 7.1.1 and 7.2.1 we found that the differences between the results of the heuristic and the model were minimal. Especially when you compare the outcomes to the actual situation in Chapter 2. The actual situation, in Chapter 2, gives an objective value of -3,000,802. That is a higher and thus a worse value than the objective values found in this chapter. This indicates that the model and heuristic are improving the actual situation.

Next to that, we found in this chapter that every internist needs to work overtime and that the current composition of internists does not allow an equal distribution of general patients. From sections 7.1.2 and 7.2.2 we saw that replacing an infectiologist with an haematologist would lower the maximum overtime and that adding an endocrinologist for example would lead to a better distribution of general patients across the department. Chapter 8 finishes this research with conclusions and recommendations for Isala.

8. Conclusion, discussion & recommendations

Section 8.1 addresses the research questions posed in Chapter 1 and provides a conclusion for Isala. Section 8.2 provides a discussion of the research in which nuances about the model and the hiring procedure are covered. Section 8.3 concludes with recommendations for future research

8.1 Conclusions and recommendations

In Chapter 1 of this thesis, we stated the following research question:

''How can the internal medicine department at Isala allocate their internists such that the balance between executing deep expertise and cross-domain treatments will be improved ?''

We answered this question by answering the knowledge questions stated in chapter 2. By answering knowledge question 1, 2 and 3, we gave an overview of how every internist currently spends his/her time. From that we could conclude that improvements could be made and that there was a potential that each internist could spend about 11% of his/her time on general patients.

We addressed this central question through the responses to knowledge questions outlined in Chapter 2. By answering knowledge questions 1, 2, and 3, we conducted an analysis of how each internist currently spends their time. This analysis enabled us to identify areas for potential improvement and ascertain that each internist could potentially allocate approximately 11% of their time to general patient care.

Based on reviewing literature, we developed a mathematical model and a heuristic. These analytical tools were designed to facilitate the equitable distribution of patients, thereby enhancing the T-shaped balance across internists. These steps answered knowledge question 4.

Subsequently, knowledge questions 5 and 6 were solved by forecasting future patient demand and subsequently applying the model and heuristic to both present and future demand scenarios. Based on these results, we can answer the last knowledge question and therewith the main research question. Our recommendation is that the Isala healthcare department should incorporate patient demand more prominently in their decisions regarding the recruitment of specialists. This can be effectively achieved by employing either the model or the heuristic; however, we advocate for the utilization of the heuristic due to its accessibility via the universally available Excel platform within Isala.

Furthermore, we emphasize the importance of not solely focusing on current demand, but rather taking into consideration anticipated future demand. For instance, our analysis revealed an increasing demand for oncologists in the future.

Traditionally, when a specialist with a particular specialty left the organization, Isala habitually replaced them with a specialist of the same category. Chapter 6 showed that this practice may not always be the wisest approach, especially with regard to the T-shaped specialist balance. In the example where Paul Internist 13, an infectiologist, is leaving it is even one of the least favourable options when considering the T-shape specialist balance.

In light of the comparison made in Section 7.3, we recommend striving towards the ideal configuration for 2030, as hiring internist is typically a long-term decision. In the real life scenario where Paul Internist 13 is leaving, we enumerated the preferable specialties for his replacement. The options are ranked from 1 (most favourable) to 7 (least favourable).

1. Haematologist
2. Endocrinologist
3. Vascular internist
4. Elderly healthcare internist
5. Nephrologist
6. Infectiologist
7. Oncologist

8.2 Discussion

In section 8.2.1 we explain how a variety of factors influence the recruitment of internists. Section 8.2.2 discusses our model and heuristic. We end with Section 8.2.3, that discusses significance and implications for this study.

8.2.1 Multiple factors influencing the hiring process

The recommendations on who to hire are solely based on improving the T-shape balance across internists. In reality, there are more factors to consider when hiring a new internist. For example, there are tasks that should be done per specialty. If Isala would follow our recommendation on not to hire a new infectiologist when Paul Internist 13 leaves, there are only 2 infectiologists left instead of 3. This could cause problems for these other tasks. So, Isala should use this tool to give an extra perspective on the decision, but not base their decisions solely on the outcomes of the tool.

The recommendations regarding the recruitment of new internists are solely based on enhancing the T-shaped specialist balance among internists. Nevertheless, it is important to acknowledge that in practice, there exists multiple factors that should be taken into account when making hiring decisions for new internists.

For instance, it is important to consider that certain tasks are specific to particular medical specialties. Should Isala adhere strictly to our recommendation of not hiring a new infectious disease specialist upon the departure of Paul Internist 13, the count of infectious disease specialists would reduce to two from the previous amount of three. This alteration could potentially lead to challenges in addressing the broader range of responsibilities associated with the field. Hence, it is advisable for Isala to view the tool as an additional perspective when making staffing decisions, but not to determine their choices solely on the outcomes generated by the tool.

8.2.2 Discussing the heuristic and model

A limitation of the model lies in its reliance on the AIMMS software. While this software offers powerful capabilities, obtaining licenses for it can be cost-prohibitive for non-students, and knowledge of AIMMS within Isala is either limited or, perhaps, non-existent. Consequently, we endeavoured to develop the heuristic within the Excel environment to mitigate these concerns.

However, the heuristic is not without its own imperfections. For instance, in Step 2 of the heuristic, the DRG types that can be allocated to two specialties are initially divided based on the remaining availability within both specialties. This methodology can result in an over-allocation of minutes to one of the specialties, potentially leading to a shortage of availability for subsequent steps. In such cases, this could inadvertently direct appointment minutes to the incorrect specialty. It is important to note that this issue is primarily relevant when there is insufficient capacity within one of the specialties during the initial steps. Although this currently applies to the field of haematology to a limited extent, we anticipate that, over time and with the utilization of this tool, Isala will progressively establish a more fitting configuration, thereby minimizing this issue. It is also worth mentioning that the minutes of these DRG types are relatively small and do not prevent the tool from giving a big improvement compared to the current situation.

Additionally, the experiments and findings about the future scenario in 2030 rely upon a demand forecasted by consulting firm X. It is important to acknowledge that the actual demand in the future may deviate from the predicted values. As a consequence, the recommendations provided in this thesis, which are founded on the predicted demand, may not align perfectly with the real demand landscape in 2030.

Finally, we wish to address is another limitation inherent to the heuristic. Specifically, when the DRG types that can be placed within the general Section of the internal healthcare department exceed the available capacity, they are distributed randomly among the general specialties. This allocation method is suboptimal, as it would be more favourable to allocate them to overtime within the appropriate specialty. However, it is important to recognize that this concern primarily surfaces when there is a substantial incongruity between the configuration of internists and the patient demand. If this mismatch is not extensive, as anticipated, the general appointments can effectively serve as a balancing mechanism. Also, an excessive misalignment signals that the configuration is markedly divergent from the ideal configuration, thereby providing valuable information for Isala.

8.2.3 Impact on science and practice

With our literature review, we found that non-linear programming is a valuable method to achieve the best or an improved outcome in a mathematical model whose requirements are represented by linear relationships. We indeed found an improved, optimal, outcome compared to the actual allocation of appointments in 2022. To facilitate practical implementation, we translated our mathematical model into an Excel-based heuristic, thereby ensuring the feasibility of real-world application.

Isala has the possibility to manipulate the input data concerning patient demand, internist availability and their respective specialties using the Excel tool. This enables Isala to quickly assess the suitability of various internist profiles when considering the recruitment of a new internist. Consequently, the outcomes of this research serve as a valuable resource for Isala, aiding them in making informed decisions regarding the selection of new hires.

8.3 Opportunities for further research

An interesting option for further investigation entails conducting a sensitivity analysis to assess the potential implications of modifying the associations between DRG appointments and specific DRG types. For example, this could involve exploring scenarios where DRG 211 is categorized not as DRG type 2 but rather as type 3. Notably, Isala is now equipped to independently perform such analyses by utilizing the tool.

Another interesting opportunity for further research is the concept of eliminating the distinction between department-specific and general patient categories, allowing all "general" patients to receive care across the entire department, including within haematology and oncology. This scenario has been incorporated into the tool, and the optimal allocation is detailed in Appendix F.

Lastly, an additional research prospect involves investigating the feasibility of applying the methodology developed in this study to other departments within the Isala organization or, indeed, to analogous departments in different healthcare settings. It is plausible that these departments encounter similar challenges to those confronted by the Isala internal healthcare department.

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Appendix A: Appointment types

Appointment description	Appointment code	Duration (min)
Afspraakomschrijving	TC	5
Telefonisch consult	NP	30
Nieuwe patiënt	CP	15
Controle patiënt	TCLANG	15
Telefonisch consult lang	CPMOB	15
Controle patiënt mobiliteitspoli	CPH	15
Controle patiënt HIV	CPRR	15
Controle bloeddruk	CPCHEMO	15
Controle chemo	TCBC	15
Belconsult	NPONC	30
Nieuwe patiënt oncologie	NPTHY	15
Nieuwe patiënt schildklier	NPMOB	15
nieuwe patiënt mobiliteitspoli	NPOG	45
Nieuwe patiënt ouderengeneeskunde	NPON	30
Oude nieuwe patiënt	CPSPINA	15
Controle patiënt spina bifida	CPOG	15
Controle patiënt ouderengeneeskunde	NWPOI	20
Nieuwe patiënt osteogenesis imperfecta	CPTRANS	15
Controle transplantatiepatiënt	*KLBEZ	30
Klinisch bezoek	CPV3.3	15
Controle + V3.3	CAPD	15
Continu ambulante peritoneaal dialyse	NPNOD	15
Nieuwe patiënt schildkliernodus	NPTC	20
Nieuwe patiënt telefonisch consult	CPMVS	15
Controle patiënt multidisciplinair voetzorgteam	TCBCCHEM	15
Belconsult chemo	CRISTAB	25
Cristabiopt	CPDIALYS	30
Controle na dialyse	CPSPOED	15
Spoedcontrole	CPMDO	30
Controle patiënt na MDO	CPSANA	15
Controle patiënt	NPBEELDB	30
Nieuwe patiënt Beeldbellen	COVUL	15
Controle Pomp vullen	CPBEELDB	15
Controle patiënt Beeldbellen	NPMDO	30
Nieuwe patiënt na MDO	CPOGGH	30
Controle patiënt ouderengeneeskunde geheugenpoli	NPOGGH	45
Nieuwe patiënt ouderengeneeskunde geheugenpoli	CPSPOED	15
Controle patiënt spoed	TCBCSANA	5
Telefonisch consult	OVLBESP	30
Overlijdensbespreking	NPHEM	30
Nieuwe patiënt Hematologie	CPV2.3	15
Controle + V2.3	*CRISTKL	25
Cristabiopt klinisch	FIB	15
Fibroscan	GESPREK	30
Gesprek	CPNACHT	15

Afspraakomschrijving	BUIKVETB	30
Telefonisch consult	NWP+CO	30
Nieuwe patiënt	CPIDE	15
Controle patiënt	*NAGESPR	60
Telefonisch consult lang	CPGROEI	15
Controle patiënt mobiliteitspoli	COPOPNAM	15
Controle patiënt HIV	COSPOED	15
Controle bloeddruk	NAGESPR	60
Controle chemo	BA	15
Belconsult	*LP	30
Nieuwe patiënt oncologie	CPTHY	15
Nieuwe patiënt schildklier	TCSANA	15
nieuwe patiënt mobiliteitspoli	NPH	15
Nieuwe patiënt ouderengeneeskunde	NPKDO	45
Oude nieuwe patiënt	KL	15
Controle patiënt spina bifida	NPTCCOV	30
Controle patiënt ouderengeneeskunde	CPALLO	15
Nieuwe patiënt osteogenesis imperfecta	CPTHD	20
Controle transplantatiepatiënt	TCNZ	5
Klinisch bezoek	NPCONTRA	15
Controle + V3.3	CPHEP	30

Appendix B: Included and excluded appointment types

Appointment description	Incl/Excl?	Appointment description	Incl/Excl?
Administratie/coördinatiewerkzaamheden	Excluded	Nieuwe patiënt telefonisch consult	Included
Doelgericht email contact	Excluded	Controle patiënt multidisciplinair voetzorgteam	Included
Nieuwe patiënt Deventer zh	Excluded	Belconsult chemo	Included
Administratie eHealth	Excluded	Cristabiopt	Included
Telefonische afspraak lang verpleegkundige	Excluded	Controle na dialyse	Included
Controle chemo VPK	Excluded	Spoedcontrole	Included
Telefonisch consult lang verpleegkundige	Excluded	Controle patiënt na MDO	Included
Telefonisch consult verpleegkundige	Excluded	Nieuwe patiënt Beeldbellen	Included
Telefonisch consult VPK	Excluded	Controle Pomp vullen	Included
Bezoeken verpleeghuis	Excluded	Controle patiënt Beeldbellen	Included
Controle patiënt vaat VPK	Excluded	Nieuwe patiënt na MDO	Included
Nieuwe patiënt mobiliteitspoli VS	Excluded	Controle patiënt ouderengeneeskunde geheugenpoli	Included
Nieuwe patiënt Co-assistent	Excluded	Nieuwe patiënt ouderengeneeskunde geheugenpoli	Included
Controle chemo VS	Excluded	Controle patiënt spoed	Included
Controle patiënt Beeldbellen verpleegkundige	Excluded	Overlijdensbespreking	Included
Controle patiënt vaat VS	Excluded	Nieuwe patiënt Hematologie	Included
Controle patiënt VPK	Excluded	Controle + V2.3	Included
Controle patiënt afdeling palliatief	Excluded	Cristabiopt klinisch	Included
Telefonisch consult	Included	Fibroscan	Included
Nieuwe patiënt	Included	Gesprek	Included
Controle patiënt	Included	Controle patiënt nachtdialyse	Included
Telefonisch consult lang	Included	Buikvetbiopt	Included
Controle patiënt mobiliteitspoli	Included	Nieuwe patiënt co	Included
Controle patiënt HIV	Included	Ideaal patiënt	Included
Controle bloeddruk	Included	Nagesprek	Included
Controle chemo	Included	Controle patiënt groeihormoon	Included
Belconsult	Included	Controle na opname	Included
Nieuwe patiënt oncologie	Included	Bezoeker arts	Included
Nieuwe patiënt schildklier	Included	Lumbaalpunctie	Included
nieuwe patiënt mobiliteitspoli	Included	Controle patiënt schildklier	Included
Nieuwe patiënt ouderengeneeskunde	Included	Telefonisch consult eHealth	Included
Oude nieuwe patiënt	Included	Nieuwe patiënt HIV	Included
Controle patiënt spina bifida	Included	Nieuwe patiënt korte diagnostische opname	Included
Controle patiënt ouderengeneeskunde	Included	Nieuwe patiënt telefonisch consult vaccinatie	Included
Nieuwe patiënt osteogenesis imperfecta	Included	Controle patiënt allo	Included
Controle transplantatiepatiënt	Included	Cpthd	Included
Klinisch bezoek	Included	Telefonisch niet zichtbaar voor patiënt	Included
Controle + V3.3	Included	Nieuwe patiënt contrast	Included
Continu ambulante peritoneaal dialyse	Included	Controle patiënt hepatitis	Included
Nieuwe patiënt schildkliernodus	Included		

Appendix C: DRG division

DRG	Diagnose	DRG type
2	Analyse afwijkende diagnostische test zonder diagnose	Algemeen
3	Analyse alg. malaise/moeheid zonder diagnose	Algemeen
4	Analyse anorexie, vermagering zonder diagnose	Algemeen
5	Analyse bewustzijnsdaling of collaps zonder diagnose	Algemeen
6	Analyse buikklachten zonder diagnose	Algemeen
7	Analyse dyspnoe zonder diagnose	Algemeen
8	Analyse electrolytstoornis zonder diagnose	Algemeen
11	Analyse hemorrhagische diathese zonder diagnose	Algemeen
15	Analyse koorts zonder diagnose	Algemeen
17	Analyse oedeem zonder diagnose	Algemeen
18	Analyse pijn op de thorax zonder diagnose	Algemeen
20	Analyse systeemaandoening zonder diagnose	Algemeen
21	Analyse klacht nno zonder diagnose	Algemeen
24	Analyse vergrote lymfeklier zonder diagnose	Algemeen
31	Pre-operatieve beoordeling	Algemeen
42	(auto)-Intoxicatie	Algemeen
107	Decompensatio cordis	Algemeen
283	Adipositas (obesitas)	Algemeen
401	Pneumonie nno	Algemeen
402	Interstitiële pneumonie	Algemeen
409	Overige luchtweginfecties nno (niet pneumonie)	Algemeen
411	Infectieuze diarree	Algemeen
421	Urineweginfectie (exclusief urosepsis, inclusief prostatitis)	Algemeen
469	Overige virusziekten nno	Algemeen
491	Infectie huid	Algemeen
499	Overige infecties	Algemeen
501	Sarcoïdose	Algemeen
513	Jicht, kristalartropathie, chondrocalcinosis	Algemeen
519	Fibromyalgie/overige gewrichtsaandoeningen nno	Algemeen
521	Reumatoïde artritis	Algemeen
524	Sjögren	Algemeen
599	Overige systeemziekten, vasculitis nno	Algemeen
614	Overgevoeligheid geneesmiddelen	Algemeen
619	Allergische aandoeningen nno	Algemeen
701	IJzergebreksanemie nno	Algemeen
702	Pernicieuze anemie	Algemeen
709	Overige erytrocytaire afwijkingen nno	Algemeen
741	Hemofilie	Algemeen
742	Von Willebrandziekte	Algemeen
781	Hemochromatose	Algemeen
920	Coeliakie/malabsorptie	Algemeen
931	Complexe chronische obstipatie	Algemeen
932	Chronische diarree zonder infectie	Algemeen
941	Alcoholische leverziekte	Algemeen

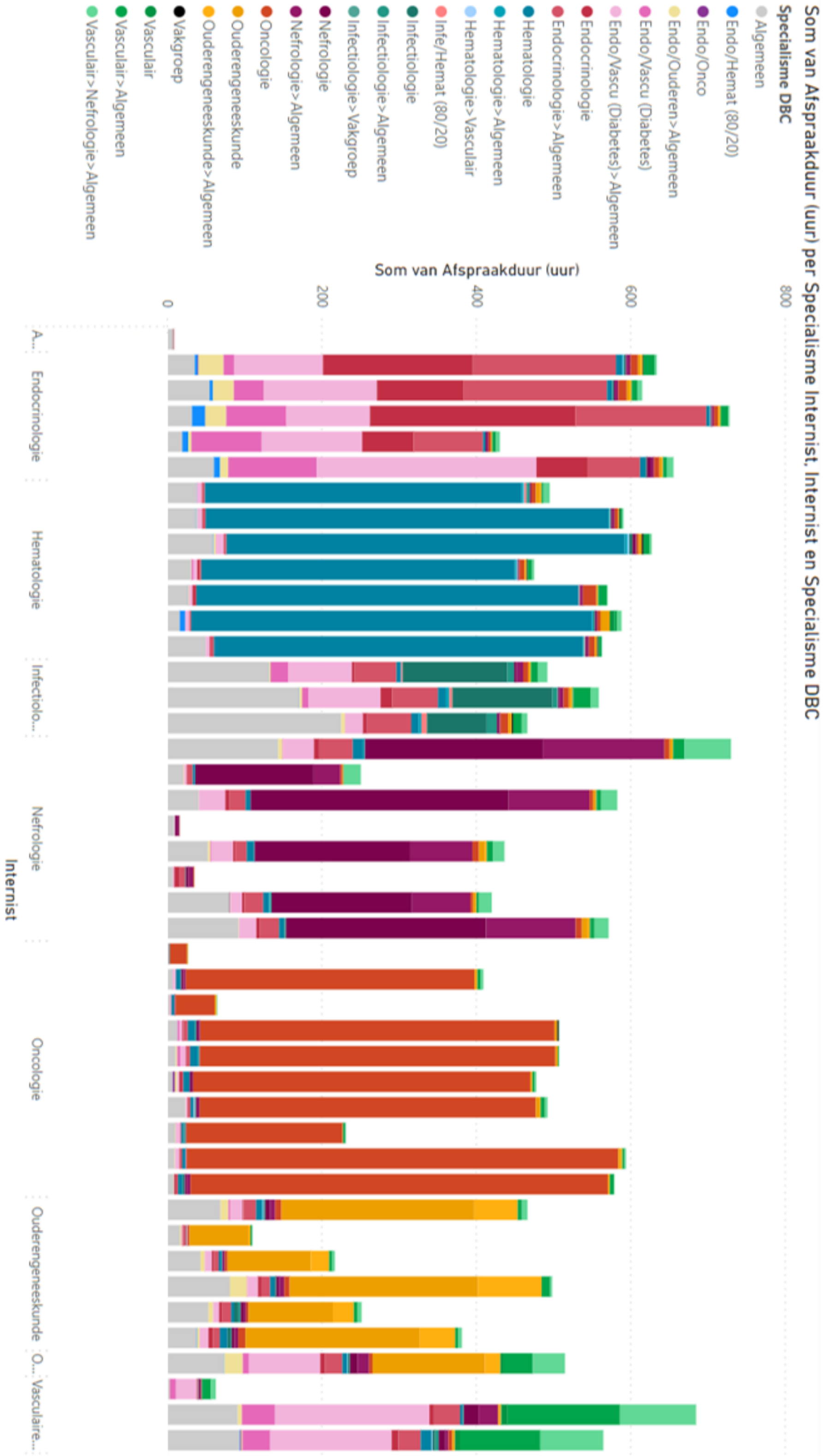
945	Levercirrose gecompenseerd	Algemeen
959	Overige lever- en galwegaandoeningen	Algemeen
961	Acute pancreatitis zonder galstenen	Algemeen
12	Analyse hematurie zonder diagnose	Endocrinologie
49	Incongruentie genderidentiteit	Endocrinologie
205	Hyperthyreoïdie en zwangerschap	Endocrinologie
206	Nodus schildklier	Endocrinologie
213	Hypothyreoïdie en zwangerschap	Endocrinologie
214	Maligniteit schildklier	Endocrinologie
224	Zwangerschapsdiabetes	Endocrinologie
232	Hypoparathyreoïdie	Endocrinologie
234	Paget	Endocrinologie
241	Hyperprolactinemie (niet prolactinoom)	Endocrinologie
242	Prolactinoom	Endocrinologie
243	Niet-functionerende hypofyse tumor	Endocrinologie
244	Acromegalie	Endocrinologie
246	Groeistoornis, groeideficiëntie nno	Endocrinologie
247	Gonadale dysfunctie	Endocrinologie
248	Hypopituitarisme	Endocrinologie
249	Overige hypofyse aandoeningen	Endocrinologie
251	Gynecomastie	Endocrinologie
252	Hirsutisme	Endocrinologie
262	Syndroom/morbus Cushing	Endocrinologie
291	MENsyndroom	Endocrinologie
292	Porfyrie	Endocrinologie
201	Hyperthyreoïdie nno	Endocrinologie>Algemeen
202	Hyperthyreoïdie autoimmuun	Endocrinologie>Algemeen
203	Hyperthyreoïdie toxisch adenoom	Endocrinologie>Algemeen
204	Hyperthyreoïdie multinodulair struma	Endocrinologie>Algemeen
207	Euthyreood struma	Endocrinologie>Algemeen
208	Thyreoïditis	Endocrinologie>Algemeen
211	Hypothyreoïdie, niet code 212	Endocrinologie>Algemeen
212	Hypothyreoïdie iatrogeen	Endocrinologie>Algemeen
219	Overige schildklieraandoeningen	Endocrinologie>Algemeen
231	Hyperparathyreoïdie	Endocrinologie>Algemeen
239	Overige stofwisselingstoornissen calcium	Endocrinologie>Algemeen
263	Niet-functionerende bijniertumor	Endocrinologie>Algemeen
269	Overige bijnieraandoeningen	Endocrinologie>Algemeen
299	Overige endocriene en metabole aandoeningen	Endocrinologie>Algemeen
233	Osteoporose, osteomalacie	Endo/Ouderen>Algemeen
221	Diabetes mellitus zonder secundaire complicaties	Endo/Vascu (Diabetes)>Algemeen
222	Diabetes mellitus met secundaire complicaties	Endo/Vascu (Diabetes)>Algemeen
223	Diabetes mellitus chronisch pomptherapie	Endo/Vascu (Diabetes)
261	Bijnierschorsinsufficiëntie/Addison	Endo/Hemat (80/20)
264	Maligniteit bijnier	Endo/Onco
29	Screening late effecten van de behandeling van kanker	Hematologie
703	sikkelcel anemie	Hematologie

706	Verworven hemolytische anemie	Hematologie
711	Agranulocytose (primair)	Hematologie
712	Aplastische anemie	Hematologie
714	Mastocytose	Hematologie
719	Overige leucocytaire afwijkingen nno	Hematologie
721	ITP	Hematologie
722	TTP (exclusief HUS)	Hematologie
729	Overige trombopenie nno	Hematologie
751	Hodgkin lymfoom	Hematologie
752	Non Hodgkinlymfoom (NHL) laaggradig	Hematologie
753	Non Hodgkin lymfoom (NHL) intermediair/hooggradig	Hematologie
754	Multipel myeloom/primaire amyloïdose	Hematologie
755	Monoklonale gammopathie (MGUS)	Hematologie
756	Acute lymfatisch leukemie	Hematologie
757	CLL, Waldenström, Hairy cell leukemie	Hematologie
759	Overige lymfoproliferatieve aandoeningen nno	Hematologie
761	Acute myeloïde leukemie/RAEB-t	Hematologie
762	RAEB	Hematologie
763	Myelodyplasie overige nno	Hematologie
771	Chronische myeloïde leukemie (CML)	Hematologie
772	Polycytemia vera, essentiële trombocytose	Hematologie
773	CMMoL	Hematologie
774	Myelofibrose	Hematologie
779	Overige myeloproliferatieve aandoeningen nno	Hematologie
704	Thalassemie	Hematologie>Algemeen
705	Overige hereditaire hemolytische anemieën	Hematologie>Algemeen
799	Overige hematologische aandoeningen nno	Hematologie>Algemeen
749	Overige hemorragische diathese obv stollingstoornis nno	Hematologie>Vasculair
1	Analyse afweerstoornis zonder diagnose	Infectiologie
13	Analyse hypofyse-assen zonder diagnose	Infectiologie
14	Analyse klachten na tropenbezoek, zonder diagnose	Infectiologie
413	Intra-abdominale infectie/peritonitis	Infectiologie
423	SOA, exclusief HIV	Infectiologie
432	Endocarditis/endovasculaire infectie	Infectiologie
441	Meningitis, encefalitis, hersenabces	Infectiologie
451	Osteomyelitis, infectie van (gewrichts)prothese of implantaat	Infectiologie
452	Spondylodiscitis / spinaal-/epiduraal abces	Infectiologie
453	Infectieuze artritis	Infectiologie
461	HIV infectie met behandelindicatie	Infectiologie
462	HIV infectie zonder behandelindicatie	Infectiologie
464	Prikaccident en andere expositie	Infectiologie
481	Malaria	Infectiologie
492	Lyme ziekte	Infectiologie
944	Hepatitis B/C	Infectiologie
431	Bacteriaemie/sepsis	Infectiologie>Algemeen
463	Virale hepatitis (niet hepatitis B/C: zie code 944)	Infectiologie>Algemeen
403	Mycobacteriële infecties	Infectiologie>Vakgroep

493	Primaire immuundeficiëntie nno	Infe/Hemat (80/20)
76	Niertransplantatietraject ontvanger	Nefrologie
77	Niertransplantatietraject donor	Nefrologie
78	Nier- en pancreastransplantatietraject ontvanger	Nefrologie
301	Glomerulonefritis/tubulo-interstitiële nefritis	Nefrologie
303	Urolithiasis	Nefrologie
304	Cystenieren en andere hereditaire nierziekten	Nefrologie
313	HUS (exclusief TTP)	Nefrologie
322	Acute nierinsufficiëntie met dialyse	Nefrologie
325	Chronische nierinsufficiëntie eGFR <30 ml/min	Nefrologie
331	Continue ambulante peritoneale dialyse (CAPD)	Nefrologie
332	Automatische peritoneale dialyse (APD)	Nefrologie
336	Chronische hemodialyse thuis	Nefrologie
339	Chronische hemodialyse in instelling	Nefrologie
522	SLE/MCTD	Nefrologie
526	Systemische vasculitis (PAN, Wegener, Churg Strauss)	Nefrologie
531	Begeleiding immunosuppressieve therapie op verzoek van derden	Nefrologie
323	Acute nierinsufficiëntie zonder dialyse	Nefrologie>Algemeen
324	Chronische nierinsufficiëntie eGFR 30-60 ml/min	Nefrologie>Algemeen
399	Overige nierziekten nno	Nefrologie>Algemeen
25	Screening belaste familieanamnese	Oncologie
622	Maligniteit, grootcellig carcinoom bronchus	Oncologie
629	Overige maligniteiten thorax nno	Oncologie
802	Maligniteit CZS (primair)	Oncologie
811	Maligniteit mamma	Oncologie
821	Maligniteit ovarium	Oncologie
822	Maligniteit cervix	Oncologie
823	Maligniteit endometrium	Oncologie
831	Maligniteit testis	Oncologie
832	Maligniteit prostaat	Oncologie
833	Maligniteit urinewegen	Oncologie
834	Maligniteit nier/Grawitz	Oncologie
839	Overige maligniteiten tractus uro/genitalis	Oncologie
841	Maligniteit bot en gewrichtskraakbeen	Oncologie
842	Maligniteit huid/melanoom	Oncologie
843	Maligniteit weke delen	Oncologie
899	Maligniteit nno	Oncologie
904	Maligniteit slokdarm/cardia	Oncologie
914	Maligniteit maag (exclusief cardia)	Oncologie
927	Maligniteit colorectaal	Oncologie
955	Levertumor nno	Oncologie
964	Maligniteit pancreas	Oncologie
979	Overige maligniteiten tractus digestivus	Oncologie
90	Multipele orgaanstoornissen	Ouderengeneeskunde
91	Geheugenproblemen en dementie	Ouderengeneeskunde
92	Delier	Ouderengeneeskunde
94	Collaps e.c.i.	Ouderengeneeskunde
95	Loopstoornis (mobiliteitsproblematiek)	Ouderengeneeskunde

93	Aandoeningen van bewegingsstelsel en bindweefsel	Ouderengeneeskunde>Algemeen
22	Analyse trombofilie zonder diagnose	Vasculair
26	Screening cardiovasculaire risicofactoren	Vasculair
131	Vena cava syndroom nno	Vasculair
132	Posttrombotisch syndroom	Vasculair
272	Hyperhomocysteïnemie	Vasculair
734	Hereditaire trombofilie	Vasculair
739	Overige verhoogde tromboseneiging	Vasculair
10	Analyse gewrichtsklachten zonder diagnose	Vasculair>Algemeen
23	Analyse trombose zonder diagnose	Vasculair>Algemeen
122	Arteriële trombose en embolie	Vasculair>Algemeen
124	Atherosclerose extremiteiten/perifeer vaatlijden	Vasculair>Algemeen
126	Raynaud/acrocyanose (niet vasculitis)	Vasculair>Algemeen
129	Aneurysma en overige arteriële vaataandoeningen	Vasculair>Algemeen
133	Chronische zorg patiënten met meerdere cardiovasculaire risicofactoren	Vasculair>Algemeen
139	Overige aandoeningen veneuze- en lymfevaten	Vasculair>Algemeen
271	Primaire dyslipidemie	Vasculair>Algemeen
506	Arteriitis temp. polymyalgia rheumatica	Vasculair>Algemeen
731	Diep veneuze trombose extremiteiten	Vasculair>Algemeen
732	Longembolie	Vasculair>Algemeen
733	Veneuze tromboembolie overige	Vasculair>Algemeen
311	Hypertensie	Vasculair>Nefrologie>Algemeen
713	Eosinofiele afwijkingen	Vakgroep

Appendix D: DRG division over internists 2022



Appendix E: DRG division over internists 2022 by Model

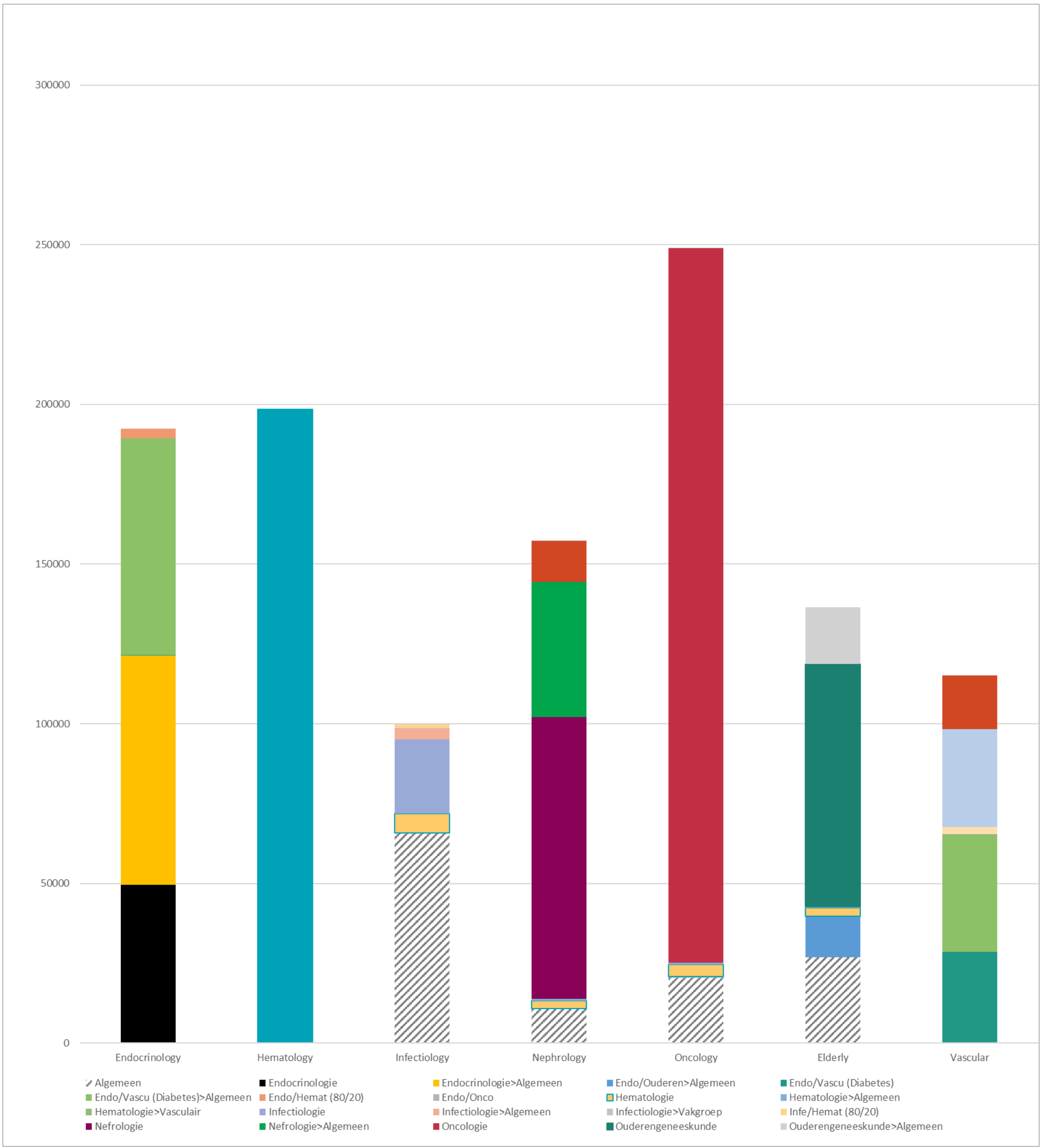
	1	2	3	4	5	6	7	8	9	10	11	12
2. Internist 1	0	0	0	0	0	41868	3115	0	0	0	0	0
3. Internist 2	0	0	5772	0	0	36617	0	0	0	0	0	0
4. Internist 3	0	14645	25952	0	0	0	0	0	0	0	0	0
5. Internist 4	0	0	34118	0	0	0	0	0	0	0	0	0
6. Internist 5	0	34865	0	0	0	0	0	0	0	0	0	0
7. Internist 6	0	0	0	0	0	0	0	0	25059	0	0	0
8. Internist 7	0	0	0	0	0	0	0	0	33917	0	0	0
9. Internist 8	0	0	0	0	0	0	0	0	29247	0	0	0
10. Internist 9	0	0	0	0	0	0	0	0	44384	0	0	0
11. Internist 10	0	0	0	0	0	0	0	0	37943	0	0	0
12. Internist 11	0	0	0	0	0	0	0	0	10273	0	0	0
13. Internist 12	0	0	0	0	0	0	0	0	32467	0	0	0
14. Internist 13	19867	0	5943	0	0	0	0	0	0	2050	0	0
15. Internist 14	12122	0	0	0	0	0	0	0	0	0	0	22780
16. Internist 15	33766	0	0	0	0	0	0	0	0	0	0	0
17. Internist 16	0	0	0	0	0	0	0	0	0	0	0	0
18. Internist 17	0	0	0	0	0	0	0	0	0	0	0	0
19. Internist 18	0	0	0	0	0	0	0	0	0	0	0	0
20. Internist 19	0	0	0	0	0	0	0	0	0	0	0	0
21. Internist 20	810	0	0	0	0	0	0	0	0	0	0	0
22. Internist 21	26371	0	0	0	0	0	0	0	0	0	0	0
23. Internist 22	0	0	0	0	0	0	0	0	0	0	0	0
24. Internist 22	0	0	0	0	0	0	0	0	0	0	0	0

25. Internist 23	0	0	0	0	0	0	0	0	0	0	0	0
26. Internist 24	0	0	0	0	0	0	0	0	0	0	0	0
27. Internist 25	0	0	0	0	0	0	0	0	0	0	0	0
28. Internist 26	0	0	0	0	0	0	0	0	0	0	0	0
29. Internist 27	0	0	0	0	0	0	0	0	0	0	0	0
30. Internist 28	0	0	0	0	0	0	0	0	0	0	0	0
31. Internist 29	0	0	0	0	0	0	0	0	0	0	0	0
32. Internist 30	0	0	0	0	0	0	0	370	0	0	0	0
33. Internist 31	0	0	0	0	0	0	0	0	0	0	0	0
34. Internist 32	0	0	0	0	0	0	0	0	0	0	0	0
35. Internist 33	0	0	0	0	0	0	0	0	0	0	0	0
36. Internist 34	0	0	0	0	0	0	0	0	0	0	0	0
37. Internist 35	5949	0	0	12880	0	0	0	0	0	0	0	0
38. Internist 36	25108	0	0	0	0	0	0	0	0	0	0	0
39. Internist 38	0	0	0	0	0	0	0	0	0	0	146	0
40. Internist 39	0	0	0	0	0	3850	0	0	0	0	146	0
41. Internist 40	0	0	0	0	18685	21805	0	0	0	0	146	0
42. Internist 41	0	0	0	0	10110	0	0	0	0	0	146	0

	13	14	15	16	17	18	19	20	21	22	23	24
1. Internist 1	0	0	0	0	0	0	0	0	0	0	0	0
2. Internist 2	0	0	0	0	0	0	0	0	0	0	0	0
3. Internist 3	0	0	0	0	0	0	0	0	0	0	0	0
4. Internist 4	0	0	0	0	0	0	0	0	0	0	0	0
5. Internist 5	0	0	0	0	0	0	0	0	0	0	0	0
6. Internist 6	0	0	0	0	0	0	0	0	0	0	0	0
7. Internist 7	0	0	0	0	0	0	0	0	0	0	0	0
8. Internist 8	0	0	0	0	0	0	0	0	0	0	0	0
9. Internist 9	0	0	0	0	0	0	0	0	0	0	0	0
10. Internist 10	0	0	0	0	0	0	0	0	0	0	0	0

11. Internist 11	0	0	0	0	0	0	0	0	0	0	0	0
12. Internist 12	0	0	0	0	0	0	0	0	0	0	0	0
13. Internist 13	3535	0	1120	0	0	0	0	0	0	0	0	0
14. Internist 14	0	0	0	0	0	0	0	0	0	0	0	0
15. Internist 15	0	0	0	0	0	0	0	0	0	0	0	0
16. Internist 16	0	0	0	0	29005	0	0	0	0	0	0	0
17. Internist 17	0	0	0	270	13355	0	0	0	0	0	0	0
18. Internist 18	0	0	0	22080	0	0	0	0	0	0	0	0
19. Internist 19	0	0	0	29063	0	0	0	0	0	0	0	0
20. Internist 20	0	0	0	33388	0	0	0	0	0	0	0	0
21. Internist 21	0	0	0	0	0	0	0	0	0	0	0	0
22. Internist 22	0	0	0	3463	0	0	0	0	0	0	0	0
23. Internist 23	0	185	0	0	0	3029	0	0	0	0	0	565
24. Internist 24	0	0	0	0	0	29304	0	0	0	0	0	0
25. Internist 25	0	0	0	0	0	21125	0	0	0	0	0	0
26. Internist 26	0	0	0	0	0	33113	0	0	0	0	0	0
27. Internist 27	0	0	0	0	0	38095	0	0	0	0	0	0
28. Internist 28	0	0	0	0	0	27972	0	0	0	0	0	0
29. Internist 29	0	0	0	0	0	29304	0	0	0	0	0	0
30. Internist 30	0	0	0	0	0	14652	0	0	0	0	0	0
31. Internist 31	0	0	0	0	0	0	0	0	0	0	0	0
32. Internist 32	0	0	0	0	0	27106	0	0	0	0	0	0
33. Internist 33	0	0	0	0	0	0	20442	17509	0	0	0	0
34. Internist 34	0	0	0	0	0	0	19312	0	0	0	0	0
35. Internist 35	0	0	0	0	0	0	21526	0	0	0	0	0
36. Internist 36	0	0	0	0	0	0	14746	0	0	0	0	0
37. Internist 37	0	0	0	0	0	0	0	0	0	0	0	0
38. Internist 38	0	0	0	0	0	0	0	0	2180	5739	29535	0
39. Internist 39	0	0	0	0	0	0	0	0	0	0	0	0
40. Internist 40	0	0	0	0	0	0	0	0	0	0	0	0
41. Internist 41	0	0	0	0	0	0	0	0	0	24895	0	0

Appendix F: Assuming that general is equal to department 2022



Appendix G: Replacing an infectiologist in 2022

6.1.4.1 Acquiring an endocrinologist

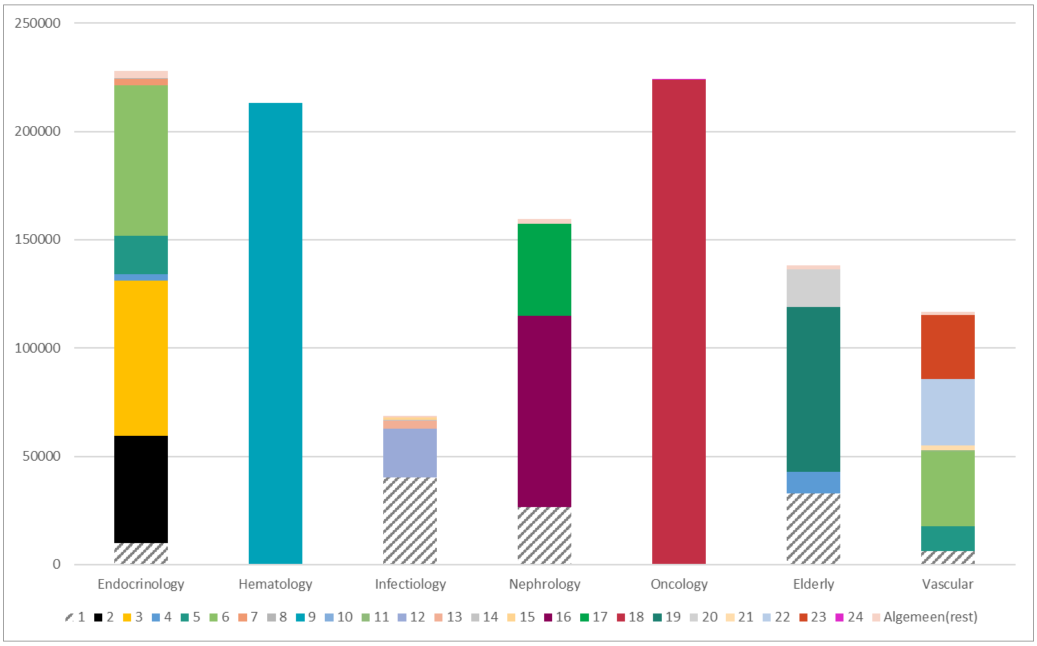


Figure 16: Optimal division when replacing an infectiologist with an endocrinologist

6.1.4.2 Acquiring an haematologist

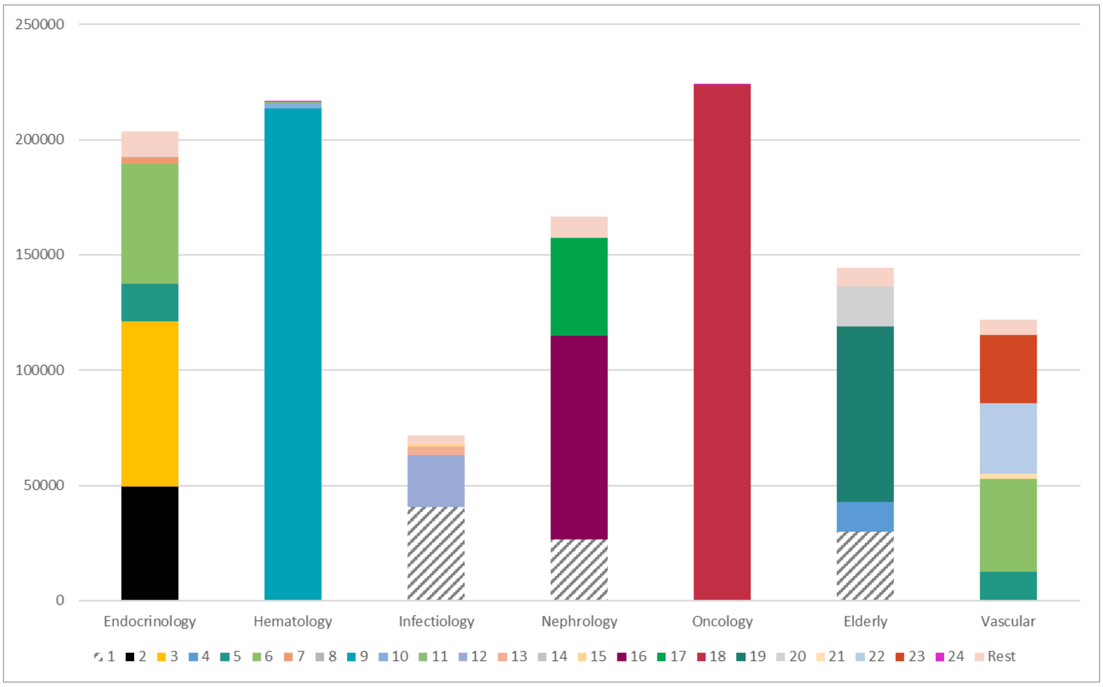


Figure 17: Optimal division when replacing an infectiologist with an haematologist

6.1.4.3 Acquiring an nephrologist

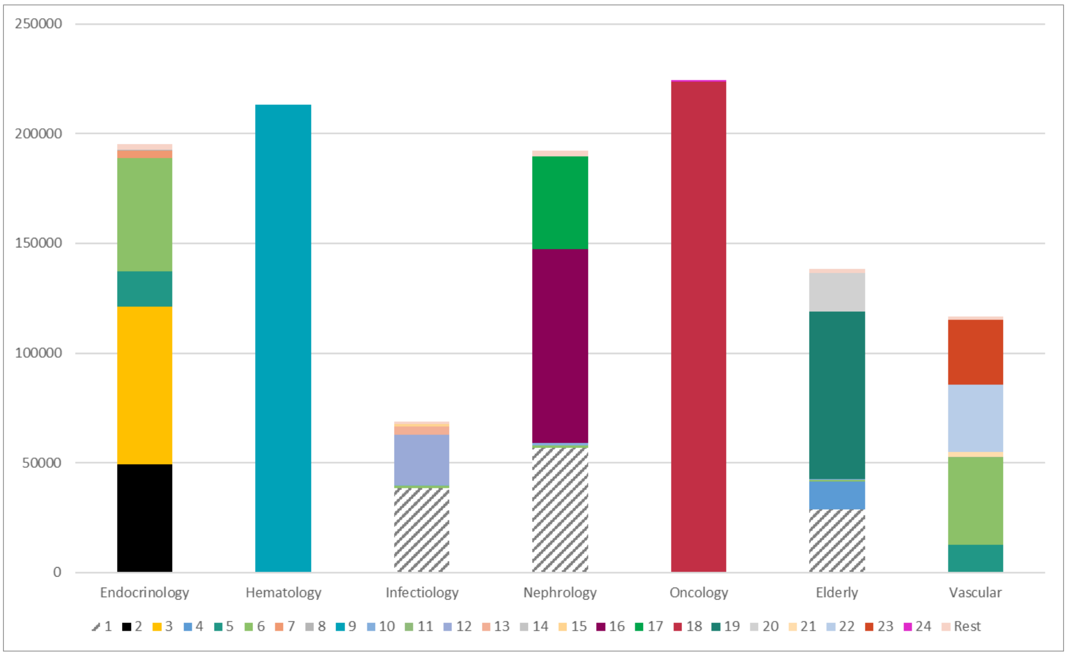


Figure 18: Optimal division when replacing an infectiologist with an nephrologist

6.1.4.4 Acquiring an oncologist

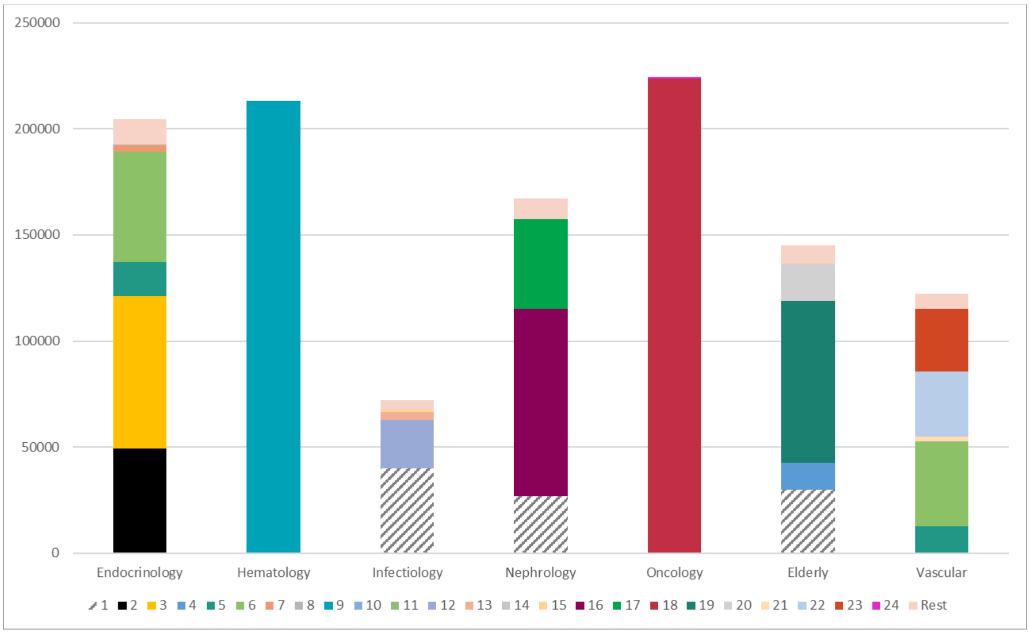


Figure 19: Optimal division when replacing an infectiologist with an oncologist

6.1.4.5 Acquiring an internist with the elderly healthcare specialty

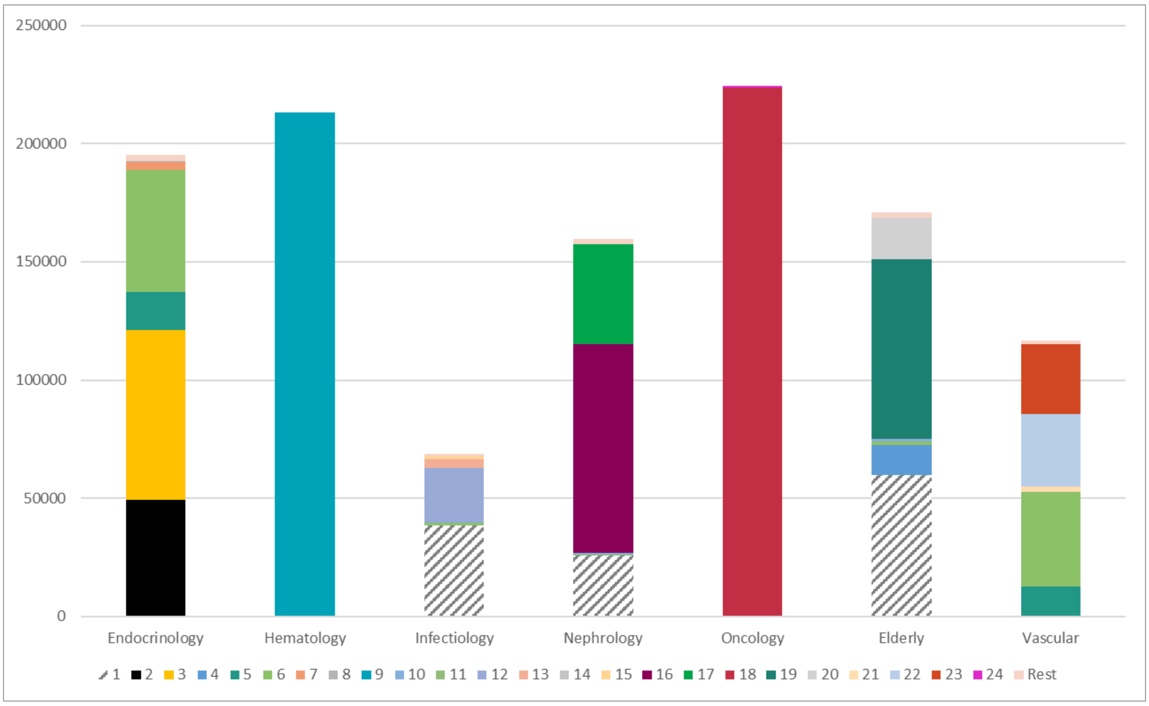


Figure 20: Optimal division when replacing an infectiologist with an elderly healthcare internist

6.1.4.6 Acquiring an vascular internist

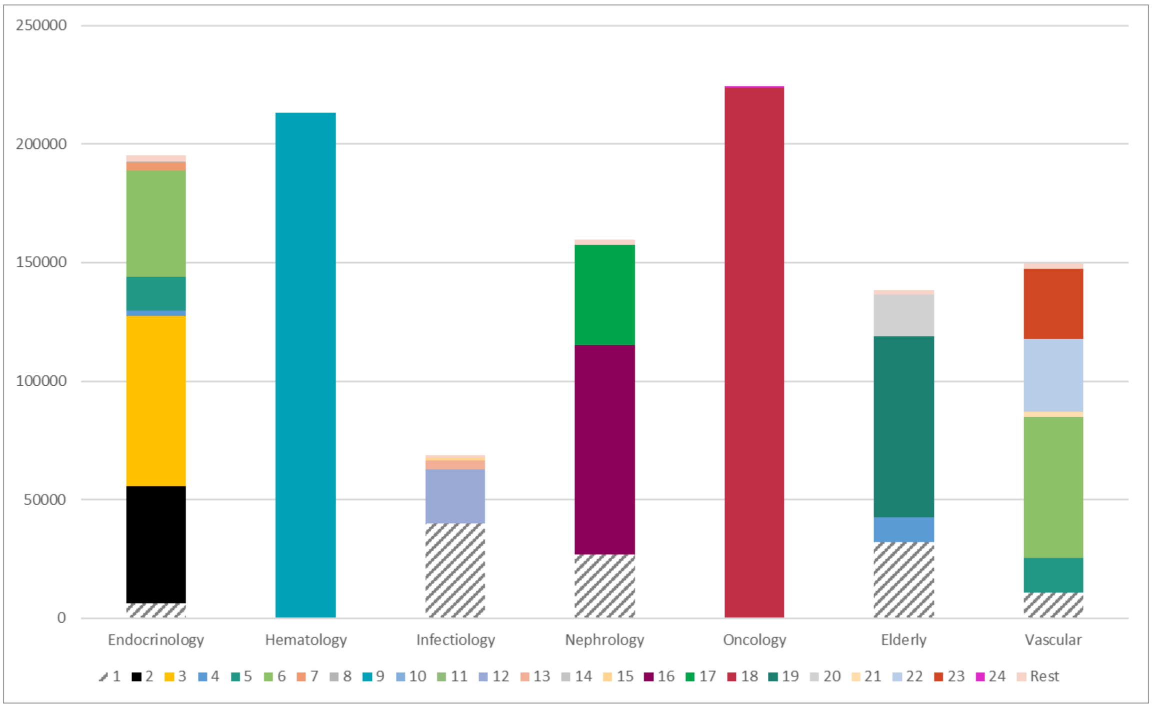


Figure 21: Optimal division when replacing an infectiologist with an vascular internist

Appendix H: Allocation tool to determine overtime per specialty

		STAP 1	STAP 2					STAP 3			
	Beschikbaar	Stap 1	END/ONC	END/HEM	END/VAS	INF/HEM	HEM/VAS	Gen	Departm		Overtime
Endocrinology	194901	49510	370	3115				188780			24,050%
Hematology	213290	213290				1120					0,525%
Infectiology	101287	22780						82715,87			4,155%
Nephrology	159381	88265						63610,12			-4,709%
Oncology	225220	223700							750		-0,342%
Elderly	138063	76026						98937,64			26,727%
Vascular	116580	2180			28795		585	4377,37			-69,174%
	1148722	675751	0	0	0	0	0	0	0		

RUN

The tool contains the following 4 steps:

1. Allocate specialty specific appointments
2. Allocate double specialty appointments
3. Place Department minutes where the least overtime is
4. Press ‘Run’ to let the tool decide how many minutes for general each specialty is needed such that overtime is equitably distributed.

So, what the tool basically does is determining the capacity of each specialty such that every internist will make an as equal amount of overtime possible.

Appendix I: Patient demand growth percentages by Consulting firm X

Left out due to confidentiality.