OPTIMISATION OF THE TACTICAL ALLOCATION OF RESOURCE CAPACITIES AT AN ACADEMIC ANIMAL HOSPITAL

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THESIS

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Abstract

This thesis seeks to improve the patient flow at an academic animal hospital. The research focusses on the main obstructions with identified root causes that can be traced back to capacity management-related problems. Here, we make a distinction between problems related to the allocation of resources (the design of the production planning) that causes over- and under capacity, extremely unbalanced workload and mismatches between the supply of and demand for resources, and problems related to the patient appointment planning processes that results in short-term inefficiencies, unrealistic schedules, unnecessary long waiting times both at home and in the hospital, and many obstructions of the patient flow.

Through an extensive analysis of the 'as-is' situation, four years of historical data and applicable literature, we conclude that the network of care processes suffers greatly from the bullwhip effect. As a result, the negative impact of variability-related phenomena is first experienced at care processes upstream (mostly at the outpatient clinic) and aggregates the further we arrive at care processes more downstream (mostly at the Radiology). Furthermore, we conclude that the allocation of resources is not demand-driven and contains non-univocal schedules, and the patient appointment planning processes have no measures in place to deal with or resolve obstructions in the patient flow.

Through the development of a stochastic discrete-event simulation model and the use of simulation based optimization, we evaluate a set of developed alternative solutions that describe either changes to the production schedule or 'what-if' scenarios. Based on the results we provide three recommendations for the allocation of resources: reduce the variability in the demand upstream by exploiting the use of variability buffering on weekly demand (1), reduce the variability in the demand downstream by clustering care processes upstream that share similar succeeding demand (2), align the demand for and supply of resources between care processes by adjusting the opening times to obtain univocal schedules (3). Managing these recommendations in the 'as-is' production schedule can result in substantial savings on capacity (in the simulation up to 45%) at the cost of small but acceptable performance degradations on other measurements. Simultaneously, this can result in significant improvements on appointment waiting times and distribution of the workload throughout the hospital. Additionally, we recommend for the patient appointment planning processes to implement measurements that deal with variability-related phenomena at operational level. These measurements can be used to achieve specific performance changes. For instance, by introducing a walk-in room at the Echo or over-excessively schedule capacity at certain care processes, we may reduce the hospital waiting times significantly. The effectiveness of the measurements highly depend on the care processes' characteristics, measurement parameters and production schedule.

Abbreviations

Abbreviation	English	Dutch
ANE	Department of Anaesthesiology	**A**fdeling **An**esthesiologie
ASA	**A**merican **S**ociety of **A**nesthesiologists Physical Status	Classificatie systeem voor het beoordelen van de fysieke status van een patiënt.
CHIR	Department of Surgery	Afdeling **Chir**ugie
CM	Case Manager	**C**ase **M**anager
CT	Computed Tomography	**C**omputer **T**omografie
DB	Department of Imaging	Afdeling **D**iagnostische **B**eeldvorming (Radiologie)
ECHO	Echography	**Echo**grafie
FTE	Fulltime-equivalent	**F**ull**t**ime **e**enheid
GD	Companion Animals	**G**ezelschaps**d**ieren
IC	**I**ntensive **C**are	Afdeling spoed intensieve zorg
ID	Integrating Disciplines (ANE + DB)	**I**ntegrerende **D**isciplines(ANE + DB)
INT	Internal Medicines	**Int**erne Geneeskunde
MRI	**M**agnetic **R**esonance **I**maging	Kernspintomografie
OBP	Support and management personnel	**O**ndersteundend en **B**eheers**p**ersoneel
OK	Operating Room	**O**peratie **K**amer
OVB	Scheduling with reservation	Plannen **O**nder **V**oor**b**ehoud, twijfels over de noodzaak
Paard / PD	Horse	Paard
RTC	Radio- and Chemotherapy	**R**adio**t**herapie en **C**hemotherapie
SIO	Specialist in training	**S**pecialist **i**n **O**pleiding
UKG	Companion clinic	**U**niversiteits**k**liniek voor **G**ezelschapsdieren

Contents

Chapter 1 Introduction

This chapter starts with the introduction of the organisation (Section 1.1) and the problem at hand (Sections 1.2 and 1.3). Next, the problem identification is discussed in the following order: a summarized description of the problem context (Section 1.4), the selection of the core problem (Section 1.5), and the formulation of research questions and approach (Section 1.6). The chapter concludes the discussion of the research design (Section 1.7), research methods and data collection techniques (Section 1.8).

1.1 Organisation description

As part of the overarching organisation *Universitair Diergeneeskundig Centrum Utrecht,* one of the worldwide leading academic animal hospitals, there is the *Universiteitskliniek voor Gezelschapsdieren* (UKG). This clinic is at the centre of the faculty Animal Healthcare (In Dutch: diergeneeskunde) and specialised in companion animals (in Dutch: Gezelschapsdieren (GD)). It is located, among many other faculties of the Universiteit Utrecht (UU), at the Uithof in Utrecht, The Netherlands. From the beginning, UKG was established to facilitate research and many practical components of the educational program Diergeneeskunde. For this reason, the clinic has a radically different healthcare setting compared to traditional animal clinics. There are three clinical disciplines on the Uithof: Horse (in Dutch: Paard), Farm animals (in Dutch: Landbouwhuisdieren) and Companion animals. Paard and GD share the same main building and many employees and physical capacity. Here, at Paard and GD, the research will take place.

This research is done at the Clinical Sciences departments Imaging and Anaesthesiology with the support of consultancy company Vintura. Vintura has specialised consult expertise in the healthcare industry and life sciences and has delivered valuable input in the problem identification process through, among other things, organising multidisciplinary meetings to attend. Vintura's project was concerned with identification and solving of problems on a strategic and organisational level, and to guide the integration of multiple departments over time. During the project, problems would be placed into context by structuring and visualizing the clinical pathways at Paard and GD. Meanwhile, this research supplements the project by elaborating and addressing a set of the problems on a tactical level.

1.2 Problem identification

As a point of departure in the problem identification process for this research, we attended numerous multi-disciplinary meetings organised by Vintura. This to obtain background information about clinical pathways, ad-hoc tasks, planning activities, and bottlenecks with possible causes and solutions. In particular capacity management problems arose with two departments at the centre of all of it: Anaesthesiology (in Dutch: Anesthesiologie (ANE)) and Radiology (in Dutch: Diagnostische Beeldvorming (DB)).

As UKG has performed little research in process optimalisation and in the field of Industrial Engineering and Management, there was a lack of information and understanding of the planning and management processes to perform identification of problems correctly. For this reason, as a second point of departure the current (‘as-is’) situation has been analysed extensively to gain an understanding of the existing management and planning processes on a tactical and operational level. This was key to identify problems and put them into context, understand their possible causes and impact, clarify if they were only perceived as problems among employees or if they were indeed a problem, and to make it possible to scope down the research to a manageable level. As a consequence, the structure of this report does not reflect the chronological order of how the research has been executed.

1.3 The problem

The reason for this research is a problem perceived by UKG within the whole clinic: the patient flow is poor. In particular, the flow of patients from one discipline to another is problematic. Discipline’s schedules are not aligned. For example, we observe shortages and surpluses in ANE’s labour capacity and DB’s physical capacity on specific weekdays and dayparts as a result of undistributed workloads imposed by other disciplines. This obstructs the planning and realisation of schedules with consequences for the capacity utilisation, patient waiting times, patient safety and more. Especially the lack of well-communicated, structured and univocal planning, admission and clinical pathway processes for the disciplines DB, ANE and Department of Surgery (CHIR) are experienced as problematic. As a result of the obstructions in the patient flow, re-occurring conflicts between and built-up frustration among disciplines throughout the whole hospital increases the need for solutions.

The experienced problems may have some roots in the characteristics of UKG’s unique healthcare setting and specific patients group (animals). According to many veterinarians and other employees at UKG with previous experience in the humane care, the clinical pathways of animals are more diverse, unpredictable and uncertain compared to human clinical pathways. This can be explained by several observations. First of all, the owners choose (to some extent, but almost freely) the clinical pathway of their pet; they may pick one treatment over another or abruptly stop the treatment. This decision is commonly dependent on financial aspects since a care system with obligated animal healthcare insurances is lacking. Some owners are insured, but many are not. Second, animals do not choose to visit the hospital. Therefore, there are many delayed owners and No Shows. Third, animals do not talk and owners have trouble in reporting the relevant circumstances and identifying and interpreting symptoms correctly. This can be troublesome for performing an accurate anamnesis and diagnosis. There is one human species but over hundreds of animal species being treated within clinics. Within species, there are many artificially selected groups based on characteristics (breeds) with their own specific diseases and pathology. Fourth, owners regularly wait with treatments or misinterpret the urgency of symptoms, unintentionally endangering their pet. This aggravates the urgency for treatments to a relatively higher level compared to human care. Fifth, animals are treated on a more symptomatic base and with a focus on quality of life. A complete diagnosis and cure may be expensive or (from a quality of life perspective) not worth it. Instead, the criteria of treatment of an animal is to:

1. extend lifetime or improve quality of life by treating the symptoms with medication;
2. diagnose symptoms and their experienced severity, not necessarily diagnosing the cause;
3. perform small interventions to eliminate or reduce the seriousness of symptoms.

However, UKG is known for their specialised second-line care and most owners are willing to push the boundaries further in terms of treatment and costs than owners visiting regular clinics. Unfortunately, specialised second-line care is growing among chains of animal clinics and increases the competitiveness felt at UKG. To differentiate itself, UKG's willingness is growing to compete on objectives such as reducing the treatment durations and access times, and serve a set target production number of patients. Summarizing, treating animals as a patient group with second-line care brings along many uncertainties, a relatively high urgency and an increasing level of competitiveness.

Aside from a very unique patient group, UKG has a unique healthcare setting on its own. UKG is not small enough, like many veterinary clinics, to be able to manage and deal with all issues on ad-hoc matter. On the contrary, UKG is not large enough to benefit from their scale. For educational and research purposes, UKG facilitates many specialised treatments which have a low market demand. Additionally, the emphasis on education dictates the clinical planning at UKG and introduces a delay in the patient healthcare.

In conclusion, the patient flow is affected by a combination of the complicated clinical capacity and healthcare setting, and the problematic patient group. UKG is a small-scale hospital that demands high flexibility in their capacity management as most patient arrivals are semi-urgent to urgent and are involved in many uncertainties. As a result, departments with in particular at ANE, CHIR and DB experience under- and overcapacity, many No-Shows, postponements, cancelations and delays of appointments, extremely high and varying workload, with major consequences for the productivity.

1.4 Problem context

This section elaborates on the problem description of Section 1.3. Many problems have been identified, clustered, quantified and their mutual relations have been visualised in a problem cluster in order to identify the core problem. In Figure 1.4.5, at the end of this section, the final problem cluster is presented. During the multi-disciplinary meetings many more problems were identified. A pre-selection of the most significant ones has been made to keep the problem cluster clear and amenable.

As addressed previously, the problem identification has been a relatively extensive part of the research. This section summarizes the problem identification. In Appendix CC the complete identification is presented with more results from our data analysis. Several care processes have been added to the scope after the selection of the core problem (e.g. outpatient clinical consults of internal medicines, Echography and X-Ray). Initially, only care processes strongly associated with problems and (root) causes were identified and elaborated on. It is advised to the reader to consult Appendix A in the case of unclarity or doubt about names and abbreviations of disciplines, departments, appointments and care processes.

Upcoming is a brief discussion of the identified root causes (highlighted by yellow squares in the problem cluster in Figure 1.4.5 at the end of this section).

1.4.1 Expectable but unaccounted for extra medical operations

During surgery and diagnostics, both expected and unexpected medical operations are executed in addition to the initial planned medical operations. Roughly one out of four surgeries at CHIR experience extra medical operations. This is the case for roughly one out of six treatments of DB. Approximately 25%-50% of treatments at the CT have additional medical operations. Commonly this is an additional treatment at the ECHO. These uncertainties are not taken into account in the patient appointment planning. Case Managers tend to schedule appointments that require ANE but do not take into account any operational deviations. This, in combination with a troublesome decision-making process during treatments to decide whether extra medical operations can and should be executed right away or be postponed, results in delayed (start of) treatments, deviations from the initial schedule and conflicts between involved disciplines and other schedules.

1.4.2 Missing, incorrect and incomplete anaesthesia applications

Roughly one out of five treatments is affected by problematic retrieval of essential, correct and complete information from anaesthesia applications as students and specialists perform the pre-anaesthesia assessments. Pre-anaesthesia assessments delay the start of outpatient clinical consults while they are performed a second time by ANE themselves for the sake of patient safety. Pre-anaesthesia assessments take roughly five minutes to be performed by ANE and commonly conclude in changes in the patient appointment planning. Regularly, appointments are scheduled without taking into account ANE-related concerns. For instance, surgeries are scheduled at times when the patient is not yet in a healthy condition to be operated or two appointments are scheduled within an unrealistic time frame that causes conflicts and problems in the operationalisation.

1.4.3 Poor time-management

All three disciplines (ANE, DB and CHIR) reported problematic time-management of treatments, which results in delay of treatments and affects successive treatments. This is a reason for conflicts (involved parties are overruled and lack authority) and complicates the operationalisation of the planning.

All three disciplines agree that the responsibility for the operationalization and safeguarding of the schedule, including the time-management of treatments, is with the specialists on duty. However, the disciplines admit there is a lack of a specialist on duty being in charge to carry out the supervision.

1.4.4 Scheduling of appointments with 'unrealistic' standard times

With a lack of communication between disciplines, a lack experience among Case Managers and employees at the front desk, the use of non-representable standard times for medical operations, many factors that affect the operationalisation of appointments are not considered. As a result, the schedule with treatments is challenging in its operationalization, sometimes even infeasible. Most disciplines agree on the incorrectness of the length and use of the standard times to schedule treatments, and experience their schedule as frustrating, tight and unrealistic. Therefore, a patient appointment planning that takes into account such factors and enhances the distribution of the workload (and its peaks) is desired.

1.4.5 No coherent efficient planning on tactical level

There is a lack of coherent and efficient production schedule. Most departments and disciplines do not take into account other department's schedules. Additionally, most departments base their production schedule on labour capacity while an approach for a more production and demand driven planning is desired. Currently, the flow of patients is regularly obstructed as a result of capacity shortages and peak workloads (commonly at DB and ANE around 11:00-13:00), and acceptable waiting times are not taken into account in the design of the production schedule. Furthermore, a shortage in ANE's labour capacity is currently observed at Tuesday, Wednesday and Thursday, while excessive capacity is observed at Monday and Friday (see Appendix DD). The estimated total demand is 7 FTE at ANE, excluding vacations, sickness, irregular shifts and other factors. The total estimated available FTE at ANE is 10.04. We may conclude that there is enough ANE if we also consider that most care processes experience low capacity utilisation. The shortage at ANE results in the temporarily closing of care processes at both CHIR and DB.

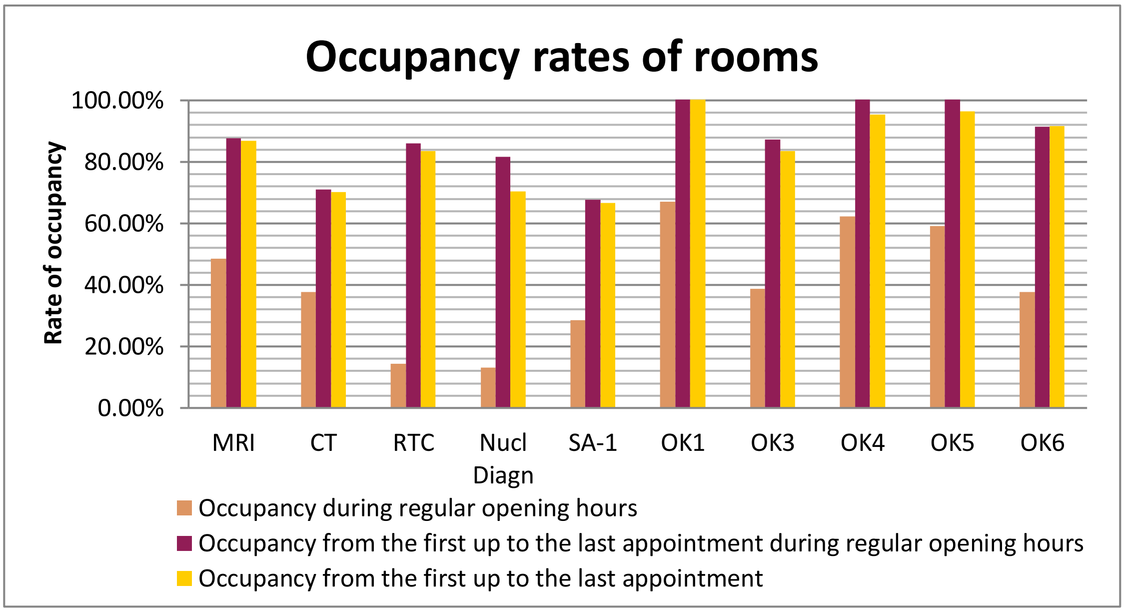

Figure 1.4.1 Occupancy rates during regular opening hours (1), from first to last appointment during these hours (2) and from the first to the last appointment on a day (3).

Figure 1.4.1 presents the occupancy rates of DB's and CHIR's rooms in three different forms: the occupancy rate during regular opening hours (1), the occupancy rate from the first treatment up to and including the last treatment during regular opening hours including overtime (2), and the occupancy rate from the first treatment up to and including the last treatment during a whole day of 24 hours (3). Overtime concerns treatments started during but finished after regular opening hours. Information about the overtime in minutes and its occurrence (described by the percentage of days with overtime as a fraction of all days) can be found in Appendix Z.

Based on the occupancy rates, we can make the following observations:

1. There is significant difference between the occupancy rates during regular opening hours (1) and occupancy rates from the first up to and including the last treatment during regular opening hours (2).
2. For operating rooms (ORs) OK1 until OK6, this can be explained by the relatively flexible planning; surgeons staff the ORs according to their preference. Occupancy rates from the first up to and including the last appointment during regular opening hours (2) and during the whole day (3) are higher, regularly (close to) 100%.
3. For RTC, the low occupancy rate during regular opening hours (1) can be explained: RTC is only partially open every day.
4. For Nucl Diagn, the low occupancy rate during regular opening hours (1) can be explained: Nucl Diagn is only operated for a daypart, if it is operated on a day.

5. For MRI and CT, the low occupancy rates during regular opening hours (1) of 48% and 37% respectively may be explained by:
    a. The daily routine experiences quiet mornings hours (8:30 – 11:00) that crumble the occupancy rates. It is then followed by a peak workload (11:00 – 15:00);
    b. the patients and owners are delayed at the outpatient clinical consults and unavailable for their scheduled appointment at the MRI and CT. The late arrivals of owners and patients (Section 1.4.7) contribute to the delayed outpatient clinical consults.
    c. the many appointments that turn within short notice into cancellations, commonly occurring at the outpatient clinical consults.
    d. the many appointments that are cancelled by the owners within short notice.

In the period of 2016-2019, the daily demand of MRI and CT slots was 3.2 and 3.9 time slots respectively (4.08 and 4.96 time slots when corrected for the percentage of cancellations). Every day, a total 5 to 7 MRI slots and 7 to 9 CT slots are available at DB. Thus, in addition to the aforementioned causes, it may also be concluded that the MRI, CT and possibly RTC, Nuclear Diagnostics and other DB rooms supply a remnant of treatment slots.

In the coordination to provide the capacity for specific treatments at the right time we observe strong relations between specific treatments. A visit to outpatient clinic neurology is frequently followed up with further diagnosis aided by a MRI scan. This coherence is partially missing in the capacity planning. Moreover, an understanding of how an efficient and effective capacity planning should look like is lacking. A well deliberated approach for an effective capacity planning to deal, for example, with the trade-off between occupancy rates and acceptable waiting times is absent. Also, discipline or room-specific planning methods and heuristics, such as walk-in periods, surgical tempo-tables, block scheduling and the application of case-mixes are absent.

In conclusion, there is no chain-wide coherence in the tactical capacity planning and management. It is not understood how much capacity must be made available and when, by which disciplines, for what reason and in what form. As a result, occupancy rates of rooms are lower than desired, the availability of capacity at the right moments is problematic and the flow of patients is obstructed.

1.4.6 One-Stop-Shop and Shortage of radiologists

The so called principle called One-Stop-Shop strives to provide a day complete diagnosis (and sometimes treatment) for patients. This contributes to the peak workloads experienced at DB after most of the outpatient clinical consults are finished in the morning (8:00-13:00). A shortage of radiologists troubles the in-time assessment of imaging results and reporting of the results.

The true added customer value of the One-Stop-Shop principal is debatable. Some owners experience long waiting times while they might prefer to come back another day or periodically let their pet be admitted to the hospital. Owners from afar may prefer to wait. Without One-Stop-Shop the available capacity may be distributed more evenly throughout the daily opening hours and over the days, e.g. by planning more treatments of DB on currently quiet hours (8:30-11:00).

1.4.7 On-time arrival delays

An estimate of one-third of the owners is delayed for 15 minutes on average during the morning hours (8:30-11:00) for their outpatient clinical consult. According to both the front desk and the department of telephony, the delayed owners are almost always from the same region as the UKG (Utrecht) and the main reason for delays is traffic related. On a daily basis, some owners cancel their appointment as a result of heavy traffic. This is why Paard welcomes most patients after 9:30 in the morning.

Employees at the outpatient clinic admit they consider the many delays the schedules experience on daily basis as a natural part of the working routine. As a result, the delayed outpatient clinics contribute to the poor patient flow and thus contribute to and aggravate the peak workload. Many owners have to wait for their appointments and many patients are treated in a disorderly matter. This requires many ad-hoc tasks to deal with the chaotic process and to keep the patient flow manageable.

1.4.8 The current planning heuristics to schedule appointments are inefficient and have many defects

In Appendix H an in-depth analysis of cancelled appointments that was performed after the problem identification during the problem solving phase can be found. Below, the initial results produced before the problem solving phase are discussed as this was perceived as the main problem. The timing (when appointments are cancelled) and the timeliness (how long in advance appointments are cancelled) of cancellations can be found in Appendix X and Appendix Y, respectively.

The amount of cancellations as a fraction of the total number of treatments is presented in Figure 1.4.2 for each room for the 4 year period of 2016 up to and including 2019. Significant fractions of cancellations are observed at the MRI (25%), CT (20%) and ORs (between 17% and 32%).

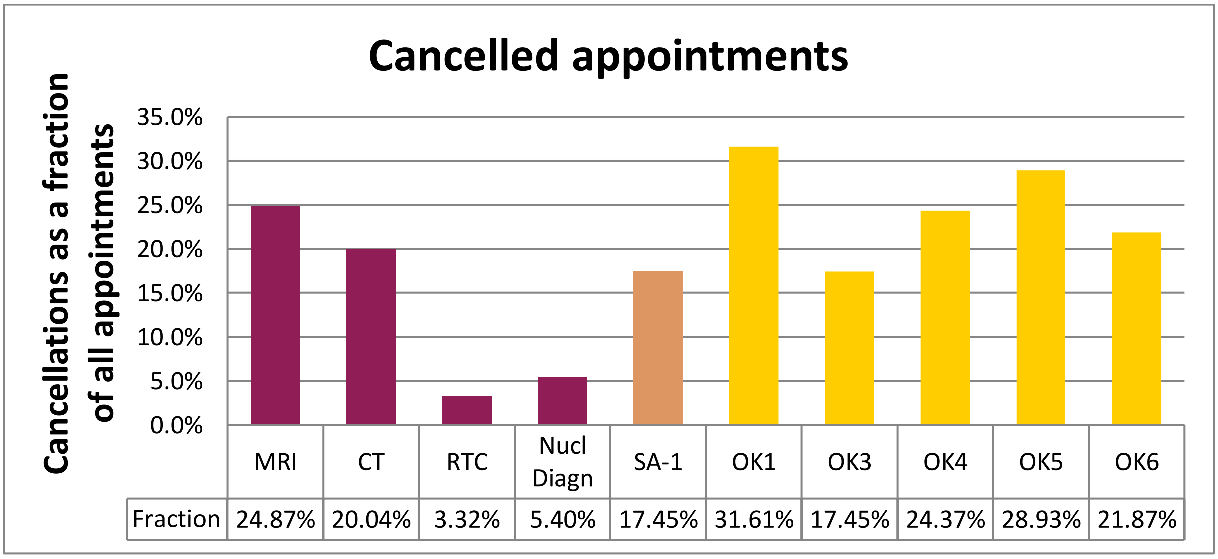

Figure 1.4.2 Cancellations as a fraction of the total number of treatments. N: *19.012 appointments of which 4.366 cancellations*, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

To understand the reasons behind appointment cancellations, Figure 1.4.3 presents the cancellations with identified known reasons as a fraction of the total number of cancellations.

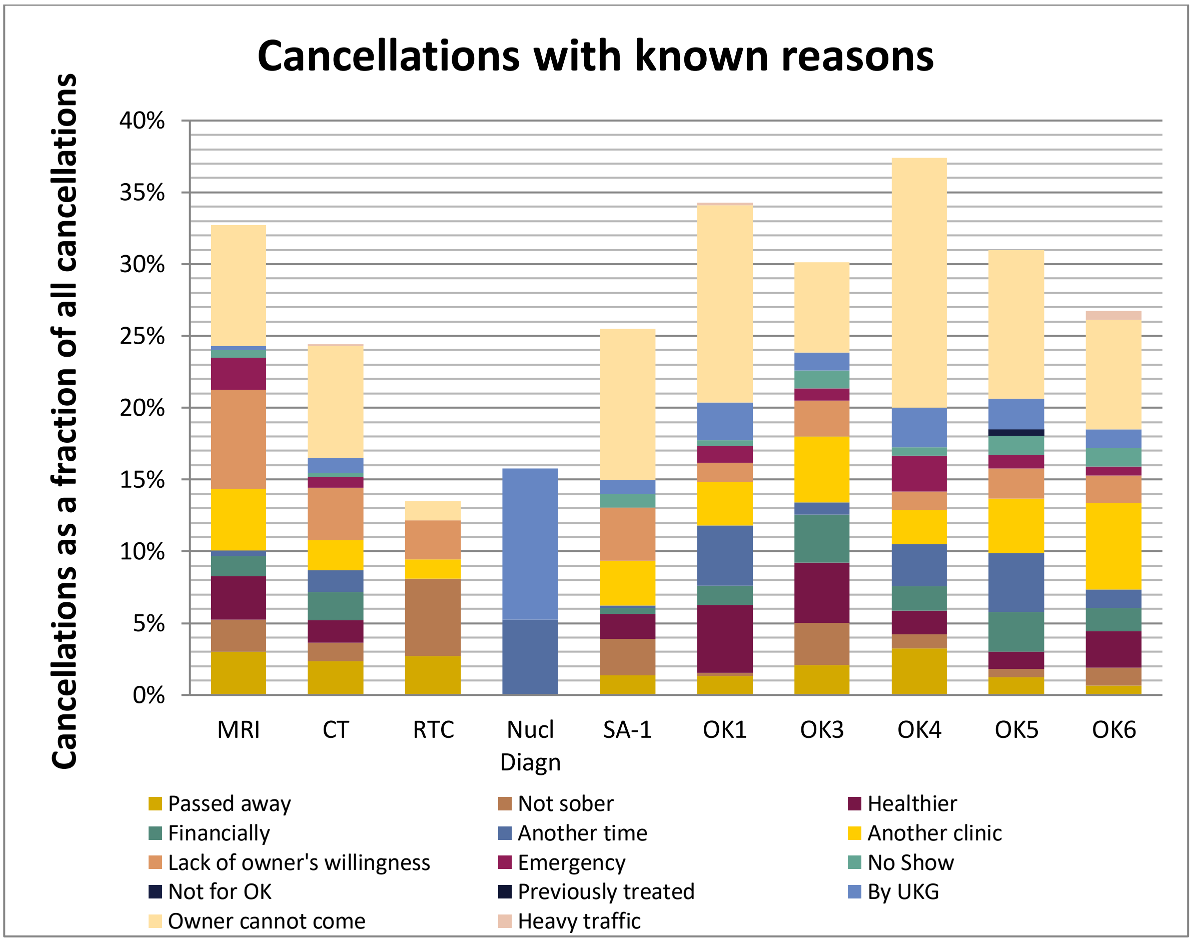

Figure 1.4.3 Cancellations with known reasons as a fraction of the total number of cancellations. N: *4.366 cancellations*, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

The first noteworthy observation is the number of cancellations due to owners' inability to come (see 'Owner cannot come'). This makes up for 5% to 15% of all the cancellations and 1% to 4% of all appointments. In many cases, appointments are scheduled 'with reservation' meaning that if a form of medical operation at DB is expected, an appointment will be scheduled. Additionally, appointments are scheduled as soon as possible (ASAP) while they require a confirmation from the owner which involves time. The owner has to agree on both the appointment time and date, and the estimated treatment costs. Scheduling appointments 'with reservation' and the need of a short-time confirmation are very problematic: many appointments appear to be unnecessary during the outpatient clinic consults and owners regularly cannot agree on the costs or appointment time and date.

The second noteworthy observation is the significant number of cancellations due to 'costs', 'other clinic' and 'lack of owner's willingness'. Many owners do not choose the appointment for financial reasons. However, in most cases such owners visit other clinics since these offer shorter waiting times and costs.

Many cancellations are reported incorrectly and/or the reasons behind the cancellations are missing. On the other hand, many cancellations are supplemented with comments that likely describe the appropriate reason behind the cancellation. Figure 1.4.4 presents the number of cancellations as the fraction of all appointments with known reasons for cancellations and cancellations that reported significant valuable information. For roughly 30% to 40% of the cancellations a known reason could be identified (reasons clearly described in the comment section of the appointments). For roughly 50% of the cancellations, meaningful information was identified and classified. For the remaining cancellations, neither meaningful information nor a known reason could be identified. Remarkable is the number of cancellations at DB through the outpatient clinical consults (see 'Cancelled by Outpatient clinic' in Figure 1.4.4). Frequently the scheduled appointments appear to be unnecessary. For ORs, the number of rescheduled appointments (see 'Moved' in Figure 1.4.4) is eye striking. Commonly, appointments are rescheduled backward or forward in time to fill time slots of other cancelled appointments, at request of the owner or if the urgency increases.

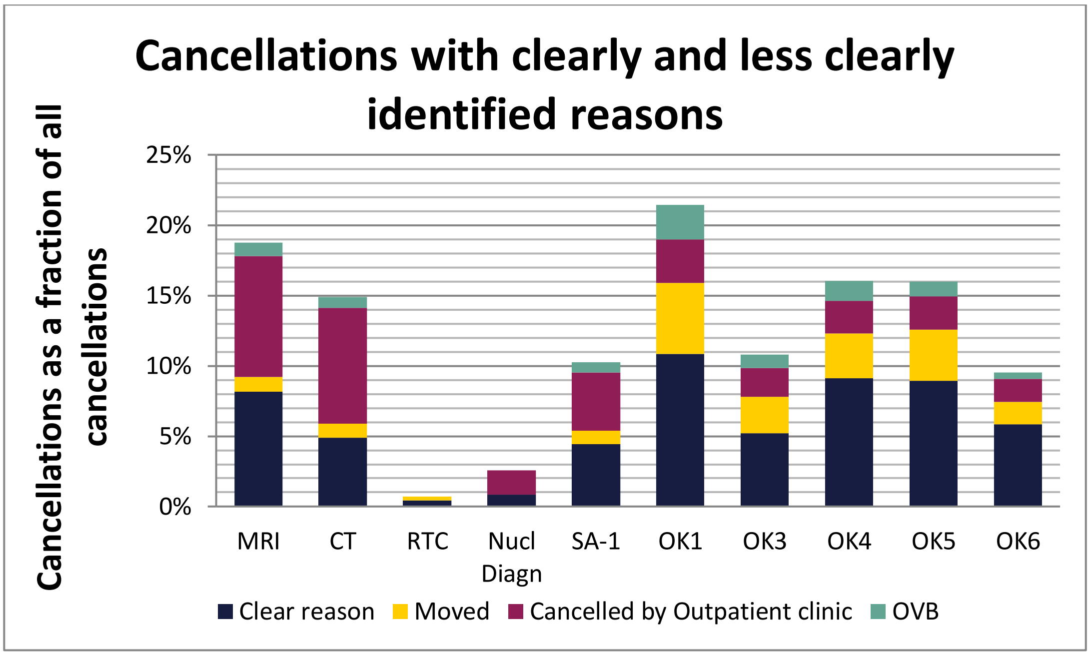

Figure 1.4.4 Cancellations with reported information and reasons as a fraction of the total cancellations. N: *4.366 cancellations*, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

A consequence of scheduling appointments 'with reservation' is the perception of a lack of capacity at DB. Whenever an appointment at DB appears to be necessary during the outpatient clinical consult and it is not scheduled 'with reservation', employees are afraid the patient cannot be treated the same day (to guarantee One-Stop-Shop) or in time. As a result, a vicious circle is entered where appointments are scheduled 'with reservation' that aggravates the perception of a capacity shortage and low capacity availability at DB and thus the need for scheduling 'with reservation'.

There is a re-occurring conflict between CHIR and DB as a result of the many cancellations: CHIR expects a high availability of treatment slots at DB for internal patients while DB prefers to treat external patients over internal patients since their turnout is way higher.

Furthermore, some employees schedule 'with reservation', others do not. Some employees agree a scheduled appointment is fixed and should be completed while other employees will treat patients only if they deem it necessary.

We summarise this root cause by: The lack of unequivocal and efficient appointment planning processes contributes to a more chaotic and difficult to manage patient flow. It the root cause for many appointment cancellations and it contributes to poor occupancy rates. As a result, many interests lies in the potential benefits and disadvantages that come with experimental scenarios such as (partially) walk-in care processes, not scheduling 'with reservation' and letting go of the One-Stop-Shop principle.

1.4.9 Problem cluster

As previously addressed at the beginning of this section, Figure 1.4.5 presents the problem cluster with the above mentioned root causes, secondary problems, observed problems and cause-effect relationships.

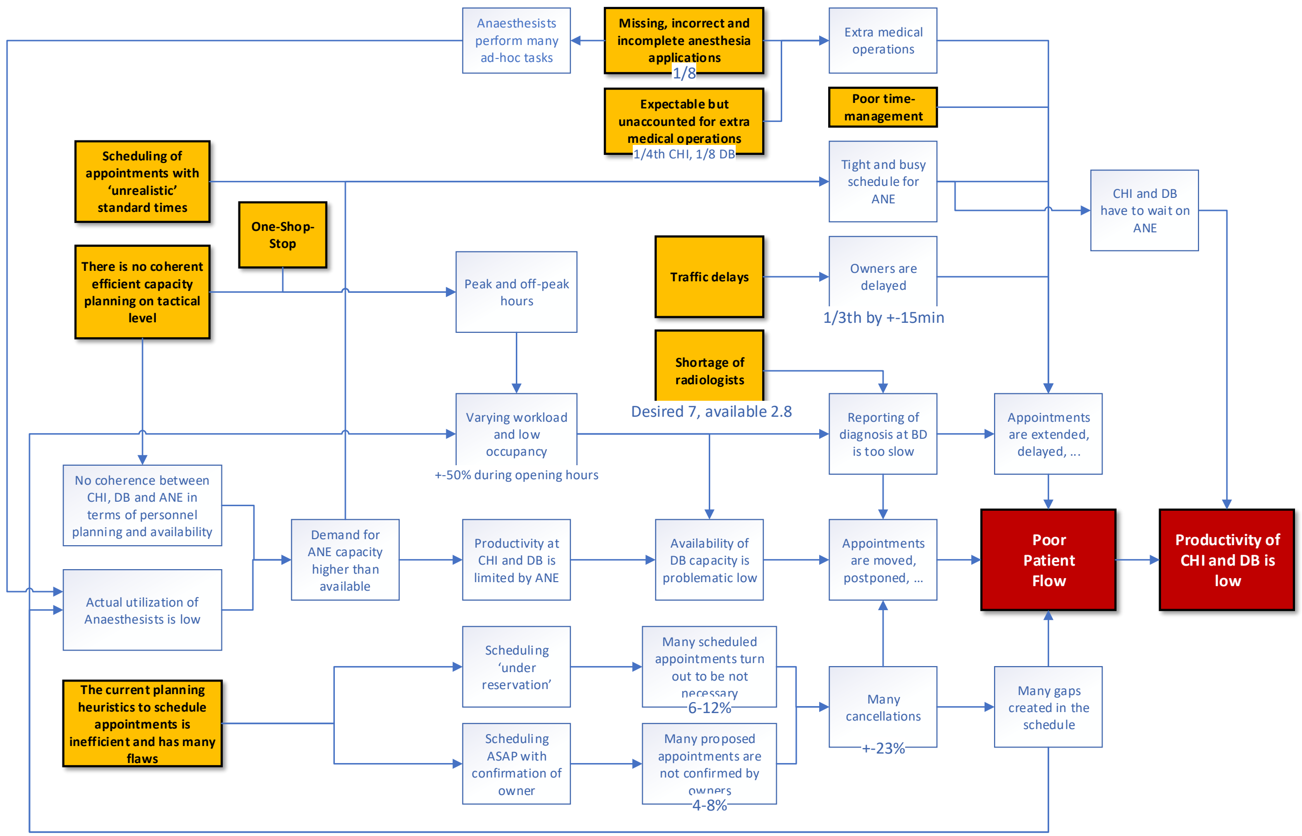

Figure 1.4.5 Problem cluster with the root causes (yellow squares), secondary problems (white squares), observed problems (red squares) and cause-effect relationships (directed arrows). Some elements are supplemented with quantitative information. N: *19.012 appointments of which 4.366 cancellations*, *and qualitative sources e.g. interviews* T: quantitative data *from 1-1-2016 up to and including 31-12-2019, qualitative data from Quartile 1 2020*, Source: *Vetware report 'OK verslagen'*.

1.5 Core problem

With the problem cluster and context discussed in Section 1.4 we will continue to demarcate this study's scope by formulating a core problem.

Most of the observed root causes in Section 1.4 are strongly related to the tactical planning of resources that is concerned with the tactical allocation of resource capacities, both physical and labour wise, and the elective patient appointment planning. In the following we explain how the most significant root causes stand in relation to these two topics (capacity management and patient appointment planning):

- The observed lack of coherence and communication between disciplines' production and personnel schedule is related to the tactical allocation of available resources. Most clinical pathways visit several disciplines and hence connect multiple disciplines and resources into a network. However, disciplines at UKG act as independent entities in this network by allocating resources without taking into consideration their interconnectedness to other disciplines. As a result of this, the workload is unbalanced, the flow of patients is obstructed frequently and there are capacity shortages (both labour and physical wise).
- The aspects of tactical planning of resources that concerns with allocation of the resources at the right time and the right place is inefficient and not well considered. The operational layout at UKG has many flaws. For instance, the outpatient clinical consults in the morning experience many traffic-related delayed appointments. A second example is the RTC room of DB which is operated in the afternoons during peak workload, while appointments for RTC are very plannable in advance and could be scheduled on a quiet daypart. Furthermore, the amount of resources that should be allocated to sufficiently meet the demand is unknown. Production schedules are not based on demand and production numbers, but on labour capacity and employees preferences. The network of disciplines and resources suffers from bullwhip effects as every discipline experiences fluctuations in the resource availability (e.g. congresses) and demand variability (e.g. seasonality, sporadic demand and cancellations). This network also suffers from other variability-related phenomena. UKG does not take into account the re-allocation of resources to deal with these phenomena (short-term inefficiencies) and as a consequence has trouble to maintain high capacity utilisation in combination with high capacity flexibility and availability for the relatively urgent patient group with relatively high expectations (very short waiting times for appointments slots, One-Stop-Shop related expectations and significant authority in clinical pathway-related decision-making). At the moment, UKG realizes this flexibility with providing overcapacity and non-univocal schedules but seeks for other optimization strokes in their capacity management.
- The aspects of tactical planning of resources that concerns with the patient appointment planning processes are observed as inefficient. For instance, the scheduling of appointments with confirmation, with reservation and as-soon-as-possible causes many cancellations and subsequently require many ad-hoc tasks. Additionally, the use of incorrect standard times to schedule appointments and inexperienced planners cause many delays and tight (sometimes infeasible) schedules. As a result, already allocated resources are wasted, the flow of patients is regularly obstructed, the workload is unbalanced and there is an impediment of the productivity of employees.

Root causes such as *poor time-management* and *missing, incorrect and incomplete anaesthesia reports* are either easily solvable on operational level, not as significant as others or are indirectly solved by solving other root causes. For instance, disciplines admit the personnel capacity shortage, which is closely concerned with the tactical planning of resources, contributes to a flawed supervision of specialists in education (SIOs) and interns that is required to guarantee better and more efficient time-management. A second root cause *missing, incorrect and incomplete anaesthesia reports* has a relatively small impact on operational level and could easily be solved with, for instance, an outpatient clinical room dedicated to pre-anaesthesia assessments. A fourth discussed root cause *Shortage of radiologists* may be solved by hiring more radiologists or can be partially solved by solving the most significant root causes that will likely contribute to a more balanced workload. We discussed the use of incorrect standard times of medical operations for the scheduling of appointment. This root cause has been analysed extensively but could not be solved. The topic is too sensitive, as many conflicting parties are involved, and is concerned with great complexity if we would try to solve it. In Appendix AA we present and elaborate on some of the results.

UKG's emphasis lies on improving the patient flow. The obstruction of the patient flow can primarily be observed in the poor occupancy rates and capacity utilisation, the mismatch of demand and supply of resources, long waiting times for appointments, delays and cancellations of appointments, and an unbalanced workloads.

Finally, the core problem that is identified is formulated as:

"The inefficient tactical planning of resources that is concerned with the allocation of resource capacities and patient appointment planning results in poor occupancy rates and capacity utilisation, a mismatch in demand and supply of resources, long waiting times for and delays of appointments and unbalanced workloads, which all contributes to the obstruction of the patient flow."

Successively, the main research question is formulated as:

"How can the patient flow be improved through improvements in the tactical planning of resources?"

1.6 Research Questions and Approach

A set of research questions are developed as a guiding framework for the research and have been grouped to form separate chapters. Figure 1.6.1 at the end of this section provides an outline of the research. The research follows the '*Algemene Bedrijfskundige Probleemaanpak*' as a research methodology [17]. This methodology consist of 7 phases (Problem identification (1), formulation of research problem and approach (2), analysis of the problem and the 'as-is' situation (3), formulation of alternative solutions (4), selection of alternative solutions (5), Implementation (6) and evaluation (7)). Phases 6 and 7 are excluded due to time related constraints.

Chapter 2. Analysis of the 'as-is' situation in terms of management and planning processes.

To begin with, we must gain an understanding of the planning and management processes involved or related to the allocation and utilisation of physical capacity and patient flow. The layout of these processes and their interdependencies are decisive for the patient flow. To cover this topic, the following research questions will be answered:

1. *What is the problem's healthcare setting?*
2. *How are resources capacities allocated on a tactical level?*
3. *How does the current allocation of resource capacities look like?*
4. *What are the patient appointment planning processes and how are they operationalised?*
5. *How does the demand for resource capabilities look like?*
6. *How is the tactical planning of resources evaluated on its performance? What are the performance goals to achieve a 'to-be' situation?*

We provide answers to these research questions by studying the management and planning processes and visualize them with descriptive diagrams, such as flow charts. Simultaneously, data is collected, analysed and the results are interpreted. The chapter is concluded by the discussion of a set of designed KPIs.

Chapter 3. Solution approaches that describe efficient capacity management

Once the 'as-is' situation is analysed and the 'to-be' situation is understood, the next step is to identify and discuss solution approaches that fit the research problem. To aid this, a literature review is conducted. Here, we first identify the characteristics of the problem setting, then discuss how similar problem settings are handled in the literature and select a suitable (modelling) solution. At the end of the chapter, we discuss the types of alternative solutions we consider in the light of tactical allocation of resources. To cover and guide the above, we formulated the following research questions for this chapter:

7. *What solution approaches can be considered and used to solve the research problem?*
8. *What models, heuristics, algorithms and/or methods may be used to guide the design and evaluation of improvements in the tactical allocation of resources and patient appointment planning processes?*

Chapter 4-5. Applying solution approaches to the problem

After the solution approaches are selected, we analyse the 'as-is' situation and adapt and apply the solution approaches accordingly. A set of alternative solutions are formulated, developed and then evaluated on their performance on Key Performance Indicators (KPIs) by a set of experiments. Chapter 4 will discuss the design, structure and use of the model, including a discussion of the collection, preparation, analyses and use of historical data (most of which will be presented in Chapter 2). Chapter 4 will elaborate on design decisions made during the development of the model and discuss the model assumptions and experiments. Chapter 5 will present the experimental results and the interpretation of these results.

9. *Which planning and management processes should be taken into account to evaluate alternative solutions? What (care) processes should be in- and excluded?*
10. *How do the alternative solutions contribute to the performance on KPIs? What are valuable and meaningful solutions?*

Chapter 6. Recommendations on implementation

The final step of the research is the formulation of recommendations on the implementation of chosen alternative solutions. Additionally, we discuss a set of recommendations and alternative solutions that came to our attention but were excluded from the research for different reasons.

11. *What can be recommended to UKG to improve their patient flow by the means of improving their tactical planning of resources?*

The research problem at hand is too extensive to be optimally solved within the available 20 weeks and, more importantly, there is a lack of correct and available data to do so. Also, during the multi-disciplinary meetings it became clear that the 'as-is' situation of UKG's planning and management processes is lacking behind when it is compared to human hospitals. Change is needed, but according to Vintura this must be done at a slow-pace. For these reasons, we only make recommendations on the implementation of alternative solutions and exclude the actual implementation.

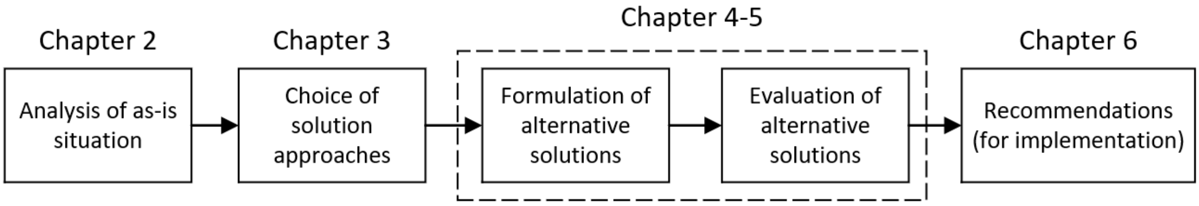

Figure 1.6.1 Outline of the research paper.

1.7 Research design

This is a descriptive case study that has both quantitative and qualitative characteristics. We are trying to understand the current 'as-is' situation of the case and how, according to literature and quantitative statistically significant experiments, alternative solutions may improve the performance on a set of KPIs.

1.8 Research methods and data collection techniques

Table 1.8.1 presents the primary data collection techniques used for each research question and describes if the research questions are qualitative or quantitative from nature, or both.

Research question	Qualitative	Quantitative	Data collection techniques and research methods
1	X	X	Multi-disciplinary meetings, Vintura consult, interviews.
2	X		Multi-disciplinary meetings, Vintura consult, observations, interviews. Processed with flowcharts.
3	X	X	Multi-disciplinary meetings, observations, interviews, Vetware historical data. Processed with tables.

4	X		Multi-disciplinary meetings, Vintura consult, observations, interviews. Processed with flowcharts.
5	X	X	Multi-disciplinary meetings, 4 year period of Vetware historical data.
6	X		Multi-disciplinary meetings, observations, interviews with management and veterinarians, knowledge about common KPIs in healthcare industries.
7	X		Literature research, mentor consult.
8	X		Literature research, mentor consult.
9	X		Result of research questions 1 – 8.
10	X	X	Result of research questions 1 – 9.
11	X	X	Result of research questions 1 – 10.

Table 1.8.1 Primary data collection techniques and methods.

It is important to validate valuable information multiple times before assuming its correctness for several reasons. First of all, we are aware that employees may be biased as a result of tunnel vision and emotions. Therefore some topics are very sensitive and may have many different faces. Thus, we fact-check information by, e.g., consulting several surgeons and performing multiple interviews with different parties. Second, many employees claim that extracted data from Vetware may be incorrect and not trustworthy. The validation of the Vetware data is therefore important and receives additional attention. Third, most employees are specialised and well educated and are tempted to overstep in their field of expertise. We try to keep thinking critical and try to spot false claims.

Considering all of the above, we concluded that the primary sources for information will be our own independent observations on collected qualitative data and the use validated historical data extracted from Vetware.

Chapter 2 Description of the 'as-is' situation

This chapter discusses the 'as-is' situation in terms of management and planning processes, the demand and arrival process of patients and their appointments, and KPIs. Section 2.1 provides an introduction to the healthcare setting and the patient groups, and discusses noteworthy differences and similarities between Paard and GD. Section 2.2 discusses the tactical planning processes, the patient appointment planning process and rules, and operationalization of the planning. An extensive analysis of the production numbers, clinical pathways, appointment cancellations and the patient arrival process (with a discussion of the demand trends, seasonality, variability, on-time arrivals, check-in times and more) can be found in Section 2.3. At last, Section 2.4 proposes a set of KPIs to evaluate the performance in the 'as-is' situation and of alternative solutions.

From this point onwards, the research will focus on physical capacity and exclude labour capacity as from the research scope for time-related reasons. That said, we do take into account the labour capacity at ANE to some extent. We also consider a less obstructed patient flow and well-balanced workload to be positively related to the well-being and productivity of employees. An initial assessment of the labour capacity can be found in Appendix DD.

2.1 Introduction

This section introduces, in chronical order, the healthcare setting, the patient groups and discusses noteworthy differences between Paard and GD. The section provides an answer to research questions 1: *What is the problem's healthcare setting?*

2.1.1 Healthcare setting

The research concerns care processes at the departments: CHIR, DB, ANE, Exotic Animals (In Dutch: Vogels en Bijzondere Dieren (VBD)), Internal Medicines (In Dutch: Interne Geneeskunde (INT)), General Medicines and partially the Emergency department (In Dutch: Afdeling Spoed (SPOED)). Departments may consist of several disciplines or specializations that may share treatment locations and may treat patients from different disciplines or specializations. In Appendix A the full list of disciplines and departments with their identification and selection process can be found. It is advised to the reader to consult this appendix in the case of unclarity or doubt about names and abbreviations of disciplines, departments, appointments and care processes. Departments such as the nursing ward and Ruminants, and relatively small disciplines are excluded or distributed under other departments or disciplines.

In Table 2.1.1, the identified care processes are grouped with their discipline (left column of sub-tables) into departments (header of sub-tables). In the upcoming sub-sections, each department will be discussed in short.

CHIR – 14 Care processes			General Medicines & INT – 16 Care processes		
CHIR_THK	Poli		GEDRAG	Poli	
CHIR_algemeen	Poli		OVERIGEPOLI	Poli	
CHIR_KNO	Poli		VOEDING	Poli	
CHIR_ONCO	Poli		CARDIO	Poli	
CHIR_ORTHO_NEURO	Poli		NEUR	Poli	
CHIR_URO_LEVER	Poli		ONCO	Poli	
CHIR_THK	Surgery	ANE	OOG	Poli	
CHIR_OVERIG	Surgery	ANE	ORTHO	Poli	
CHIR_KNO	Surgery	ANE	SPOED	Poli	
CHIR_ONCO	Surgery	ANE	VPL	Poli	
CHIR_ORTHO_NEURO	Surgery	ANE	ENDO	Poli	
CHIR_URO_LEVER	Surgery	ANE	DERM	Poli	
CHIR_OVE	Surgery	ANE	GAHE	Poli	
CHIR_OOG	Surgery	ANE	HEMA	Poli	
			URO	Poli	
			ALG_INT	Poli	
DB (Radiology) – 10 Care processes			**OTHER – 2 Care processes**		
RAD	Poli		VBD	Poli	
RAD	Nucl_Diagn	ANE	ANE	SA	ANE
RAD	MRI	ANE			
RAD	RTC	ANE			
RAD	CT	ANE			
RAD	X_RAY_GD				
RAD	X_RAY_PD				
RAD	ECHO_GD				
RAD	ECHO_PD				
RAD	FLUOR				

Table 2.1.1 Identified Care processes with the discipline in left column of sub-tables and treatment type in centre column of sub-tables. Most right column in sub-tables states whether the assistance of ANE is a mandatory.

Outpatient clinic (General medicines)

The department of general medicines has 9 disciplines with their own outpatient clinical consult day(s) throughout the week. The disciplines are:

- Behaviour (GEDRAG)
- Nutrition (VOEDING)
- Cardiology (CARDIO)
- Neurology (NEUR)
- Oncology (ONCO)
- Physiology/Orthopaedics (ORTHO)
- Dermatology (DERM)
- Reproduction (VPL)
- Remaining/general (OVERIGEPOLI)

Outpatient clinic (INT)

INT exists of 5 disciplines that operate at 3 shared clinical consult rooms (INT-1, INT-2 and INT-3). Within INT, we have the following disciplines with each their own outpatient clinical consult day(s) throughout the week:

- Endocrinology (ENDO)
- Haematology (HEMA)
- Gastro-hepatology (GAHE)
- Urology (URO)
- General INT (ALG_INT

Exotic animals (VBD)

VBD is a specialised department for exotic animals that perform imaging diagnostics, outpatient clinical consults, surgeries, hospitalizations and manage a day care. They use one calendar for all their appointments and are opened each weekday.

Emergency department (SPOED)

The emergency department is mostly excluded from the research as they operate independent of UKG, where most overlap may be found in the sharing of the agenda for outpatient clinical consults. Emergencies arriving throughout opening hours (8:00-16:30) are treated by UKG on any of the discussed departments. The outpatient clinic for SPOED is opened each weekday at regular opening hours and managed by UKG. Between 16:30 and 8:00, this is managed by *Spoedeisende hulp Gezelschapsdieren Midden-Nederland* (SGMN). We are interested in the SPOED during regular opening hours as the core problem is experienced at those times.

Surgery (CHIR)

CHIR operates 2 to 3 outpatient clinical rooms and 2 to 4 ORs every weekday. There is a total of 6 ORs of which 5 are suitable for surgical operations. CHIR is divided into the following disciplines:

- General surgery and oncology (*CHIR_ACO*)
- Orthopaedics and neurosurgery (*CHIR_ORTHO/NEURO*)
- Otorhinolaryngology (*CHIR_KNO*) including Head-, Neck- and Thorax surgery
- General surgery (*CHIR_algemeen_poli* for clinical consults and *CHIR_OVERIG* for surgeries)
- Oncology (*CHIR_ONCO*)
- Urology (*CHIR_URO_LEVER*)
- Dentistry (*CHIR_THK*)
- Ovariectomy (*CHIR_OVE*)
- Eye surgery (*CHIR_OOG*)

Radiology (DB)

There is a wide range of care processes available at DB. They both treat patients of Paard and GD, roughly 20% and 80% respectively. However, the treatment duration of Paard is significant longer compared to GD. Physically there is a distinction between general diagnostics, nuclear diagnostics (*Nucl_Diagn*) and Radio- and Chemotherapy (*RTC*).

General diagnostics consist of the following treatments types with their care processes (provided between the brackets in *italic font*):

- Echography (*ECHO_GD* and *ECHO_PD*), 3 rooms (2 for GD, 1 for Paard)
- X-Ray diagnostics (*X_RAY_GD* and *X_RAY_PD*), 2 rooms (1 for GD, 1 for Paard)
- Fluoroscopy (*FLUOR*), 1 room
- Computed Tomography (*CT*), 1 room
- Magnetic Resonance Imaging (*MRI*), 1 room
- Angiography (*ANGIO*), 1 room

Nucl_Diagn is used for bone and thyroid gland scans. *RTC* is located at the so called 'bunker' and used to treat tumours with radiation and drug treatments. DB has their own outpatient clinical consult. During irregular shifts (weekends and nights), mainly the *ECHO* is operative.

Anaesthesiology (ANE)

ANE takes part in almost all treatments at DB and surgeries at CHIR. Similar to DB, ANE shares many activities with other departments and is involved in treating roughly 80% of the patients at some point in their clinical pathways. Therefore, the availability of both ANE and DB is crucial for an unobstructed patient flow. ANE and DB are part of the Department of Integrated Disciplines (ID).

Roughly 55% of ANE's labour capacity is assigned to surgeries at CHIR, roughly 40% is assigned to DB and 5% is assigned to Service Anaesthesia (SA). The distribution of ANE's labour capacity during regular shifts is visualized in Figure 2.1.1.

At DB, the *CT, MRI, ANGIO* and *RTC* are always staffed by anaesthetists. For *Nucl_Diagn*, most sedations and anaesthesia are performed by the executive veterinarian. Furthermore, Anaesthetists are frequently requested to assist treatments at the *ECHO_GD* if a patient is not cooperating. Whether a patient is expected to cooperate or not, is made up from the patient record or from the outpatient clinical consult beforehand. Sometimes, patients are identified as non-cooperative on-site.

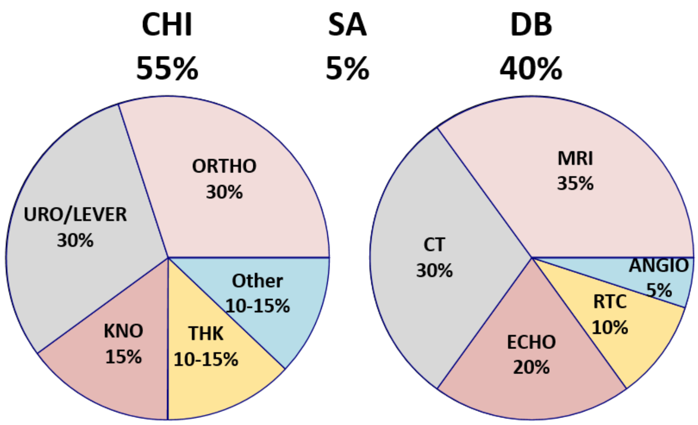

Figure 2.1.1 Estimated distribution of ANE's available labour capacity.

At *SA*, ANE assists other disciplines that normally require no staffing of an anaesthetist. This concerns mostly short sedations and anaesthesia's for *ECHO*, castrations and emergencies. ANE also staffs irregular shifts (weekends and nights).

2.1.2 Patient groups

Three main patient types have been identified:

1. *Emergency patients* that visit for appointments with extremely high urgency.
2. *Elective patients* that are plannable and will close to always visit for an outpatient clinical consult as their first appointment.
3. *External patients* that are directed through specialists or external veterinarians.

Additionally, patients are classified into New Patients (NP) appointments if it is their first visit and Control Patients (CP) appointments if they revisit the clinic. This classification is used in different ways. For instance, some employees use NP to address patients starting a new clinical pathway, while may use NP only for newly registered patients. We use both interpretations to the identify the start of new clinical pathways. In general, NP appointments and CP appointments have specific characteristics. For instance, NP appointments at specific care processes tend be delayed more often for their appointments (see Appendix L). Additionally, percentage of cancellations of NP and CP appointments are different (see Appendix H) and so are their appointment durations (see Appendix O).

2.1.3 Paard versus GD

The overlap between Paard and GD is covered by the so called *Integrated Disciplines* that primary consists of DB and ANE. The focus of the research is GD since Paard makes up for only roughly 20% of DB's patients. GD's planning and management processes are completely different and far more complex and problematic than that of Paard.

The planning and management processes can be summarized for Paard as follows: the planning is completely centralized, including the staffing of personnel. Appointments are scheduled in clear consultation with owners and employees. Billing of costs is based on the actual treatment times in minutes, instead of standard times at GD.

Paard and GD differ in many ways culturally speaking. In view of the research it is worth mentioning the following differences between Paard and GD:

1. GD exceeds Paard by far considering the complexity of planning and management processes. Over the years, Paard's planning and management processes evolved into a simplistic centralized graspable system through trial and error. On the contrast, at GD the processes are still decentralized and are organised into a complex structure.
2. Employability of interns at Paard is broad as a result of frequent rotations between disciplines. This employability is introduced for more capacity flexibility. Something GD may exploit more. Currently at ANE, one specialist and two SIO's are employable at both clinics. This employability is tried to be broadened in the future, both at ANE and at other disciplines.
3. There are many cultural differences. A feeling of solidarity and joint responsibility is present at Paard. Employees complement each other on mistakes and incorrect behaviour. Finding a substitute for a shift is easy and disciplines show respect towards each other. GD shows the same strengths, but in a lesser way. Regularly, conflicts occur between various disciplines and there are less respectful situations where one party may be overruled by another or there is no sense of unambiguity about who is responsible for what.
4. For ANE there exist 18 different medical operations at Paard and 582 different medical operations at GD. A treatment at Paard is scheduled in consultation with the owner and executive personnel. The patient appointment planning at GD is based on specifically designed standard times where communication between disciplines is more deficient. Commonly, parties have the authority over decision-making processes of which they are not home to.
5. Disciplines at GD have a strong sense of gardening their freedom and less feeling of responsibility for their actions if it affects other disciplines. One example is the transparency of employability at Paard that is absent at GD.

2.2 Planning processes

In the upcoming sub-sections the planning processes involved in the allocation of resources (both physically and labour-wise) are comprehensively described and supplemented by tables and flowcharts. Sub-section 2.2.1 discusses the planning processes to develop timetables and the final production schedule, followed by Sub-section 2.2.2 that discusses the 'as-is' production schedule. These sub-sections answer the research questions 3: *How are resources capacities allocated on a tactical level?* And 4: *How does the current allocation of resource capacities look like?*

Sub-section 2.2.3 discusses patient appointment planning processes and give an answer to research question 5: *What are the patient appointment planning processes and how are they operationalised?*

2.2.1 Allocation of capacity on a tactical level

The flowchart in Figure 2.2.1 at the end of this section provides a simplified visual representation of the planning processes up to and including the development of timetables. A legend for the flowchart can be found in Appendix B. In the following sub-sections we elaborate on the flowchart and the planning processes.

General tactical planning

The stochasticity associated with the management and planning of clinical work is far greater than with research and (non-clinic related) educational activities. Nevertheless, UKG has decided and is somewhat forced by the university to prioritize the planning of all education and research activities over clinical work. This is strongly related to the idea that UKG's purpose of existence is dedicated to facilitate education and research, not primarily to deliver healthcare to patients. Therefore, the commencement of capacity management on a tactical level starts with Education. A significant part of education is integrated in clinical work (e.g. close to all outpatient clinical consults), while the remaining part is much more plannable (e.g. lectures and practical sessions).

Tens of different timetables at different time intervals and frequencies are developed and retrieved each year. Most of them are either supplied to and integrated by, or developed by the planning department of Education (OWP).

The first step in the development of timetables related to clinical work, education and research starts with the request and retrieval of employability at disciplines for over 8 months in advance (this is concerned with research periods, standard free days, vacation periods, congresses, and more). This is done twice a year, since education is planned twice a year. Disciplines establish the employability within their discipline by coming up with a realistic and fair distribution of, e.g., standard free days and vacation periods. During the retrieval, OWP will consider the educational timetables, student timetables and the production schedule of CHIR to develop a Master roster and subsequently a Bachelor schedule.

After the retrieval of employability and the design of the master and bachelor schedule, a Concept schedule is developed by taking into account the employability, emergency rosters, SIO program schedules and more. This takes weeks to months to develop.

When the Concept schedule is developed, it is proposed to disciplines (including ANE and DB). If the roster is infeasible, problematic or long-lasting absence emerged among employees in the meantime, a feedback-loop is present to make alterations to the Concept roster. Eventually, a timetable with clinical shifts, education and research time for students, teachers and veterinarians is delivered to each discipline. In contrast to Paard, employees are only partially assigned by OWP. Actually staffing, in particular clinical shifts, is primarily coordinated by the disciplines themselves.

Surgery (CHIR)

CHIR is well integrated within the centralized planning process. The establishment of the employability is well coordinated and results in a fair distribution according to two interviewed surgeons. After CHIR receives their timetables, OWP will staff the clinical shifts every 2 to 3 months. Alteration to the timetable will take place, in consultation with one of the surgeons, if this is deemed necessary. Frequently, SIOs and specialists who staff the same room are split to staff more rooms. Sometimes, rooms are closed in advance if no qualified staff member is available.

A set of planning rules are in place to guide the staffing of timetables. The primary rules are:

1. Outpatient clinic AKO must be opened every day.
2. OK2 is not for surgeries.
3. THK is always planned on OK6.
4. ORs may be interchanged if necessary (e.g. if an OR is too dirty).
5. The operation of ORs and outpatient clinics must follow the production schedule.
6. Rooms may be closed if there is not sufficient demand or qualified staff available.
7. Part of the daily but sometimes only weekly routine is the discussion of patients between 8:00-8:30.
8. SIO's cannot always independently operate always. Complex surgeries require the assistance of a specialist.
9. Some owners prefer the same surgeon for the outpatient clinical consult as the surgery. Some surgeons show the same preference. This is communicated between Case Managers, owners and surgeons.
10. Qualifications of SIO's, specialists and interns differ and must be taken into account in the staffing of rooms. For instance, some interns are qualified to perform outpatient clinical consults with the absence of an SIO or specialist for supervision, while others may not.

The production schedule is a weekly routine that determines which rooms will be opened for how long and on which weekdays. The production schedule is adjusted to facilitate educational programs and meet the 'perceived customers demand and employees preferences. According to OWP and surgeons, changes to the production schedule only occur at the start of the development of a new education rosters. This is contrast to the many alterations that can be noted in the agenda in the past few years and even months.

ORs follow no specific planning structure (i.e. a slot planning) as surgeries are variable in length and the availability of ANE and patients have to be considered in the planning of appointments. For surgeries at CHIR there is regularly close contact between the surgeon and owner. Therefore, deviations from the standard opening times or production schedule happens frequently at some disciplines. On the contrast to ORs, The scheduling of outpatient clinical consults is guided by timeslots. The duration of time slots is dependent on the discipline and type of patient.

Radiology (DB)

In contrast to CHIR, DB's employability is not requested and retrieved by and well communicated with OWP. Fortunately, education at DB is barely involved in the clinical work that is performed. The staffing of rooms is completely coordinated by DB, including the staffing of educational activities.

A set of planning rules are in place to guide the staffing of timetables. The primary rules are:

1. RTC is operated every day for treatments programs of tumours, unless there are no patients.
2. ECHO is operated every day and must be available during irregular shifts too.
3. MRI and CT are operated every day, but suffer from ANE shortages and tend to be (partially) closed if the situation forces to do so.
4. Assessments of images by SIOs require extra evaluation of a specialist (radiologist).
5. Qualifications of SIO's, specialists and interns differ and must be taken into account in the staffing of clinical shifts.

The staffing of clinical work is performed in a similar way to CHIR, however DB takes full responsibility for it and does not communicate with OWP. As a consequence, the employability is one big blur for OWP who cannot take this into account in the planning of education.

Comparable to CHIR, the production schedule describes a weekly routine of which rooms to open when. Specific rooms are important for research purposes, like Nuclear Diagnostics and RTC. Most of the research is easy to plan and scheduled around clinical work. DB's rooms follow a flexible planning with time slots. DB strives to operate strictly within the regular opening hours (8:00-16:30).

Anaesthesiology (ANE)

Comparable to DB, employability is not requested and retrieved by OWP but completely decentralized. OWP delivers a timetable with (partially staffed) educational moments. The employability at ANE is established in reasonable consultation between OBP and WP employees where the staffing of weekdays is equally distributed. The current employability has little to no coherence with the production schedules of CHIR and DB. At most days a total of 7 rooms must be staffed: 3 to 4 ORs and 3 to 4 DB rooms, with the addition of SA.

The staffing of a week is done roughly 5 weeks in advance. The primary rules are:

1. First all educational moments must be staffed.
2. Then the 'Anesthesist Van Dienst' (AvD) who is responsible for the supervision over and primary contact for colleagues is scheduled. This is, preferable, a specialist. The AvD is not scheduled on a room.
3. After that the rooms that are operated are staffed with the remaining available staff.
4. In case of a staff shortage, DB rooms or ORs are (partially) closed or extra staff is arranged for the day.
5. Meanwhile, one staffed employee is appointed as 'prep'. The anaesthetist is responsibility for the operationalization of the schedule and the communication between disciplines and colleagues.

Remaining departments

Most of the outpatient clinic (care processes at INT and General Medicines) are planned by OWP in a similar way to CHIR. Department VBD manage their own planning similar to ANE.

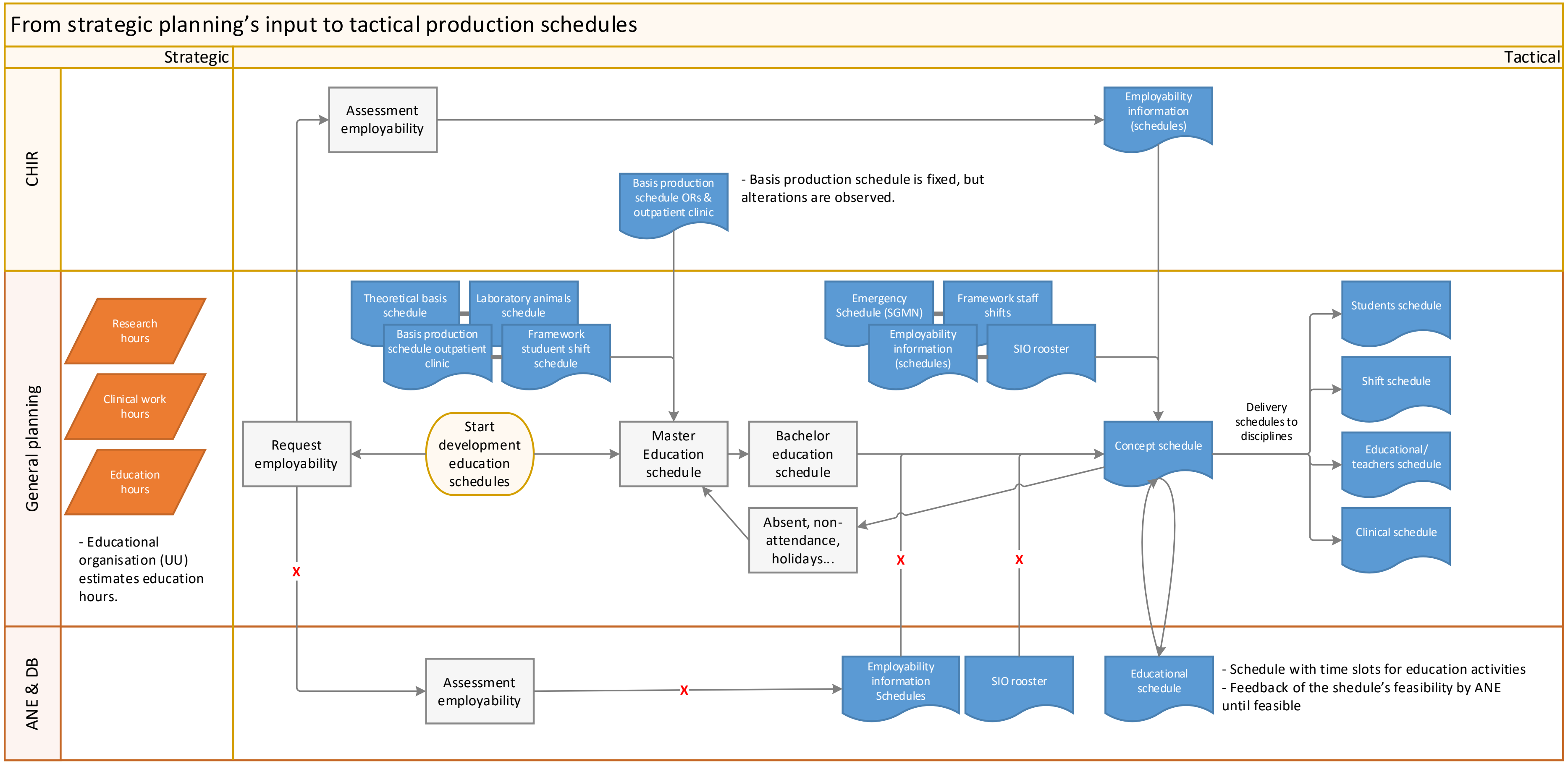

Figure 2.2.1 Flowchart describing the general planning processes up to and including the development of timetables.

Summary

The previous sub-sections answered research questions 3 : *How are resources capacities allocated on a tactical level?* And 4: *How does the current allocation of resource capacities look like?* by elaborating on the processes and developing a flowchart (Figure 2.2.1).

From the analysis we conclude that the production schedule is mostly based on non-stochastic plannable educational activities, the perceived capacity demand by employees and the preferences of employees of when to supply capacity (e.g. their preference for specific free weekdays, when to start or end a workday, or working two days in a row). From a demand-driven perspective, this is less than optimal. To illustrate this, take outpatient clinical consult *THK_Poli* that is opened two days in a row (Wednesday and Thursday). If a patient arrives on a Thursday afternoon, it may end up waiting a full week for their outpatient clinical consult. More deficiencies can be found in the production schedule, e.g. when we look into the excessive slots supplied at some of DB's care processes (see Appendix AA, section *No coherent efficient planning on tactical level*).

For CHIR and most other departments, the main outline of the planning process at OWP are followed. However, departments DB, VBD and ANE have a more decentralized planning for aspects such as the staffing of personnel, the communication and retrieval of employees employability for upcoming periods, and establishment of a production schedule. This reduces the transparency of, for example, the employability for management and planners, as well as it introduces difficulties for financial and production analysis. This becomes especially problematic for the planning of patients and communication between departments in the case when employees decide to close their care process or to be absent on a short notice without consulting and informing others.

We conclude that improvements and hence changes to the process structure visualised in the flowchart (Figure 2.2.1 will require much effort since the process structure is very complex and involves several third parties (e.g. *Spoedkliniek voor Gezelschapsdieren Midden-Nederland* (SGMN) and the *University of Utrecht*). Vintura's project is occupied with organisational changes to this structure as well as centralising and standardising the processes.

We also conclude that changing the production schedule to a more demand-driven schedule may substantially improve the hospital's overall performance while the changes require less effort. We find frequent changes to the production schedule and consulted many employees about the possibilities to change and adjust opening times.

2.2.2 'As-is' Production schedule

As of the end of 2019, the 'as-is' production schedule can be found in Table 2.2.1 for all weekdays (excluding weekend days). A care process may have one or more service stations (rooms) opened at the same day and can be restricted a limited number of available slots (valued at '999' in the table if not applicable for the care process). The total opening, break and effective opening time (total break time subtracted from the total opening time) in hours is reported in the last three columns respectively. In Vetware's schedules we observe many urgent appointments at the care processes *OOG_Poli* and *ONCO_Poli* scheduled outside the regular opening times. Therefore, we added representative small time windows (coloured red in Table 2.2.1) that facilitate the treatment of these appointments and prevents the accumulation of appointments over time.

Table 2.2.1 'as-is' production schedule of all care processes (left coloured column) with the number of service stations, opening and closing time, number of slots per weekday and total (effective) opening time and break times per week. Red coloured information is added in addition to regular opening hours to treat relatively urgent appointments and prevent accumulation of appointments over time. N: *n/a*, T: *2019, Q4,* Source: *Vetware*

			Monday				Tuesday				Wednesday				Thursday				Friday						
			Stations	Opened	Closed	Slots	Stations	Opened	Closed	Slots	Stations	Opened	Closed	Slots	Stations	Opened	Closed	Slots	Stations	Opened	Closed	Slots	Opening time (Hours)	Break time (Hours)	Effective opening time (Hours)
CHIR	CHIR_THK	Poli									1	9:00	9:30	2	1	8:15	9:15	4					1.5	0.0	1.5
	CHIR_algemeen	Poli	2	9:00	14:25	6	2	9:00	14:25	6					2	9:00	14:25	6	1	9:00	14:25	8	37.9	12.5	25.4
	CHIR_KNO	Poli													1	9:00	12:00	3	1	9:00	12:00	3	6.0	0.0	6.0
	CHIR_ONCO	Poli									2	9:00	12:00	3									6.0	0.3	5.8
	CHIR_ORTHO_NEURO	Poli					1	9:00	14:30	8	2	9:00	12:00	3					2	9:00	14:30	8	22.5	5.3	17.3
	CHIR_URO_LEVER	Poli	1	9:00	11:45	3																	2.8	0.0	2.8
	CHIR_THK	Surgery									1	8:00	12:30	999	1	8:00	16:30	999					13.0	0.0	13.0
	CHIR_OVERIG	Surgery	2	9:00	16:30		1	9:00	16:30	999	1	8:30	16:30	999	1	8:30	16:30	999	2	8:30	16:30	999	54.5	0.0	54.5
	CHIR_KNO	Surgery					1	8:30	16:30	999	1	8:30	16:30	999									16.0	0.0	16.0
	CHIR_ONCO	Surgery													1	8:30	16:30	999					8.0	0.0	8.0
	CHIR_ORTHO_NEURO	Surgery	2	9:00	16:30	999	2	9:00	16:30	999					2	9:00	16:30	999	2	9:00	16:30	999	60.0	0.0	60.0
	CHIR_URO_LEVER	Surgery									1	8:30	16:30	999									8.0	0.0	8.0
	CHIR_OVE	Surgery	1	9:00	16:30	999																	7.5	0.0	7.5
	CHIR_OOG	Surgery									1	8:30	16:30	999					1	8:30	16:30	999	16.0	0.0	16.0
General Medicines & INT	GEDRAG	Poli					1	8:15	14:00	3													5.8	0.0	5.8
	OVERIGEPOLI	Poli	1	9:00	16:30	999	1	9:00	16:30	999	1	9:00	16:30	999	1	9:00	16:30	999	1	9:00	16:30	999	37.5	0.0	37.5
	VOEDING	Poli	1	8:00	13:00	999																	5.0	0.0	5.0
	CARDIO	Poli	1	8:15	14:15	5					1	8:00	13:00	5					1	8:15	14:15	4	17.0	0.0	17.0
	NEUR	Poli	1	8:30	15:00	8	1	8:30	15:00	8					1	8:30	15:00	8	1	8:30	15:00	8	26.0	6.0	20.0
	ONCO	Poli					1	8:30	12:00	7	1	9:00	10:30	4	1	8:15	12:00	7	1	9:00	10:30	4	10.3	0.0	10.3
	OOG	Poli	2	8:15	12:30	4	1	9:00	10:30	2	1	9:00	10:30	2	2	8:15	12:30	4	1	9:00	10:30	2	21.5	0.0	21.5
	ORTHO	Poli	1	9:10	16:30	8					1	14:00	18:30	5									11.8	0.5	11.3
	SPOED	Poli	2	8:00	16:30	999	2	8:00	16:30	999	2	8:00	16:30	999	2	8:00	16:30	999	2	8:00	16:30	999	85.0	0.0	85.0
	VPL	Poli	1	8:00	12:00	4					1	8:00	12:00	4					1	8:00	12:30	4	12.5	0.0	12.5
	ENDO	Poli	1	8:45	11:30	5									1	8:00	11:30	5					6.3	0.0	6.3
	DERM	Poli					1	8:30	12:30	4					2	8:00	12:30	4	2	8:00	12:30	4	22.0	2.0	20.0
	GAHE	Poli									1	8:30	10:45	3					1	8:30	11:30	5	5.3	0.0	5.3
	HEMA	Poli					1	8:30	11:30	6	1	8:30	11:30	6									6.0	0.8	5.3
	URO	Poli					1	8:30	12:00	6					1	8:30	12:00	6					7.0	1.0	6.0
	ALG_INT	Poli	1	8:45	12:00	6																	3.3	0.3	3.0
VBD	VBD	Poli	1	8:45	16:30	6	1	8:45	16:30	6	1	8:45	16:30	6	1	8:45	16:30	6	1	8:45	16:30	6	38.8	0.0	38.8
ANE		SA	1	8:00	16:30	999	1	8:00	16:30	999	1	8:00	16:30	999	1	8:00	16:30	999	1	8:00	16:30	999	42.5	0.0	42.5
DB	RAD	Poli	1	13:30	16:00	999	1	13:30	16:00	999	1	13:30	16:00	999	1	13:30	16:00	999	1	13:30	16:00	999	12.5	0.0	12.5
		Nucl_Diagn	1	8:00	16:00	999	1	8:00	16:00	999	1	8:00	16:00	999	1	8:00	16:00	999	1	8:00	16:00	999	40.0	5.3	34.8
		MRI	1	8:30	16:30	7	1	8:30	16:30	7	1	8:30	16:30	7	1	8:30	16:30	7	1	8:30	16:30	7	40.0	7.5	32.5
		RTC	1	13:30	16:30	999	1	13:30	16:30	999	1	13:30	16:30	999	1	13:30	16:30	999	1	13:30	16:30	999	15.0	7.5	7.5
		CT	1	8:30	16:30	9	1	8:30	16:30	9	1	8:30	16:30	9	1	8:30	16:30	9	1	8:30	16:30	9	40.0	7.5	32.5
		ECHO_PD	1	9:00	16:30	13	1	9:00	16:30	13	1	9:00	16:30	13	1	9:00	16:30	13	1	9:00	16:30	13	37.5	7.5	30.0
		ECHO_GD	1	9:00	16:30	13	1	9:00	16:30	13	1	9:00	16:30	13	1	9:00	16:30	13	1	9:00	16:30	13	37.5	7.5	30.0
		X_RAY_PD	1	8:00	16:30	15	1	8:00	16:30	15	1	8:00	16:30	15	1	8:00	16:30	15	1	8:00	16:30	15	42.5	7.5	35.0
		X_RAY_GD	1	8:30	16:30	28	1	8:30	16:30	28	1	8:30	16:30	28	1	8:30	16:30	28	1	8:30	16:30	28	40.0	7.5	32.5
		FLUOR	1	8:00	16:30	5	1	8:00	16:30	5	1	8:00	16:30	5	1	8:00	16:30	5	1	8:00	16:30	5	42.5	7.5	35.0

2.2.3 Patient Appointment Planning

Handling of Emergencies

Owners will have to visit their own veterinarian first for emergencies. External veterinarians may use the emergency service at UKG in case they cannot treat the patient. This ensures that UKG provides as much second-line care as possible, and less first-line. Most emergencies are registered at a separate front desk specifically designed for emergencies. There, the cases are communicated with the necessary disciplines and scheduled. Emergencies without a referral and outside regular opening hours in need of acute care are handled by *Spoedkliniek voor Gezelschapsdieren Midden-Nederland* (SGMN). They manage their own planning, including the planning of labour and physical capacity.

The occurrences of emergencies is limitedly taken into consideration in the development and operationalisation of the tactical planning. Disciplines try to maintain a high availability of physical and labour capacity to handle emergencies quick enough, but this is based on merely habits and gut feeling. Commonly, one of the specialists at CHIR and one at ANE (normally the AvD) are 'not allowed' to be occupied by one treatment for too long or be incapacitated by a treatment.

Outpatient clinical consults

Most clinical pathways will start with an outpatient clinical consult. The outpatient clinical consults arrive at the **front desk or telephony** and are scheduled as soon as possible. Almost all care processes of the outpatient clinic follow strict time slots. The duration of time slots is dependent on the outpatient clinic and whether the appointment is CP or NP. In most cases, small breaks of 5, 10 or 15 minutes between consults are scheduled to deal with delays or spend extra time for educational activities. We find many inconsistencies in the length of breaks as each discipline has the freedom on how to structure their daily schedule and their own reasons for the length. Commonly, longer breaks occur after NP appointments and smaller after CP appointments. Some disciplines have specific designated slots for NP or CP appointments. In particular in the afternoon, we find time windows for only CP appointments. Nevertheless, we find many days at which disciplines deviate from these designated slots.

Surgery (CHIR)

Figure 2.2.2 visualizes the core of CHIR's patient appointment planning process through a flowchart. A legend for the flowchart's elements can be found in Appendix B.

A patient that passes through a clinical pathway that includes a surgical operation will always, with only a few exceptions, visit the UKG more than once. An outpatient clinical consult is compulsory and always schedules for patients if they come into contact for a surgical operation, irrespective of the patient type (internal/external). If there is a need for diagnostics at DB or merely a suspicion for one, it is scheduled in combination with the outpatient clinical consult. This might be the case when the externally retrieved imaging results are insufficient or they are simply lacking. Based on the outpatient clinical consult (and imaging results), the need and urgency for a surgical operation is reviewed. Appointments are scheduled as soon as possible, at the first available date that facilitates it, unless the owner prefers otherwise.

There two main ways to register and schedule patient for a surgical operation. One way is through **telephone or at the front desk** when the concerned employee suspects the need for a surgery. In this case, appointment planning process will be forwarded to a Case Manager (CM) of CHIR. The CM will schedule an outpatient clinical consult at the fitting specialization and, if necessary, an appointment at DB. In case of a consult and treatment at DB, they will both be scheduled on the same day for the sake of One-Stop-Shop.

Sometimes, employees at the front desk or telephony will schedule an outpatient clinical consult for the reason that the appointment can directly be confirmed by the owner or the employee is able to make a good estimation of the expected clinical pathway. The CM of CHIR will then, if necessary, schedule the additional DB treatment on the same day of the already scheduled consult. It may occur that there are no treatment slots available at DB. Consequently, a new date is selected, the consult is cancelled and moved, and a new appointment time and date with cost estimation is proposed to and communicated with the owner.

The second main way to register and schedule a patient for a surgical operation is **through direct contact with external veterinarians or known patients**. Many surgeons are contacted by external veterinarians or known patients and communicate and schedule the patients by involving a CM. Patients are still have to first visit for an outpatient clinical consult and, if necessary, a treatment at DB, the CM will schedule the appointments in the same way as discussed before.

In special occasions, a patient's diagnosis is so extensive a surgeon is willing to immediately proceed to a surgical operation and skip the outpatient clinical consult. This is especially the case for patients from afar (e.g. from abroad) who value a quick accessible care. For such patients, the need of a surgical operation is most likely certain as well as the diagnosis.

For elective patients, a confirmation on a cost estimation and appointment time is send to the owner. Simultaneously, the appointments are scheduled in Vetware and commented by 'eig. moet nog bevestigen' (owner must yet confirm). If an owner confirms the appointment(s), this comment is changed to 'eig heeft bevestigd' (owner has confirmed). After the owner visited UKG and the diagnosis is complete, the same procedure is followed to schedule an appointment for a surgical operation (if necessary). If the owner cannot confirm the appointment time, the appointments are removed from Vetware and a appointment time is proposed.

Specialization THK is responsible for their own patient registrations. For each patient, a two hour time slot is reserved on OK6. On the same day, a consult at the outpatient clinic will take place to determine whether a surgery is necessary. In some cases, the reserved 2 hours is not enough and the patient cannot be treated the same day.

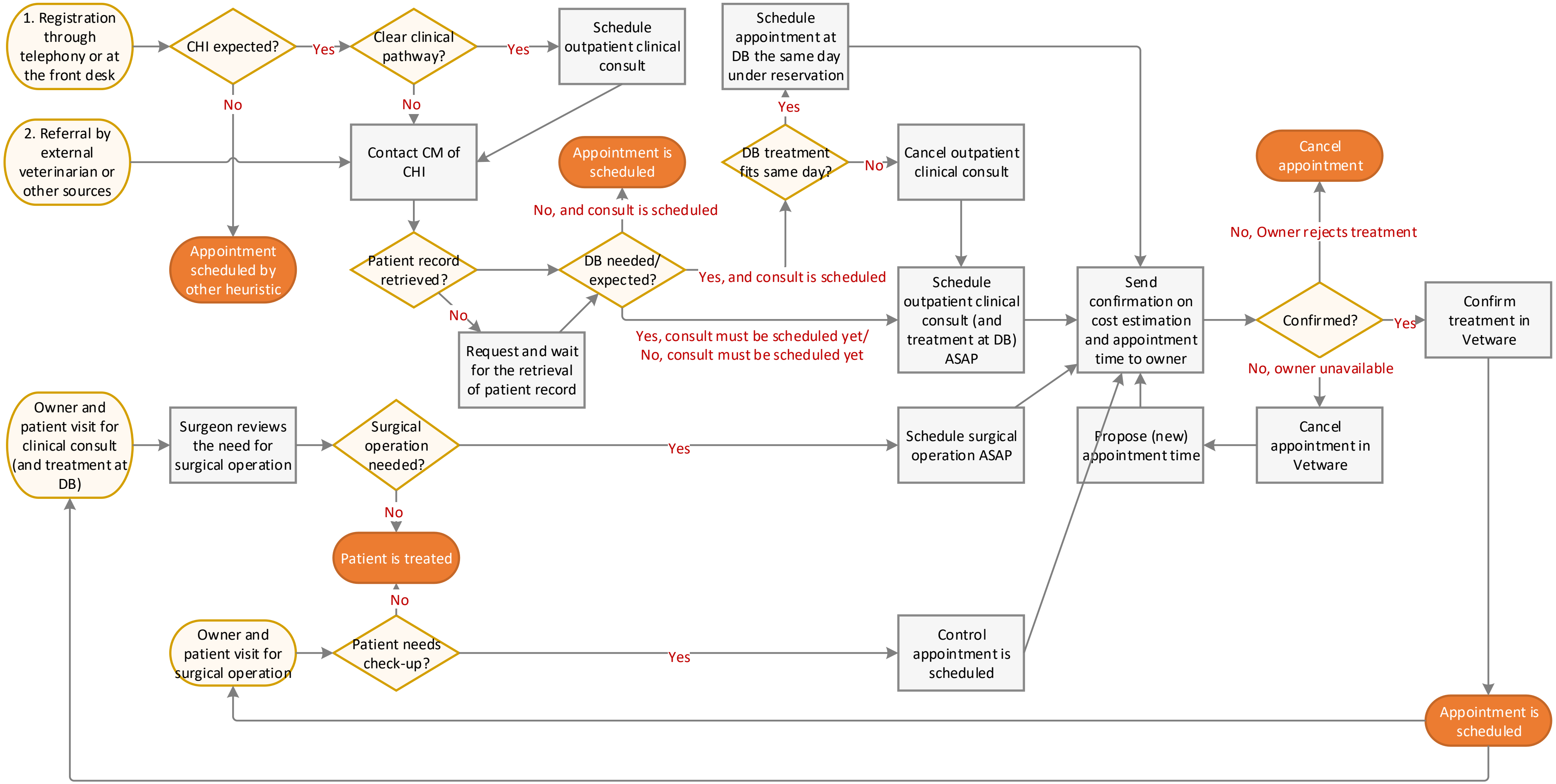

Figure 2.2.2 Flowchart of the appointment patient planning process for appointments at CHIR.

Radiology (DB)

DB treats two patient groups: external and internal patients. A flowchart that visualizes the core of DB's patient appointment planning process is presented in Figure 2.2.3. A legend for the flowchart can be found in Appendix B.

The main paths for a patient's appointment to be scheduled at DB are:

1. **Through the front desk or telephony**, where the patient will be registered as an internal patient and an outpatient clinical consult with a treatment at DB is scheduled by a CM (with reservation with a request for confirmation of the appointment time and cost estimation).
2. **At the outpatient clinical consult**, when the need for treatment at DB arises. The executive employee of the consult will schedule the treatment, normally in consultation with DB. Sometimes, a CM is contacted to process the scheduling of the treatment or the owner will get in touch with the front desk or telephony.
3. **Through the front desk, telephony, external veterinarians, specialists and other sources.** Here, the owner desires that the patient is treated as an external patients. A referral of an external veterinarian is requisite. The patient is not compulsory to visit for an outpatient clinical consult beforehand. External patients are registered and scheduled by DB.
4. **Emergencies are scheduled and coordinated by DB**.

According to radiologists, external patients (roughly 15% of all treated patients at DB) are scheduled in off-peak hours and can be used to fill up gaps in the timetable at a relatively short notice. External patients may only be treated if they comply with a set of requirements (e.g. a minimum ASA classification).

Appointments are scheduled based on standard time slots. Though, these times are regularly adjusted to the case's needs. Furthermore, appointments are scheduled 'with reservation' (In Dutch: Onder Voorbehoud (OVB)). Those appointments are regularly cancelled at the end of the outpatient clinical consult if the appointment appears to be unnecessary. There are no consequences for departments if they cancel an appointment at DB which contributes to the excessive use of scheduling 'with reservation'.

Anaesthesiology (ANE)

ANE's schedule is in the hands of other disciplines. Here, ANE is taken little into account. Many appointments are scheduled without consulting ANE. As a result, we observe the following:

- Appointments are scheduled without concern for the patient's health. Therefore, some patients cannot be treated at the appointment times.
- The schedule may be infeasible as appointments are scheduled unrealistically close to each other. Treatments at DB are scheduled without breaks in between. There is no time taken into account to prepare, transport and wrap-up patients.
- Sometimes, appointments overlap each other (in particular at SA). In many cases, the patient is not yet ready for the scheduled appointment as it is delayed at a prior care process.
- Many employees at ANE have to switch from one workplace to another several times a day. According to ANE's employees, this is a waste of time and increases the workload.

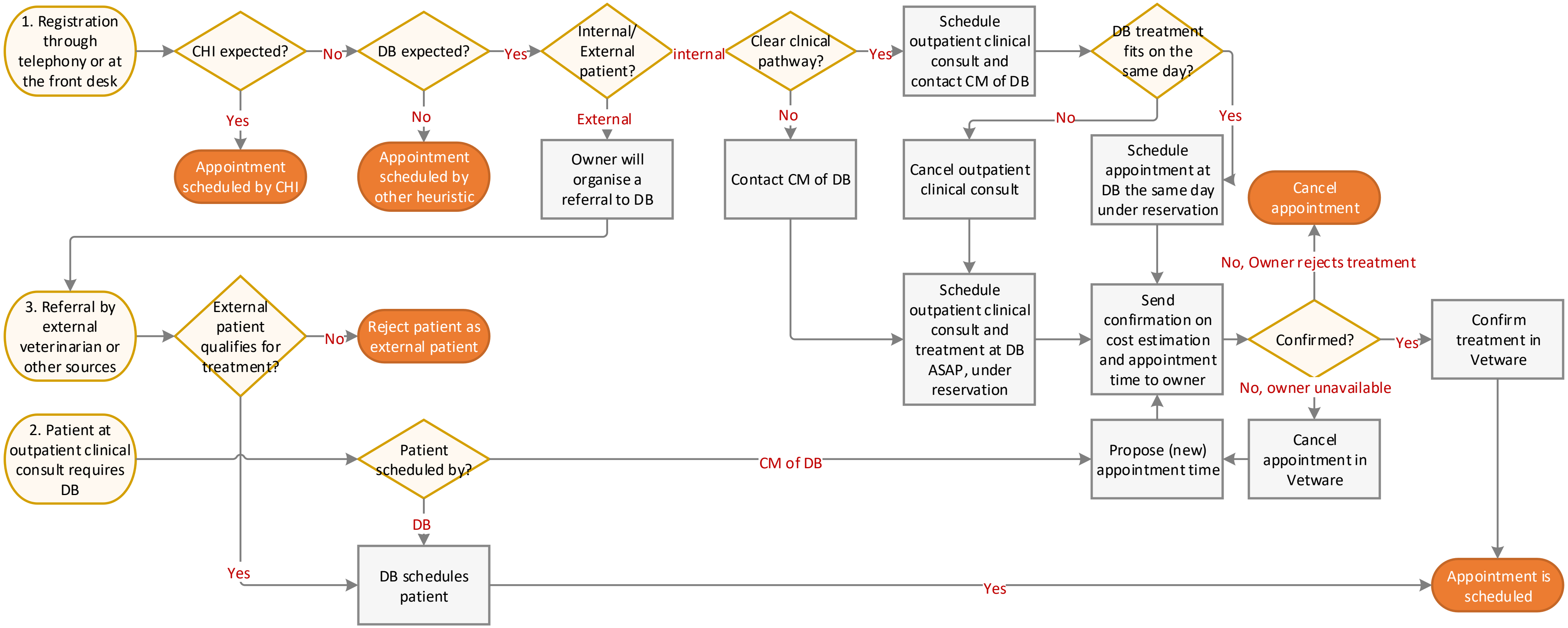

Figure 2.2.3 Flowchart of the appointment patient planning process for appointments at DB.

Summary

In the previous sub-sections we analysed the patient appointment planning process to understand

At the core of the patient appointment planning, we find a simplistic First-Comes-First-Served heuristic (appointments are scheduled as soon as possible) to satisfy the high customer value placed in quick accessible care. If possible, appointments are scheduled on the same day to satisfy One-Stop-Shop appointments. As a result of One-Stop-Shop, but also in response to a perceived capacity scarcity, many appointments are scheduled ‘with reservation’. With the additional need for the owner to confirm the appointment(s) and agree with the cost estimation(s), many appointments are postponed, cancelled, moved or altered in some way. We conclude that the core of the patient appointment planning is simplistic, undeveloped and unexplored. Example of exploratory improvements could be:

- Fastening the patient appointment planning process to reduce short-term inefficiencies, e.g. by calling the owner after a confirmation and cost estimation is send, or immediately inform the owner about the estimated cost after their consult or the diagnosis.
- Develop a more complex heuristic, e.g. a heuristic that reduces the number of gaps in the final operationalised schedule by over-scheduling capacity in compensation for short-term cancellations. Or schedule specific appointment (e.g. definite CP appointments) at certain times (e.g. mornings to prevent a delay of all appointments throughout the day).
- Eliminate scheduling ‘with reservation’ to reduce the short-term inefficiencies created by cancellations on a short notice.
- Identify and characterize patient groups to exploit the boundaries set by customers in terms of customer values, e.g. if we identify a group of patients that do not value One-Stop-Shop we may exploit this.

Aside from an undeveloped patient appointment planning, we find the processes not to be standardised. Some examples are:

- The front desk may schedule an appointment at DB instead of referring to a CM.
- Surgeons schedule appointments with and sometimes without the support of a CM.
- Appointments are scheduled with standard times, but sometimes adjusted with or without consultation of other involved disciplines.
- At some occasions, standard times are adjusted after the surgery or appointment by ANE.
- ANE is taken rarely into account in the planning processes.
- There are many exceptions on how a patient may end up with a scheduled appointment at some care process.

Why the processes are unstandardised may have some roots in the unequivocalness between care processes on the following topics:

- Opening and closing times.
- Opened time in relation to the number of demanded time.
- Use of a maximum number of NP and CP appointments.
- Strictness in the handling of time slot.
- Duration of time slots.
- Timing and duration of and reasons behind breaks.

- Reasons behind and the magnitude of scheduling ‘with reservation’.
- Employees values related to One-Stop-Shop and other customer values.

We find more undeveloped aspects in the patient appointment planning processes that play out in the many obstructions that occur in the operationalisation of the schedule. There is a lack of flexible measurements or mechanics (e.g. buffers or available ‘back-up’ patients/appointments) to deal with the following deviations:

- Patients and owners arrivals are delayed. In particular outpatient clinical consults are delayed very often. Even while owners are asked to arrive 10 minutes in advance of their appointment time.
- Patients and owners are missing in the waiting room at the time of their appointments as patients are not updated on their estimated waiting time left.
- The standard times used to schedule appointments for surgeries at CHIR are unrealistic. As a result, appointments (and patients) are delayed.
- Additional (unexpected) medical operations have to performed very often. As a result, appointments (and patients) are delayed. In particular at the CT, where acute additional ECHO is performed in roughly 25%-50% of the cases.
- Unexpected demand appears during clinical consults, but frequently there is a lack of capacity available to treat it the same day.
- Patients are delayed at other care processes. Therefore, the appointment cannot start.
- Appointments are cancelled and the gaps cannot be filled with patients, as no patients are available to be treated instead.
- Emergency appointments arrive and have to wait, and they delay other appointments.

The flexible measurements and mechanics that are in place are:

- Small breaks between appointments for most care process with outpatient clinical consults to deal with delays, preparation tasks, introduction and farewells with owners and patients and discussion time with students.
- Appointments may be scheduled on and treated at various care processes and the employability is widened within departments. This to increase the flexibility on how capacity is made available and used, and to decrease the waiting time in days for appointments.
- External patients at DB are scheduled within gaps and at quiet hours.
- If patients are delayed other already arrived patients may be treated first regardless their appointment time.
- CP appointment are sometimes scheduled in the afternoon as they do not require One-Stop-Shop treatment. They are also less interesting for educational activities that happen in the morning hours.
- The planning is sometimes constrained to a maximum number of NP appointments, as CP appointments are less stochastic (in both their arrival and appointment duration).
- Some care processes with two service stations will start the shift of the second service station with a delay of 15 minutes. Thereby, an apparently comfortable overlap between the treatment start times of appointments is achieved. Some care processes may start simultaneously as the morning hours are quite busy, and will create this overlap at later slots.

Some care processes will start at 8:30, while others start at 9:00 with their first patients. All of this inconsistency is a result of employees preferences or their way of dealing with deviations in the operationalisation.

- Appointments are sometimes scheduled with reservation (OVB) if care is likely to be expected.
- Owners with patients are requested to arrive 10 minutes before their appointment.

We also conclude that Vetware is used to schedule patients and to develop a schedule that represents the appointment times. However, Vetware's schedule does not reflect the actual hustle and bustle of the days. It neglects many side activities and tasks that are now partly expressed by small breaks after and in between appointments. The schedule should reflect the activities and tasks of employees and not only serve as a tool to schedule appointments and capture their scheduled appointment times. This would greatly benefit, for instance, planners to take into account ANE. A specially designed schedule for ANE's activities can also contribute to take ANE into account. Additionally, it will represent the activities at other departments, e.g. surgeries at CHIR, more realistic. For now, it is impossible to visually observe when a surgeon starts and finishes a surgery since the visualised appointment time will also cover ANE's medical operations before and after the actual surgical operations.

2.3 Production numbers and patient arrival process

Section 4.1.4 covers the classification (process) of appointments, appointments types, clinical pathways and more data preparation-related topics. This section presents and discusses the main results concerning production numbers and clinical pathways (Sub-section 2.3.1), appointment cancellations (Sub-section 2.3.2) and the patient arrival process and demand seasonality's and trends (Sub-section 2.3.3). The section gives answer to research question 5: *How does the demand for resource capabilities look like?* A summary of the sub-sections is processed into a table found at sub-section 2.3.4.

2.3.1 Production numbers

We analysed a total of **114.715 appointments** in the 4 year period between 1-1-2016 up to and including 31-12-2019. The appointments are classified by whether they are NP, CP, OVB and/or One-Stop-Shop appointments and by what appointment type (Elective, Extern, Emergency or Cancellation) they can be described. The production numbers can be found in Table 2.3.1 (NP, CP and grand totals) and Table 2.3.2 (OVB, One-Stop-Shop, clinical pathways of single (NP) appointments and average path lengths). The tables are also available with percentages as a fraction of the total appointments and can be found in 0. Observations on the tables are made at the end of this sub-section.

To understand the relations between different appointments and thereby care processes (and departments and disciplines), we designed clinical pathways. Clinical pathways are built up by one NP appointment or a set of successive appointments. How the clinical pathways were designed is explained in Section 4.2.2. The result is a total of **61.977 clinical pathways**.

We designed a frequency table (split up into multiple tables) to provide insights in the relations that can be found in our network of resources. We have looked into the frequency at which a partition of a clinical pathway occurred. Here, we also considered the appointment types (elective, extern, emergency and cancellation). One partition of the frequency table is presented in Table 2.3.3 as an example. The complete frequency table can be found in Appendix D. With these tables, we can answer the following questions:

- Which appointments preceded the appointment and for how many times (per appointment type)?
- Which appointments succeeded the appointment and for many times (per appointment type)?

The frequency table has been converted into two different tables with percentages and conditional formatted cells for quicker analysis of the results. Percentages in the first table (see Appendix E) refer to the fraction of all CP appointments of the appointment in the column that were preceded by the appointments in the rows. Percentages in the second table (see Appendix F) refer to the fraction of all appointments of the appointment in the row that were succeeded by appointments in the columns. This can be confusing, that is why Figure 2.3.1 is provided to visually illustrate which information can be found where.

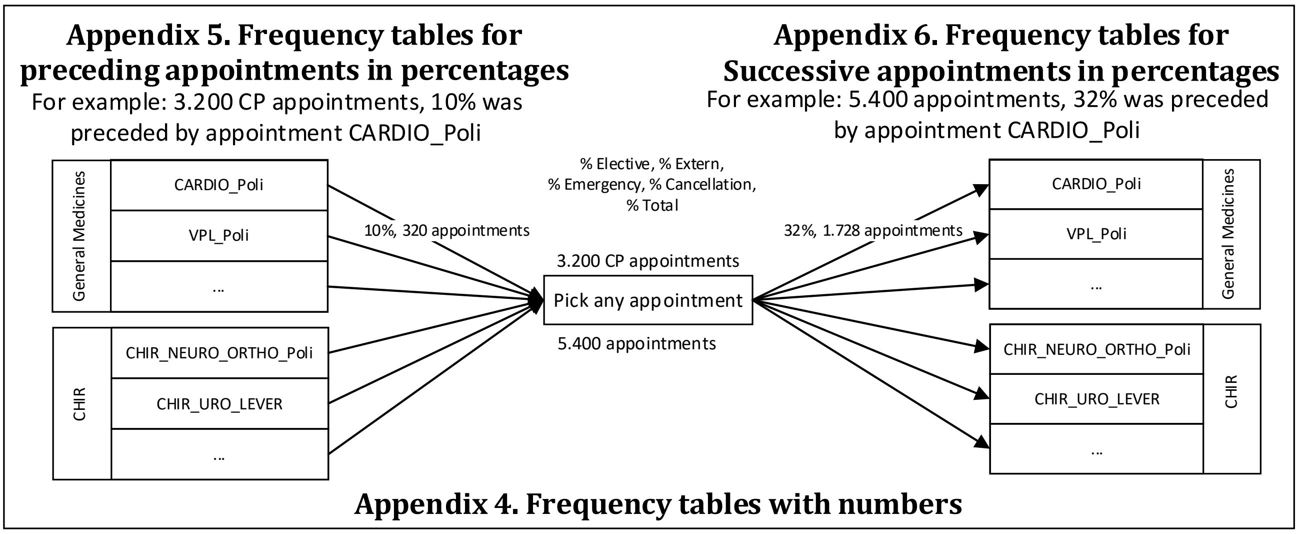

Figure 2.3.1 Visual representation of which information can be found where about clinical pathway production numbers and percentages.

On the basis of the presented tables, we make the following primary observations:

- Most emergencies arrive at *SPOED_Poli* (81.7%), *CHIR_Overig(2)* for surgery (2.8%), *OOG_Poli* (1.5%), *ECHO_GD* (3.8%) and *X_RAY_GD* (1.9%).
- Most extern appointments arrive at *MRI* (30.4%), *CT* (24.9%) and *ECHO_GD* (36.9%).
- Most cancellations of NP appointments (5.2%) arrive at Outpatient clinical consults and of CP appointments (6.2%) at DB and CHIR's ORs.
- Most outpatient clinical consults have more NP appointments (average of 65.0%) than CP appointments.
- Most clinical pathways at the outpatient clinical consults consist of single NP appointments.
- Many appointments are succeeded by the same kind of appointment (mostly between 8% to 60% of the CP appointments).
- Many of CHIR's outpatient clinical consults are succeeded by surgeries at the same discipline (commonly 6% of all appointments). Subsequently, many of the surgeries are succeeded by

outpatient clinical consults at the same discipline (commonly between 8% to 12% of all appointments).

- Many appointments at CHIR's ORs and DB are One-Stop-Shop and OVB appointments.
- We make many more observations and find many more relations. They are too many to point out all of them. We find, for example, many appointments at *NEUR_Poli* being succeeded by a treatment at the *MRI* (51.4% of all MRIs).

In sub-section 2.3.4 a set of tables with, among other information, the most frequent successive and preceding appointments is presented for each appointment. From the presented results, we conclude that the network of resources is very complex but find clear relations between specific departments, disciplines and appointments. We also find clear patients flows of specific appointment types at specific care processes. The tables can guide the planners to understand the likelihood of an appointment type to appear at a care process and the likelihood it is succeeded another appointment.

We visualised the strongly connected care processes through relationships diagrams that can be found in Appendix G. We excluded the care process from the diagrams to keep it orderly: *SPOED_Poli* (connected to many disciplines as <u>preceding</u> care process), *CHIR_Algemeen_Poli* (connected to most of CHIR's outpatient clinic as <u>successive</u> care process) and *SA* (connected to many disciplines as both <u>preceding and successive</u> care process). We identified three clear clusters of strongly connected disciplines and grouped them into: Oncology (1), General medicines and most INT care processes (2), and Neurology and Orthopaedics (3). The latter can be found as an example in Figure 2.3.2 below. The diagrams are used in the solving phase to better understand the interactions between specific care processes that can be expected from an alternative solution.

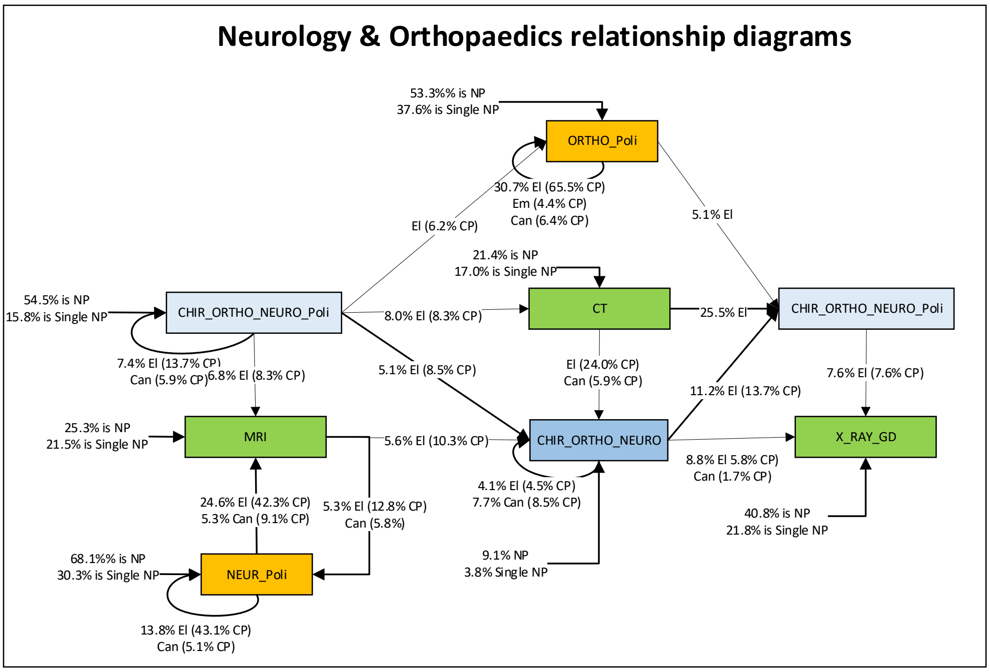

Figure 2.3.2 Relationship diagram of Neurology and Orthopaedics. An arrow depicts the direction of the patient flow, where the text near the arrow describes the patient flow. The text first indicates the fraction of all the appointments at the preceding care process that flow towards the next care process and then indicates how big of a fraction this is of all CP appointments at the succeeding care process. For example: we find a patient flow from *CHIR_ORTHO_NEURO_Poli* to *CT* with the text *'8.0% El (8.3% CP)'*. This indicates that 8.0% of all appointments at *CHIR_ORTHO_NEURO_Poli* flow towards *CT*. These are elective appointments (therefore, it states *8.0% <u>El</u>*). This flow of patients represents 8.3% of all the CP appointments at CT. Arrows without a preceding care process describe the amount of NP appointments and single NP appointments.

Table 2.3.1 Per appointment type and total production numbers for NP, CP and all appointments. Each wide white cell may contain up to four values, from left to right: Elective, Extern, Emergency, Cancellation. Adjacent to these cells, the grand totals can be found. N: 114.715 appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

			Totals														
			NP APPOINTMENTS					CP APPOINTMENTS					GRAND TOTAL				
CHIR	CHIR_THK	Poli	388		2	146	536	127		3	53	183	515		5	199	719
	CHIR_Overig(1)	Poli	231			5	236	232			8	240	463			13	476
	CHIR_Overig(2)	Poli	351		6	658	1015	999		34	317	1350	1350		40	975	2365
	CHIR_algemeen	Poli	1988		5	463	2456	2129		25	441	2595	4117		30	904	5051
	CHIR_KNO	Poli	262			33	295	860		5	142	1007	1122		5	175	1302
	CHIR_ONCO	Poli	228			74	302	136		2	33	171	364		2	107	473
	CHIR_ORTHO_NEURO	Poli	1063		2	132	1197	1210		3	222	1435	2273		5	354	2632
	CHIR_URO_LEVER	Poli	269		1	70	340	208		7	55	270	477		8	125	610
	CHIR_THK	Surgery	224		12	97	333	490		26	173	689	714		38	270	1022
	CHIR_Overig(1)	Surgery	16		1	3	20	127		25	20	172	143		26	23	192
	CHIR_Overig(2)	Surgery	81		89	36	206	878		656	245	1779	959		745	281	1985
	CHIR_KNO	Surgery	38		22	14	74	493		125	208	826	531		147	222	900
	CHIR_ONCO	Surgery	9			4	13	256		16	94	366	265		16	98	379
	CHIR_ORTHO_NEURO	Surgery	94		13	52	159	1053		148	386	1587	1147		161	438	1746
	CHIR_URO_LEVER	Surgery	66		28	49	143	797		200	299	1296	863		228	348	1439
	CHIR_OVE	Surgery	572	1	35	277	885	221	1	38	143	403	793	2	73	420	1288
	CHIR_OOG	Surgery	173		4	25	202	413		14	95	522	586		18	120	724
General Medicines & INT	GEDRAG	Poli	278			103	381	11			4	15	289			107	396
	OVERIGEPOLI	Poli	2554		68	14	2636	382		8	14	404	2936		76	28	3040
	VOEDING	Poli	83			6	89	8				8	91			6	97
	CARDIO	Poli	1765		110	338	2213	748		72	107	927	2513		182	445	3140
	NEUR	Poli	2051		12	481	2544	1005		5	183	1193	3056		17	664	3737
	ONCO	Poli	806		1	193	1000	2538		10	288	2836	3344		11	481	3836
	OOG	Poli	2755		355	473	3583	1007		46	223	1276	3762		401	696	4859
	ORTHO	Poli	446		29	43	518	347		28	79	454	793		57	122	972
	SPOED	Poli			19565		19565			2345		2345			21910		21910
	VPL	Poli	739		7	69	815	1377		11	45	1433	2116		18	114	2248
	ENDO	Poli	875		7	219	1101	675		30	102	807	1550		37	321	1908
	DERM	Poli	985		3	376	1364	1264		3	206	1473	2249		6	582	2837
	GAHE	Poli	891		2	227	1120	682		9	169	860	1573		11	396	1980
	HEMA	Poli	455		6	110	571	755		6	111	872	1210		12	221	1443
	URO	Poli	844		2	189	1035	639		7	140	786	1483		9	329	1821
	ALG_INT	Poli	445		4	111	560	307		4	76	387	752		8	187	947
VBD	VBD	Poli	2856		131	346	3333	2543		167	182	2892	5399		298	528	6225
ANE		SA	116	3	14	21	154	2132	2	200	457	2791	2248	5	214	478	2945
DB	RAD	Poli	152			1	153	182			17	199	334			18	352
		Nucl_Diagn						317	12	6	17	352	317	12	6	17	352
		MRI	189	430	14	103	736	1342	63	207	563	2175	1531	493	221	666	2911
		RTC	17			2	19	2115		28	69	2212	2132		28	71	2231
		CT	388	366	9	60	823	2162	37	157	664	3020	2550	403	166	724	3843
		ECHO_PD	1702	10	12	52	1776	687	5	8	19	719	2389	15	20	71	2495
		ECHO_GD	2616	556	514	223	3909	3049	42	499	307	3897	5665	598	1013	530	7806
		X_RAY_PD	1632	38	11	21	1702	716	3	7	16	742	2348	41	18	37	2444
		X_RAY_GD	1524	32	205	40	1801	2216	16	305	80	2617	3740	48	510	120	4418
		FLUOR	52	3	5	4	64	120	1	20	14	155	172	4	25	18	219
	Grand Total		33269	1439	21306	5963	61977	39955	182	5515	7086	52738	73224	1621	26821	13049	114715

Table 2.3.2 Per appointment type and total production numbers for OVB, One-Stop-Shop and Single NP appointments. Each wide white cell may contain up to four values, from left to right: Elective, Extern, Emergency, Cancellation. Adjacent to these cells, the grand totals can be found. Additionally, the average path length can be found in the last column in a similar way. N: 114.715 appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

			Totals																			
			OVB					One-Stop-Shop					Single (NP) appointments					Average path length				
CHIR	CHIR_THK	Poli	27		1	15	43	15		1	8	24	181		2	82	265	1.9		1.0	1.8	1.9
	CHIR_Overig(1)	Poli	18			2	20	59			1	60	162			3	165	1.5			1.8	1.5
	CHIR_Overig(2)	Poli	80		1	90	171	94		5	36	135	129		4	445	578	2.9		1.3	1.5	2.0
	CHIR_algemeen	Poli	222		1	100	323	126		3	57	186	627		3	207	837	3.2		1.8	2.5	3.1
	CHIR_KNO	Poli	20			2	22	14			6	20	40			11	51	4.9			3.4	4.7
	CHIR_ONCO	Poli	22			9	31	12			6	18	48			40	88	4.0			2.0	3.5
	CHIR_ORTHO_NEURO	Poli	104			25	129	73			24	97	360		1	54	415	3.2		2.0	2.7	3.1
	CHIR_URO_LEVER	Poli	33			23	56	11			5	16	113		1	36	150	2.4		1.0	2.0	2.3
	CHIR_THK	Surgery	75		5	48	128	401		23	146	570	167		11	73	251	1.7		1.1	1.4	1.6
	CHIR_Overig(1)	Surgery	25		3	5	33	87		16	8	111	6			1	7	3.9		6.0	3.0	3.9
	CHIR_Overig(2)	Surgery	150		50	93	293	336		394	65	795	51		54	16	121	1.9		1.8	3.0	2.0
	CHIR_KNO	Surgery	121		18	80	219	228		85	92	405	21		14	7	42	1.9		1.7	2.8	2.0
	CHIR_ONCO	Surgery	23		3	24	50	41		1	9	51	5			1	6	5.1			3.0	4.5
	CHIR_ORTHO_NEURO	Surgery	189		27	105	321	260		70	40	370	34		8	24	66	2.9		2.4	2.7	2.8
	CHIR_URO_LEVER	Surgery	227		36	120	383	210		115	65	390	34		18	18	70	2.5		1.6	2.3	2.2
	CHIR_OVE	Surgery	41		6	25	72	40		18	24	82	514	1	23	177	715	1.1	1.0	1.5	1.5	1.3
	CHIR_OOG	Surgery	43		2	23	68	79		9	20	108	122		2	14	138	1.5		2.0	1.9	1.6
General Medicines & INT	GEDRAG	Poli	2			12	14	1				1	271			100	371	1.0			1.0	1.0
	OVERIGEPOLI	Poli	240		2	5	247	47		1	3	51	2402		66	9	2477	1.1		1.0	1.9	1.1
	VOEDING	Poli	40				40	0					77			4	81	1.1			1.3	1.1
	CARDIO	Poli	276		40	58	374	103		29	17	149	1244		80	289	1613	1.7		1.7	1.3	1.6
	NEUR	Poli	236		8	75	319	85			27	112	861		4	269	1134	2.1		2.8	1.7	2.0
	ONCO	Poli	82			28	110	59			4	63	209			135	344	6.1		2.0	2.3	5.4
	OOG	Poli	236		46	67	349	190		16	47	253	1824		271	418	2513	1.6		1.5	1.2	1.6
	ORTHO	Poli	14		1	8	23	30		2	6	38	312		27	26	365	2.2		1.2	1.9	2.1
	SPOED	Poli	0		489		489	0		469		469			15950		15950			1.5		1.5
	VPL	Poli	94			19	113	49			5	54	240		3	53	296	3.5		3.7	1.4	3.3
	ENDO	Poli	130		1	35	166	53		1	9	63	374		2	123	499	2.4		3.4	1.8	2.2
	DERM	Poli	101		1	49	151	102			18	120	481		1	279	761	2.3		3.7	1.7	2.2
	GAHE	Poli	131		1	55	187	95			35	130	403		1	155	559	2.4		1.5	1.9	2.3
	HEMA	Poli	71			31	102	22		1	9	32	190		3	71	264	2.7		1.7	2.3	2.6
	URO	Poli	130		3	49	182	51		1	18	70	401		2	130	533	2.4		1.0	1.7	2.3
	ALG_INT	Poli	74		3	28	105	35			11	46	218		3	78	299	2.2		1.3	1.7	2.1
VBD	VBD	Poli	128		33	41	202	216		9	21	246	1938		82	269	2289	2.0		2.0	1.6	1.9
ANE		SA	407	1	39	178	625	1816	1	150	402	2369	50	3	11	9	73	3.1	1.0	2.1	2.3	2.8
DB	RAD	Poli	76			6	82	133			10	143						3.6			3.0	3.6
		Nucl_Diagn	69	7	1	5	82	317	12	6	17	352										
		MRI	759	386	100	398	1643	1096	26	145	506	1773	136	402	13	75	626	1.8	1.1	1.1	1.8	1.4
		RTC	3				3	220		5	8	233	4				4	10.5			11.0	10.5
		CT	1029	301	66	451	1847	1799	16	112	573	2500	272	338	5	37	652	1.8	1.1	2.3	1.8	1.5
		ECHO_PD	151	6	2	10	169	226	2	3	6	237	1257	10	6	37	1310	1.4	1.0	1.6	1.5	1.4
		ECHO_GD	1064	387	214	203	1868	1555	10	233	146	1944	1944	511	383	155	2993	1.6	1.1	1.6	1.6	1.5
		X_RAY_PD	101	13	3	7	124	252		1	4	257	1060	25	9	9	1103	1.5	1.5	1.4	1.9	1.5
		X_RAY_GD	186	19	33	34	272	1192	7	171	31	1401	805	20	117	23	965	2.1	1.5	1.9	1.7	2.0
		FLUOR	30	1	5	7	43	56		5	4	65	22	1	3	1	27	2.0	2.7	1.6	3.0	2.0
	Grand Total		33153	33153	33153	33153	132612	33153	33153	33153	2549	102008	170863	308573	583993	1165437	2228866	2.1	1.1	1.5	1.8	1.9

Table 2.3.3 Occurrence frequency of partitions of clinical pathways involving appointments at DB. Partitions should be read from appointments (left columns) to appointments (top rows). Each cell may contain up to four values, from left to right: Elective, Extern, Emergency, Cancellation. For example: cell sharing the first row of left columns ‘CHIR_THK Poli’ and third column of top row ‘RAD_MRI’ has values [Blanc, Blanc, Blanc, 1] meaning 1 cancellation was observed at the MRI coming from CHIR_THK Poli. N: 114.715 appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report ‘OK verslagen’*.

			DB																																							
			RAD_Poli				RAD_Nucl_Diagn				RAD_MRI				RAD_RTC				RAD_CT				RAD_ECHO_PD				RAD_ECHO_GD				RAD_X_RAY_PD				RAD_X_RAY_GD				RAD_FLUOR			
CHIR	CHIR_THK	Poli												1					12			2					2			1					3							
	CHIR_Overig(1)	Poli									2			1					8			4					1								53							
	CHIR_Overig(2)	Poli									9			29	2			2	105			77					7		1	30					65		1	30				
	CHIR_algemeen	Poli	7			2					90			23	10				509		1	107					189			31					152			29	4			
	CHIR_KNO	Poli									2								50		1	6					3								3							
	CHIR_ONCO	Poli									6			2	1				92			25					28			5					14			3				
	CHIR_ORTHO_NEURO	Poli	7			2					180			20					210			18					24			4	1				200			43	1			
	CHIR_URO_LEVER	Poli									1			1					11								76			26					5			2	6			1
	CHIR_THK	Surgery									3			1	1				10			2					12			1					14			1				
	CHIR_Overig(1)	Surgery																	3								8			1					11		1	1				
	CHIR_Overig(2)	Surgery									2		3	2	4		2		10		3	8	1				32		20	11					39		26	10	1			
	CHIR_KNO	Surgery													2			1	25		3	19					9		3	3					21		11	5	1			1
	CHIR_ONCO	Surgery									1				6		1		4								7			3					3							
	CHIR_ORTHO_NEURO	Surgery	2								6		3	1	1				19		1	5	1				22		5	6					153		11	45	1			
	CHIR_URO_LEVER	Surgery											1		2			1	10		1	3					93		13	14					20		12	12	5		2	
	CHIR_OVE	Surgery																1				1					7		1	6								1				
	CHIR_OOG	Surgery									2				1							1					11		3	5												
General Medicines & INT	GEDRAG	Poli																												1												
	OVERIGEPOLI	Poli	1								20			1	7		1		18								15		1	1					29			1				
	VOEDING	Poli																									1															
	CARDIO	Poli	1								21		1	2	3				72		5	5					72		12	6					97		4	8	37		2	2
	NEUR	Poli	1								919		3	199				1	26			4					40			5					20		1	3	1			
	ONCO	Poli	2								11			1	66			5	254			7					163			11					63			6	1			
	OOG	Poli				1					21		2	4					41		1						100		5	9					17		1					
	ORTHO	Poli																									2			1	1				13		1	4				
	SPOED	Poli			1								277				25				150				1				535				2				270				13	
	VPL	Poli									1								2								278			8					22				1			
	ENDO	Poli	14			1					18							1	272		4	44					51		3	12					8			1				
	DERM	Poli									1			1	1				6			1					20			1					9			2				
	GAHE	Poli	2								8			1					60			5					220		2	32					27			5	10			2
	HEMA	Poli									4			1					7			2					99		1	10					22			3				
	URO	Poli									4				1				14			2					249		3	44					22			1	3			
	ALG_INT	Poli				1					10			1				1	10		1	1					95			19					27			4	1			1
VBD	VBD	Poli			1						5				35				198		10	5					74		5	6	1				39		4	3				
ANE		SA																																								
DB	RAD	Poli					325			17					2				2																							
		NuclDiagn	43	3		3					1				77	2		1	4	1		1					6							2	1							
		MRI		1		1					18	5	8	47	1				34	5	4	9	1			2	21	4	4	11	2			1	28	2	5	11	1			
		RTC	80			1	2								1764		21	53	1								13		1	2					3							
		CT	3					1		1	31	1	3	8	74	1	1	5	30	11	6	48	21	4			65	2	8	12	27	4		3	24	1	10	5	3	1		
		ECHOPD									3								37		1	1	221		2	11	1		1		387	1	5	8	1			1				
		ECHOGD									25	1	6	6	11			1	49	3	7	7	2				229	14	53	42	2				251	5	58	2	15		2	1
		XRAYPD				1					27	6		1	1				57		1	1	438	7	2	4	2				277	1	1	12	3				1			
		XRAYGD	2								19		5	1	4				39		4	2	1				254	6	56	5	2				186		18	17	15		1	1
		FLUOR																	3								12	1		4	2				19	1	4		1		1	
	Grand Total		165	4	2	13	327	1		18	1471	13	312	355	2077	3	51	73	2314	20	204	423	686	11	5	17	2613	27	736	389	702	6	8	26	1687	9	438	259	109	1	21	9

2.3.2 Appointment cancellations

After our first analysis into cancellations at the problem identification in Chapter 1, we concluded the number of cancellations is very impactful on the hospital's performance. In response to this, an extensive analysis of the cancellations is performed for all the selected disciplines and can be found in Appendix H.

We are interested in understanding the owner's motives behind cancelling their appointments and how the patient appointment planning processes are affected by the cancellations. For example, we are interested in the impact that One-Stop-Shop and scheduling 'with reservation' has on the operationalisation. In this way, we can understand where we may improve the patient appointment planning processes by concerning ourselves with the cancellations. For example, we might be able to reduce the number of cancellations and thereby reduce short-term inefficiencies. Also, the analysis may provide insights in the customer values of owners and which of those are not met and result in cancellations.

We classified a total of **13.049 cancellations** (11.4% of all appointments). The classification process is described in Section 4.2.3.

Cancellations have been identified by 'known' reasons by using a set of very specific keywords that can be associated with a reason for cancellation. Figure 2.3.3 presents the number of cancellations as a fraction of all appointments that could be identified by a known reason in the comment field.

Not yet identified cancellations were tried to be identified by a 'commented' reason. These are less specific reasons, for instance cancellations labelled by *via poli* refers to cancellations happened at the outpatient clinical consults and cancellations labelled by *OVB* refers to cancellations that reported to be scheduled 'with reservation'. Figure 2.3.4 presents the number of cancellations as a fraction of all appointments that could be identified by a reason that is regularly reported in the comment field. In the same figure, the known reasons are also clustered into one category labelled *known reason* and cancellations without any identified reason are clustered by the category *Unknown*.

To provide a quick analysis of the results, Table 2.3.4 presents the percentages of cancellations as a fraction of all appointments. The table is supplemented with conditional formatting to quickly find the most frequent reasons behind cancellations.

From the presented results, we make the following main observations:

- Roughly one-third of the appointments is classified by a known reason, another one-third is classified by a commented reason and for the remainder of the cancellations could not be classified.
- Most of the cancellations (roughly 10% to 40%) are classified with the reason 'moved' in the figures and 'moved/postponed' in the tables with the exception of cancellations at DB. Considering the additional fraction of cancellations classified by the known reasons 'Owner cannot come' and 'Another time' we conclude that many appointments are cancelled in the progress of finding a suitable time and date for the appointment. Improvements to the structure of these patient appointment planning processes is there for promising.

- ‘Via consult’ is the most frequent reason (roughly between 12% to 40% of the time) behind cancellations at DB. For surgeries, this percentages lies around 9% of the cancellations. The cancellation of these appointments commonly occurs at the outpatient clinical consults in the morning on a short-notice and cause short-term inefficiencies (e.g. gaps in the schedule). Eliminating the scheduling ‘with reservation’ and thereby reducing these inefficiencies is promising to be very beneficial.
- For most outpatient clinical consults, roughly 40% of the cancellations are cancellations of NP appointments or a set of successive cancellations (see Table 2.3.4, column *Clinical pathway consisting of single cancellations*). This means that this portion of cancellations are never caught up by not cancelled appointments. Probably the need for care appeared to be non-existent or the owners found another clinic to treat the patient at.
- For most outpatient clinical consults, ‘lack of owner’s willingness’ and ‘another clinic’ is a common reason behind cancellations. According to employees at telephony, these are mostly owners that found another (cheaper) clinic to treat their patient at in the meantime. Reducing the waiting time for appointments may reduce these cancellations, as owners do not get the time to find another clinic.
- *CARDIO_Poli, NEURO_Poli, ONCO_Poli, VBD_Poli* and *ECHO_PD* have high rates of ‘passed away’. In most cases, the patient was euthanized or passed away before the start of the appointment.
- Numerous outpatient clinical consults have high rates of ‘Healthier’. Meaning the patient was reported as healthy by the owner or at the clinic before the start of the appointment.
- Some appointments score uniquely high on specific reasons. To give an example, the cancelled surgeries at *CHIR_OVERIG(2)* are reported to be cancelled for 12.8% wit the reason ‘*OVB*’.
- Cancellations at DB and care processes of CHIR for surgeries have reported cancellations incorrectly (see Table 2.3.4, column *Incorrectly reported*).
- For most outpatient clinical consults, slightly less than 40% of the cancellations are part of a clinical pathway containing multiple additional cancellations (see Table 2.3.4, column *Multiple Cancellations*).

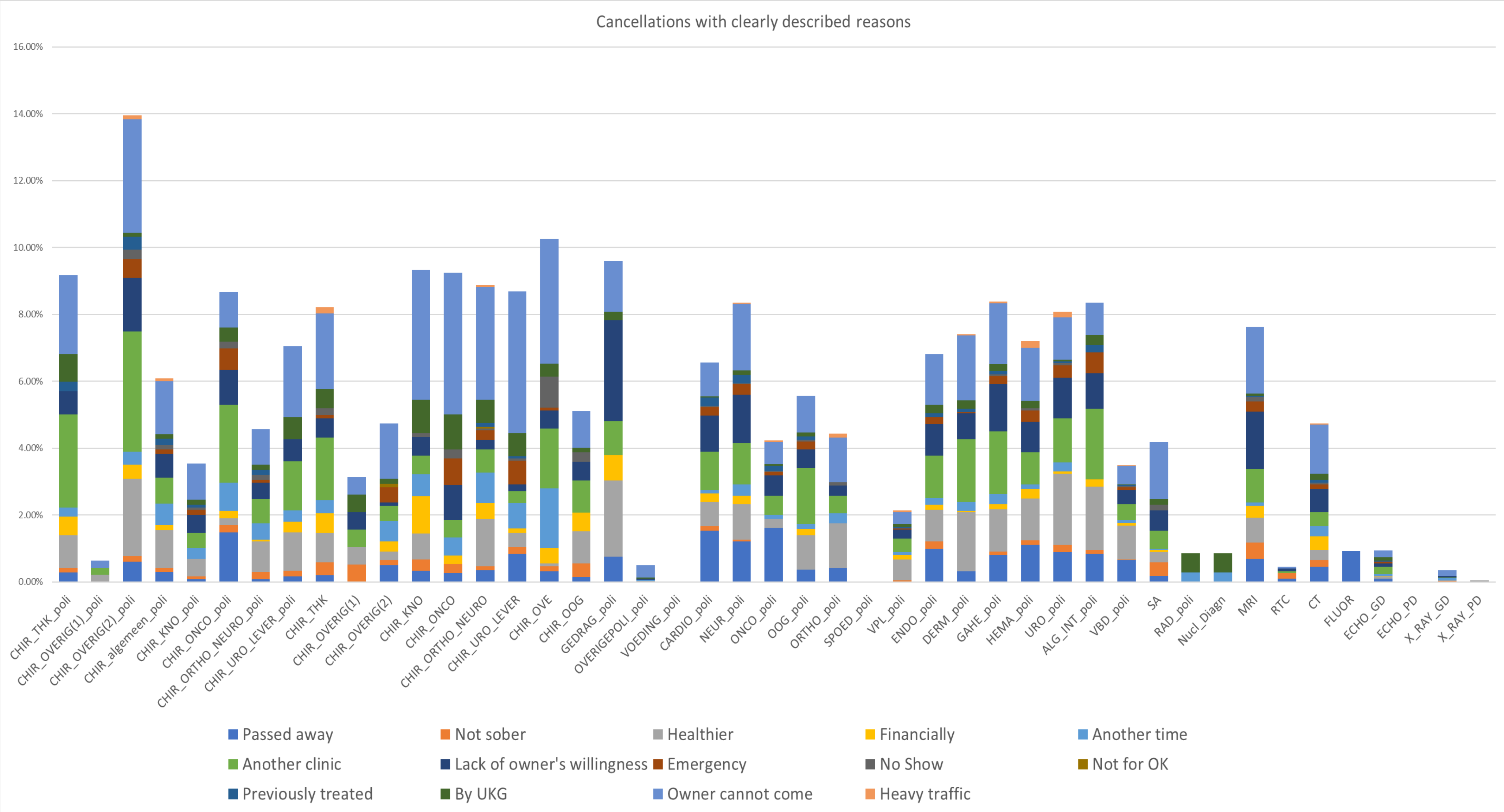

Figure 2.3.3 Number of cancellations with clear reasons as a fraction of the total appointments, for each care process. N: 114.715 appointments of which 13.049 cancellations, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

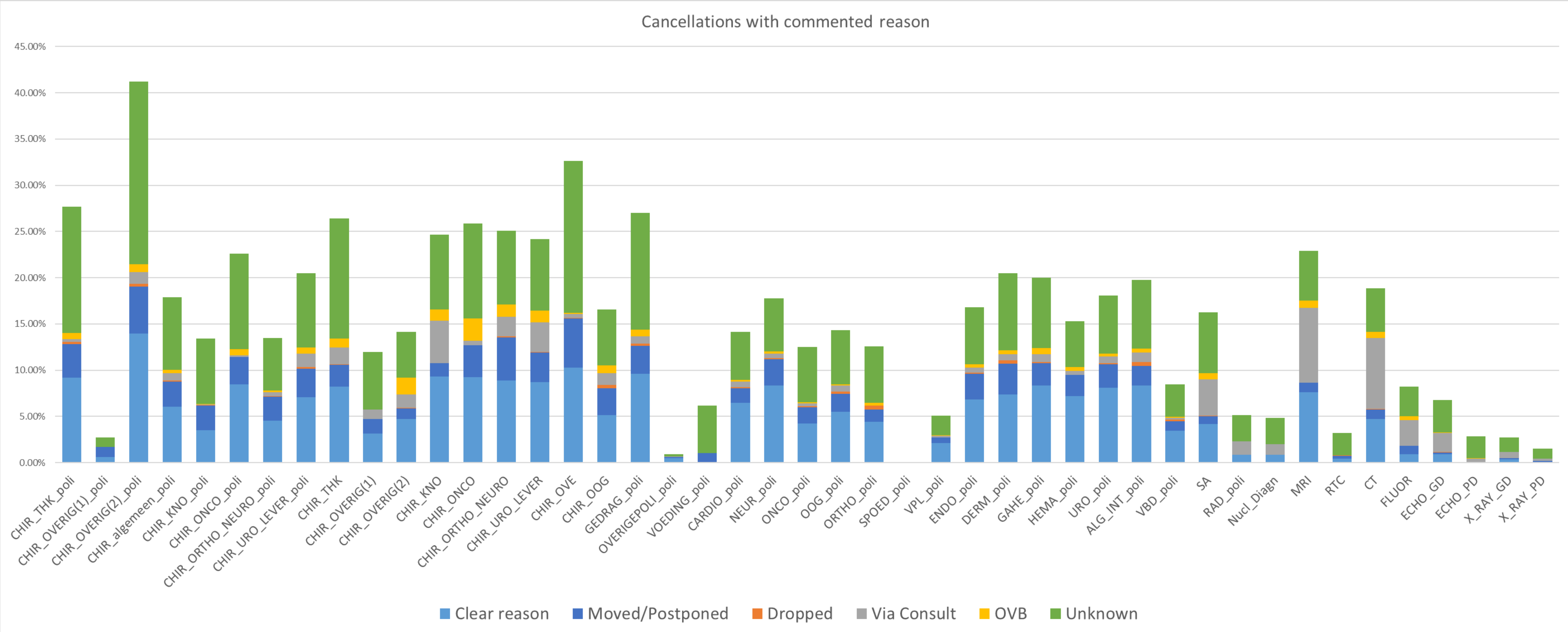

Figure 2.3.4 Number of cancellations with commented reasons as a fraction of the total appointments, for each care process. Fraction of clear reasons and the unclassified cancellations (see category 'Unknown') are also included. N: 114.715 appointments of which 13.049 cancellations, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

Table 2.3.4 Information on cancellations and reasons behind cancellations. Conditional formatted cells contain percentages representing the percentage of cancellations identified by the reasons described at the column above. Conditional formatting can be interpret by: from red to yellow to green we find frequent to less frequent reported reasons for the appointment. N: 114.715 appointments of which 13.049 cancellations, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

		General information								Clear reason														Commented reason			
		Total appointments	Not Cancelled	Cancelled	Fraction cancelled	Correctly cancelled	Incorrectly canceleld	Clinical pathway consisting of single cancellation	Multiple Cancellations	Passed away	Not sober	Healthier	Financially	Another time	Another clinic	Lack of owner's willingness	Emergency	No Show	Not for OK	Previously treated	By UKG	Owner cannot come	Heavy traffic	Moved/Postponed	Dropped	Via Consult	OVB
CHIR_THK	Poli	719	520	199	27.68%	89.45%	10.55%	41.21%	42.71%	1.01%	0.50%	3.52%	2.01%	1.01%	10.05%	2.51%	0.00%	0.00%	0.00%	1.01%	3.02%	8.54%	0.00%	13.07%	1.01%	1.01%	2.51%
CHIR_Overig(1)	Poli	476	463	13	2.73%	61.54%	38.46%	23.08%	7.69%	0.00%	0.00%	7.69%	0.00%	0.00%	7.69%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.69%	0.00%	38.46%	0.00%	0.00%	0.00%
CHIR_Overig(2)	Poli	2365	1390	975	41.23%	84.62%	15.38%	45.64%	49.13%	1.44%	0.41%	5.64%	1.03%	0.92%	8.72%	3.90%	1.33%	0.72%	0.00%	0.92%	0.31%	8.21%	0.31%	12.31%	0.72%	3.08%	2.15%
CHIR_algemeen	Poli	5051	4147	904	17.90%	80.75%	19.25%	22.90%	21.24%	1.66%	0.66%	6.31%	0.88%	3.54%	4.31%	3.98%	0.77%	0.77%	0.00%	1.00%	0.77%	8.85%	0.44%	15.15%	0.88%	4.42%	1.88%
CHIR_KNO	Poli	1302	1127	175	13.44%	81.71%	18.29%	6.29%	0.00%	0.57%	0.57%	4.00%	0.00%	2.29%	3.43%	4.00%	1.14%	0.57%	0.00%	0.57%	1.14%	8.00%	0.00%	19.43%	0.57%	0.57%	0.57%
CHIR_ONCO	Poli	473	366	107	22.62%	86.92%	13.08%	37.38%	39.25%	6.54%	0.93%	0.93%	0.93%	3.74%	10.28%	4.67%	2.80%	0.93%	0.00%	0.00%	1.87%	4.67%	0.00%	13.08%	0.00%	0.93%	2.80%
CHIR_ORTHO_NEURO	Poli	2632	2278	354	13.45%	80.79%	19.21%	15.25%	1.41%	0.56%	1.69%	6.78%	0.28%	3.67%	5.37%	3.67%	0.56%	1.13%	0.00%	1.13%	1.13%	7.91%	0.00%	18.93%	0.85%	2.82%	1.41%
CHIR_URO_LEVER	Poli	610	485	125	20.49%	78.40%	21.60%	28.80%	19.20%	0.80%	0.80%	5.60%	1.60%	1.60%	7.20%	3.20%	0.00%	0.00%	0.00%	0.00%	3.20%	10.40%	0.00%	15.20%	0.80%	7.20%	3.20%
CHIR_THK	Surgery	1022	752	270	26.42%	55.56%	44.44%	27.04%	24.81%	0.74%	1.48%	3.33%	2.22%	1.48%	7.04%	2.22%	0.37%	0.74%	0.00%	0.00%	2.22%	8.52%	0.74%	8.89%	0.37%	6.67%	3.70%
CHIR_Overig(1)	Surgery	192	169	23	11.98%	26.09%	73.91%	4.35%	4.35%	0.00%	4.35%	4.35%	0.00%	0.00%	4.35%	4.35%	0.00%	0.00%	0.00%	0.00%	4.35%	4.35%	0.00%	13.04%	0.00%	8.70%	0.00%
CHIR_Overig(2)	Surgery	1985	1704	281	14.16%	52.31%	47.69%	5.69%	7.47%	3.56%	1.07%	1.78%	2.14%	4.27%	3.20%	0.71%	3.20%	0.00%	0.71%	0.00%	1.07%	11.74%	0.00%	7.83%	0.36%	10.32%	12.81%
CHIR_KNO	Surgery	900	678	222	24.67%	63.06%	36.94%	3.15%	14.41%	1.35%	1.35%	3.15%	4.50%	2.70%	2.25%	2.25%	0.00%	0.45%	0.00%	0.00%	4.05%	15.77%	0.00%	5.86%	0.00%	18.47%	4.95%
CHIR_ONCO	Surgery	379	281	98	25.86%	62.24%	37.76%	1.02%	3.06%	1.02%	1.02%	0.00%	1.02%	2.04%	2.04%	4.08%	3.06%	1.02%	0.00%	0.00%	4.08%	16.33%	0.00%	13.27%	0.00%	2.04%	9.18%
CHIR_ORTHO_NEURO	Surgery	1746	1308	438	25.09%	62.56%	37.44%	5.48%	4.11%	1.37%	0.46%	5.71%	1.83%	3.65%	2.74%	1.14%	1.14%	0.23%	0.23%	0.46%	2.74%	13.47%	0.23%	18.49%	0.68%	8.22%	5.48%
CHIR_URO_LEVER	Surgery	1439	1091	348	24.18%	60.06%	39.94%	5.17%	8.91%	3.45%	0.86%	1.72%	0.57%	3.16%	1.44%	0.86%	2.87%	0.29%	0.00%	0.29%	2.87%	17.53%	0.00%	13.22%	0.29%	13.22%	5.46%
CHIR_OVE	Surgery	1288	868	420	32.61%	77.62%	22.38%	42.14%	47.14%	0.95%	0.48%	0.24%	1.43%	5.48%	5.48%	1.67%	0.24%	2.86%	0.00%	0.00%	1.19%	11.43%	0.00%	16.43%	0.24%	1.19%	0.48%
CHIR_OOG	Surgery	724	604	120	16.57%	31.67%	68.33%	11.67%	10.83%	0.83%	2.50%	5.83%	3.33%	0.00%	5.83%	3.33%	0.00%	1.67%	0.00%	0.00%	0.83%	6.67%	0.00%	17.50%	2.50%	7.50%	5.00%
GEDRAG	Poli	396	289	107	27.02%	92.52%	7.48%	93.46%	86.92%	2.80%	0.00%	8.41%	2.80%	0.00%	3.74%	11.21%	0.00%	0.00%	0.00%	0.00%	0.93%	5.61%	0.00%	11.21%	0.93%	2.80%	2.80%
OVERIGEPOLI	Poli	3040	3012	28	0.92%	89.29%	10.71%	32.14%	32.14%	0.00%	0.00%	3.57%	0.00%	3.57%	0.00%	3.57%	0.00%	0.00%	0.00%	0.00%	3.57%	39.29%	0.00%	14.29%	0.00%	3.57%	0.00%
VOEDING	Poli	97	91	6	6.19%	83.33%	16.67%	66.67%	50.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	16.67%	0.00%	0.00%	0.00%
CARDIO	Poli	3140	2695	445	14.17%	87.42%	12.58%	64.94%	48.09%	10.79%	0.90%	5.17%	1.80%	0.67%	8.09%	7.64%	1.80%	0.22%	0.00%	1.80%	0.22%	7.19%	0.00%	10.79%	0.90%	4.49%	1.12%
NEUR	Poli	3737	3073	664	17.77%	84.64%	15.36%	40.51%	46.08%	6.78%	0.30%	6.02%	1.36%	1.96%	6.93%	8.13%	1.81%	0.15%	0.00%	1.36%	0.75%	11.30%	0.15%	15.81%	0.75%	2.86%	1.36%
ONCO	Poli	3836	3355	481	12.54%	90.44%	9.56%	28.07%	17.46%	12.89%	0.00%	2.08%	0.00%	1.04%	4.57%	4.78%	0.83%	0.21%	0.00%	1.25%	0.42%	5.20%	0.42%	13.93%	1.25%	2.08%	1.25%
OOG	Poli	4859	4163	696	14.32%	88.65%	11.35%	60.06%	48.42%	2.59%	0.00%	7.18%	1.29%	1.01%	11.64%	3.88%	1.72%	0.29%	0.00%	0.72%	0.86%	7.61%	0.00%	13.51%	1.44%	4.60%	1.01%
ORTHO	Poli	972	850	122	12.55%	85.25%	14.75%	21.31%	4.10%	3.28%	0.00%	10.66%	0.00%	2.46%	4.10%	2.46%	0.00%	0.82%	0.00%	0.00%	0.00%	10.66%	0.82%	10.66%	3.28%	0.00%	2.46%
SPOED	Poli	21910	21910	0	0.00%																						
VPL	Poli	2248	2134	114	5.07%	90.35%	9.65%	46.49%	43.86%	0.00%	0.88%	12.28%	2.63%	1.75%	7.89%	5.26%	0.88%	0.00%	0.00%	0.88%	1.75%	7.02%	0.88%	11.40%	0.00%	3.51%	0.88%
ENDO	Poli	1908	1587	321	16.82%	91.28%	8.72%	38.32%	38.94%	5.92%	1.25%	5.61%	0.93%	1.25%	7.48%	5.61%	1.25%	0.00%	0.00%	0.62%	1.56%	9.03%	0.00%	16.51%	0.93%	3.12%	2.18%
DERM	Poli	2837	2255	582	20.51%	90.03%	9.97%	47.94%	36.60%	1.55%	0.00%	8.59%	0.17%	1.37%	9.11%	3.78%	0.17%	0.00%	0.00%	0.52%	1.20%	9.45%	0.17%	16.15%	1.72%	3.09%	2.06%
GAHE	Poli	1980	1584	396	20.00%	92.17%	7.83%	39.14%	33.08%	4.04%	0.51%	6.31%	0.76%	1.52%	9.34%	7.07%	1.26%	0.25%	0.00%	0.51%	1.01%	9.09%	0.25%	12.12%	0.76%	4.04%	3.28%
HEMA	Poli	1443	1222	221	15.32%	89.59%	10.41%	32.13%	25.34%	7.24%	0.90%	8.14%	1.81%	0.90%	6.33%	5.88%	2.26%	0.45%	0.00%	0.00%	1.36%	10.41%	1.36%	14.93%	0.00%	2.71%	2.71%
URO	Poli	1821	1492	329	18.07%	85.71%	14.29%	39.51%	30.40%	4.86%	1.22%	11.85%	0.30%	1.52%	7.29%	6.69%	2.13%	0.30%	0.00%	0.30%	0.30%	6.99%	0.91%	14.29%	0.61%	3.95%	1.82%
ALG_INT	Poli	947	760	187	19.75%	87.17%	12.83%	41.71%	31.55%	4.28%	0.53%	9.63%	1.07%	0.00%	10.70%	5.35%	3.21%	0.00%	0.00%	1.07%	1.60%	4.81%	0.00%	10.70%	2.14%	5.35%	2.14%
VBD	Poli	6225	5697	528	8.48%	81.25%	18.75%	50.95%	37.88%	7.77%	0.19%	11.93%	0.95%	0.95%	5.68%	4.92%	0.95%	0.38%	0.00%	0.38%	0.19%	6.63%	0.19%	12.12%	1.70%	2.46%	0.95%
	SA	2945	2467	478	16.23%	41.84%	58.16%	1.88%	8.16%	1.05%	2.51%	1.88%	0.42%	0.21%	3.35%	3.77%	0.00%	1.05%	0.00%	0.00%	1.05%	10.46%	0.00%	5.44%	0.42%	24.06%	3.97%
RAD	Poli	352	334	18	5.11%	66.67%	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.56%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	11.11%	0.00%	0.00%	0.00%	0.00%	27.78%	0.00%
	NuclDiagn	352	335	17	4.83%	64.71%	35.29%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	5.88%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	11.76%	0.00%	0.00%	0.00%	0.00%	23.53%	0.00%
	MRI	2911	2245	666	22.88%	48.50%	51.50%	11.26%	26.43%	3.00%	2.10%	3.30%	1.50%	0.45%	4.35%	7.51%	1.35%	0.60%	0.00%	0.15%	0.30%	8.71%	0.00%	4.35%	0.15%	35.29%	3.45%
	RTC	2231	2160	71	3.18%	63.38%	36.62%	0.00%	0.00%	2.82%	5.63%	0.00%	0.00%	0.00%	1.41%	2.82%	0.00%	0.00%	0.00%	0.00%	0.00%	1.41%	0.00%	8.45%	1.41%	0.00%	0.00%
	CT	3843	3119	724	18.84%	49.45%	50.55%	5.11%	25.00%	2.35%	1.10%	1.66%	2.07%	1.66%	2.21%	3.73%	0.69%	0.28%	0.00%	0.41%	0.97%	7.87%	0.14%	5.39%	0.28%	40.75%	3.73%
	ECHOPD	219	201	18	8.22%	5.56%	94.44%	5.56%	5.56%	11.11%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	11.11%	0.00%	33.33%	5.56%
	ECHOGD	7806	7276	530	6.79%	2.45%	97.55%	29.25%	30.94%	1.32%	0.00%	0.94%	0.38%	0.75%	3.21%	1.51%	0.75%	0.00%	0.00%	0.38%	1.51%	3.02%	0.00%	2.26%	0.57%	30.57%	0.94%
	XRAYPD	2495	2424	71	2.85%	2.82%	97.18%	52.11%	35.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.82%	0.00%	12.68%	1.41%
	XRAYGD	4418	4298	120	2.72%	2.50%	97.50%	19.17%	22.50%	0.00%	0.83%	0.83%	0.00%	2.50%	0.83%	1.67%	0.00%	0.00%	0.00%	0.00%	0.00%	5.83%	0.00%	5.83%	0.00%	23.33%	0.00%
	FLUOR	2444	2407	37	1.51%	0.00%	100.00%	24.32%	24.32%	0.00%	0.00%	2.70%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.11%	0.00%	16.22%	0.00%
Grand Total		114715	101666	13049	15.19%	65.73%	34.27%	27.69%	24.88%	2.78%	0.86%	4.44%	1.00%	1.74%	4.77%	3.50%	0.88%	0.37%	0.02%	0.36%	1.76%	8.13%	0.16%	12.02%	0.65%	9.38%	2.42%

2.3.3 Patient arrival process

In execution of the problem identification, many employees reported the delay of owners and patients and the negative impact it has on the operationalisation of the schedule. In addition to this, many employees reported peaks in the arrivals of patients on certain times and weekdays at telephony and the front desk. For these reasons, we analysed the patient arrival process. The patient arrival process consist of three parts: the arrival of patients (1), the on-time arrival of patients at the hospital for their appointments (2) and the check-in time of patients at the hospital (3).

Arrival of patients

For the arrival of patients, NP appointments are analysed on their monthly, weekly and weekday seasonality, cycle index (periodically) and trend. The yearly, monthly and weekly demand is portrayed with figures in Appendix I for elective appointments and in Appendix J for Extern, Emergency, Cancellations appointments. In Figure 2.3.5, the total demand of elective patients per year per departments is presented to visualise the yearly trends.

We make the following observations on (yearly) demand trends:

- The number of cancellations has increased steadily over the four year period for most care processes, with the exception of CHIR's outpatient clinical consult care processes. In particular at the care process *SA* at ANE, the number of cancellations has tripled in this period.
- The number of extern appointments treated on care processes *MRI* and *ECHO_GD* decreased drastically (30% and 50% respectively).
- The number of emergency appointments have drastically increased from 2016 to 2017 at care process *SPOED_Poli*, however this can be explained by changes made to the planning. For this reason we exclude year 2016's production numbers in the estimation of the parameters for a representative patient arrival process for *SPOED_Poli*.
- The total number of elective appointments has increased steadily over the four year period for most care processes. The total demand of departments can be found in figure
- Care process *CHIR_algemeen_Poli* has decreased over the years significantly in its demand. This has to do with the different way of scheduling appointments at CHIR.

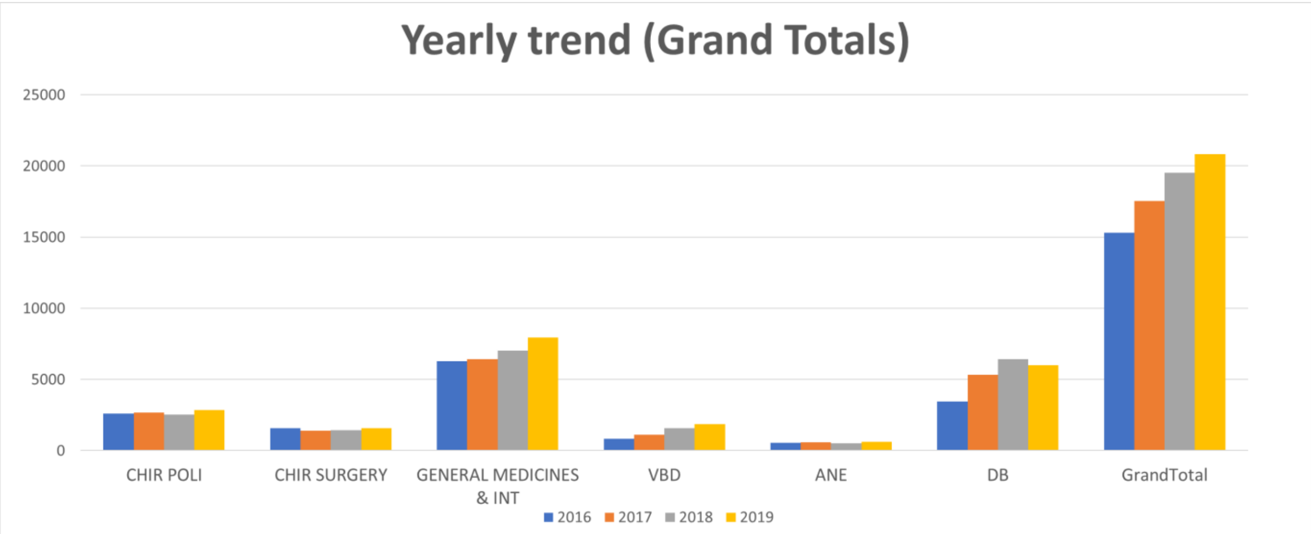

Figure 2.3.5 Total demand of elective (NP) appointments for each department each year. N: 73.224 elective appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

We make the following observations on monthly and weekly demand seasonality:

- We observe a periodic cycle where the demand drops drastically during the new year periods as the hospital is partly closed (see Figure 2.3.6). We exclude this period (week 1, week 52 and, if existing, week 53) in further analysis of patient arrival process.
- We find a peak in demand in week 1 and week 52 in the number of emergencies as most other clinics are closed and the demand is directed to UKG.
- We observe no obvious monthly and weekly seasonality's in the demand. However, at most care processes the weekly demand is very variable and sometimes sporadic.

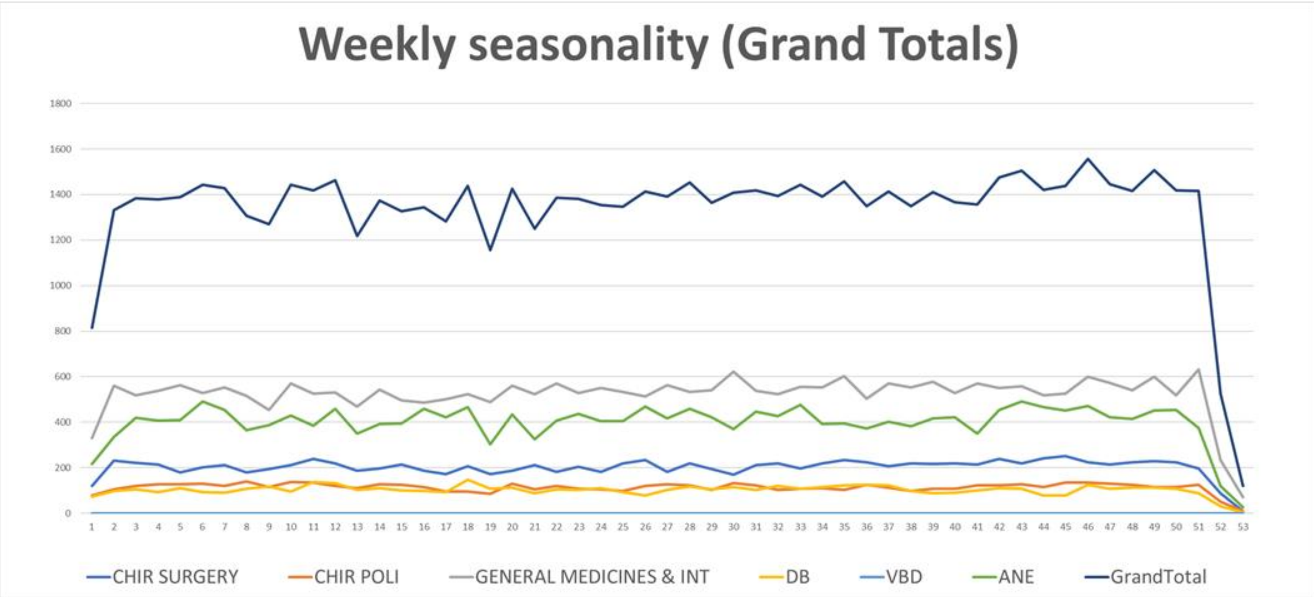

Figure 2.3.6 Weekly average demand of NP appointments per department. N: 114.715 appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

In the analysis of weekday seasonality, we are interested in NP appointments only. Most of the CP appointments are correlated with the arrival and timing of the first appointment of the clinical pathway or, if existing, the previous CP appointment.

Furthermore, in the analyses of weekday seasonality's, we may not use the actual day an appointment is realized. The day of the appointments are strongly correlated with the production schedule that was is in place at the time of the appointment. Thus, this data is not a useable to analyse the arrival process. However, we may use the recorded scheduling day of the appointment and set it as the arrival day. Then we make the assumption that NP appointments are immediately scheduled at the moment of first contact with the owners. This also implies that we consider the time of scheduling to be equal to the arrival time of the demand.

In Appendix K the patients arrivals of NP appointments per weekday per appointment type per appointment are presented. Some relations between the production numbers and the 'as-is' production schedule can still be observed, as many appointments are scheduled in consultation with specialists on the days at which their care process is operated. After analysing different appointments and to reduce the dependency on the production schedule, we clustered the appointments into 9 different patient arrivals that have similar hourly and weekday seasonality's, and appointment characteristics.

The 9 different patient arrivals are:

- Elective outpatient clinical consults (*Poli_El_Patients*)
- Elective remaining appointments (*Remaining_El_Patients*)
- External patients (*Extern_Patients*)
- Emergency outpatient clinical consults at SPOED_Poli (*SPOED_Poli_Em_Patients*)
- Emergency remaining outpatient clinical consults (*Poli_Em_Patients*)
- Emergency CHIR_OVERIG(2) surgeries (CHIR_overig2_OR_em_Patients)
- Emergency remaining appointments (*Remaining_Em_Patients*)
- Cancellation outpatient clinical consults (Cancellations_Poli)
- Cancellation remaining appointments (Cancellations_Remaining)

According to Case Manager CHIR, two employees at the front desk and one veterinarian at the emergency outpatient clinic is the arrival of *emergency* patients at *SPOED_Poli* in particular sensitive to both the time of day and weekdays. We observed this in our data analyses too. In Figure 2.3.7 the arrival rate per hour for each weekday as a fraction of the total average arrivals per week can found for the *SPOED_Poli*.

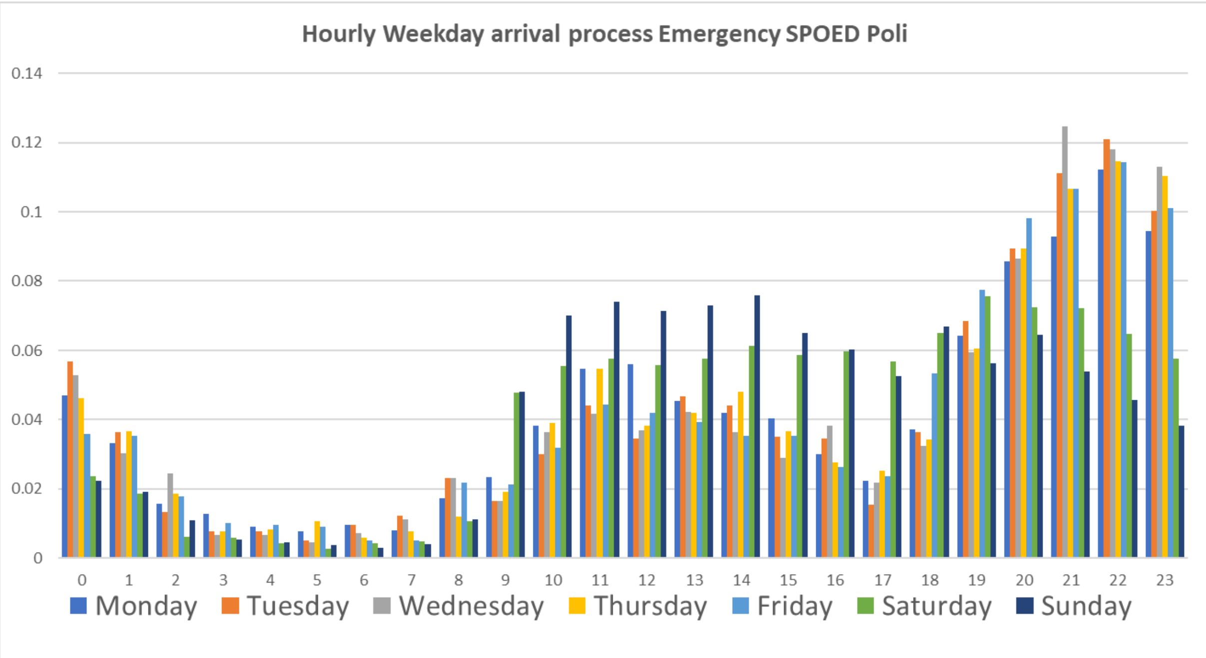

Figure 2.3.7 Hourly arrival rate as a fraction of the total weekly average demand per weekday for care process SPOED_Poli. N: 26.821 emergency appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

The hourly distributions were validated with a veterinarian at *SPOED_Poli*. According to the veterinarian, weekend days (Saturday and Sunday) should have roughly quadruple the production numbers when compared to mid-week days (Monday up to and including Friday). We observe roughly double the production numbers and have tried to clarify why there is a deviation. We counted the mid-week production numbers and weekend day production numbers for 8 different weeks, 6 months between each week of counting. We found a little more than double the production numbers in weekend days. If we consider the total production numbers (NP and CP combined) instead of looking only at NP appointments as we did in *Appendix 11* we make the same observation.

For the *SPOED_Poli* patient arrival, we observe in particular high arrival rates after 19:00 until 24:00 when other veterinarian clinics are closed. We see low arrival rates during midnight hours, early in the morning and around 17:00.

Other patient arrivals tend to be sensitive to the time of day and weekdays. The arrival rate per hour and per weekday are not strongly correlated. The weekday arrival rates can be found in Figure 2.3.8 and the hourly patient arrival rates can be found in Figure 2.3.9.

Our main observations are on weekday and hourly seasonality are:

- Most of the outpatient clinical consults are, if clustered, observed to be relatively many at the start of the week (Monday), decreasing over the week (Tuesday, Wednesday, Thursday) and increasing at the end of the week (Friday). One surgeon, a veterinarian of INT and two employees at Telephony ratify this distribution and argument that many owners call at the end of the week, quickly before the start of the weekend, and at start of a new week, after the weekend has ended.
- Hourly arrival rates peak in the morning for most patient arrivals. After opening, arrival rates peak around 9:00-10:00 and then decreases over time.

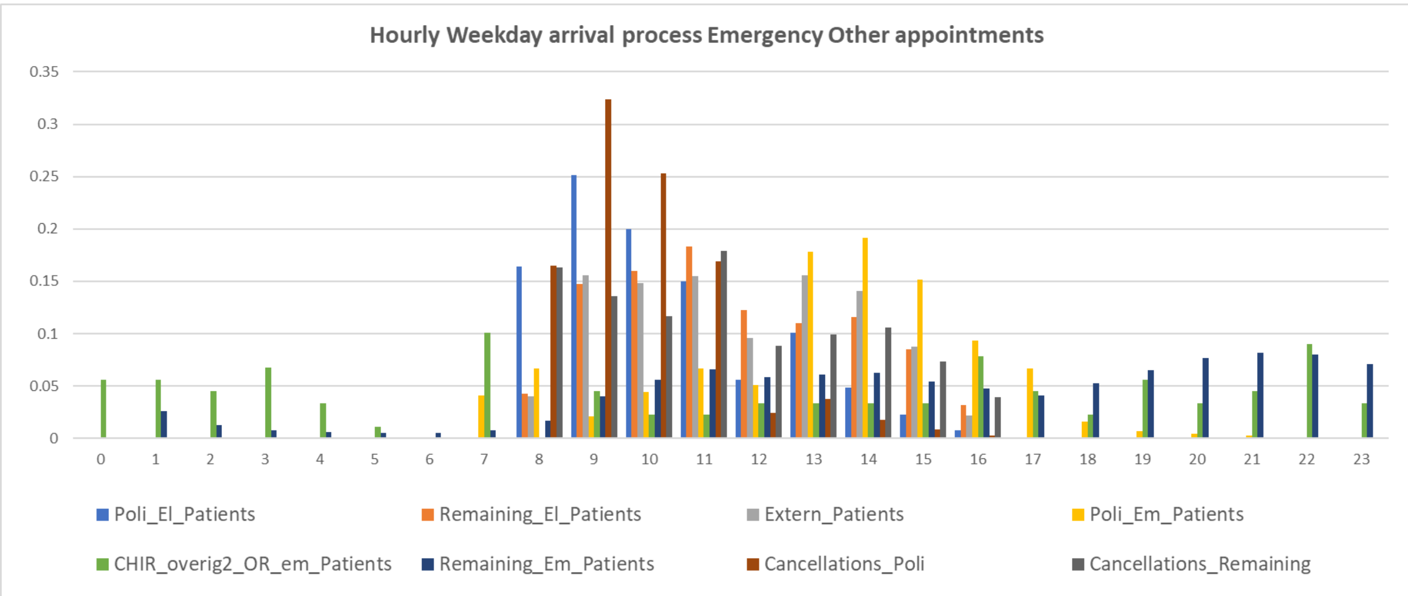

Figure 2.3.8 Hourly arrival rate as a fraction of the total weekly average demand on any day. N: 114.715 appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

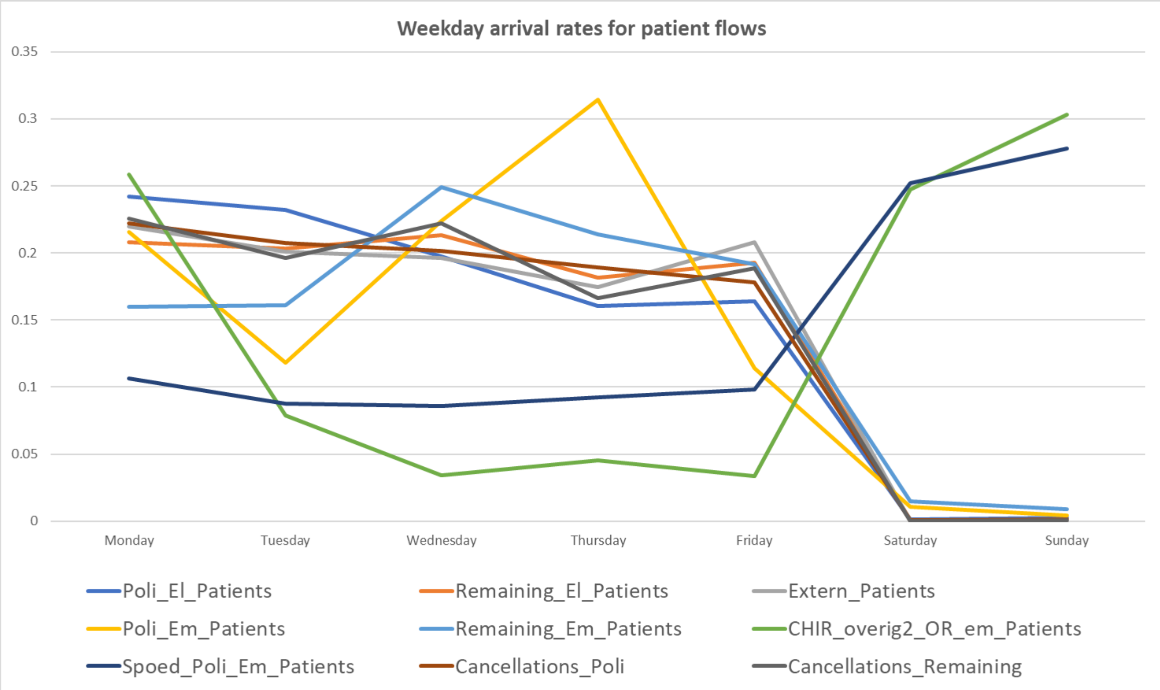

Figure 2.3.9 Weekday arrival rate as a fraction of the total weekly average demand. N: 114.715 appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

The demand per week (and per day) has been reported by employees to be very stochastic. To express this variability, we may use descriptive statistics like the standard deviation. The standard deviation is especially useful since the weekly demand is observed to be normally distributed over all weeks. The weekly average demand and the standard deviation of this demand are presented in Table 2.3.5 per appointment type per appointment. The design of this table is similar to the tables of Section 2.3.1. We may think of the standard deviation as the average deviation of the demand's mean.

A high standard deviation in comparison to the average demand describes high variability in the demand and may be the cause of many short-term inefficiencies. On the contrast, a lower demand variability describes a more constant demand. Many measures have impact on how the demand variability affects the performance of the hospital. By reducing the demand variability, short-term inefficiencies are reduced and we may, for example, find a better way to utilize the available resources.

In Table 2.3.5 we observe high standard deviations of the demand at the outpatient clinical consults. In particular the emergency arrival at *SPOED_Poli* has a high standard deviation (47.0 with an average weekly demand of 102.5) and the same counts for elective arrivals of appointments *NEURO_Poli, VPL_Poli* and *VBD_Poli*.

Most outpatient clinical consults exist of single NP appointments. Therefore we expect they are little affected by the variability in the demand at other care processes and more by the variability in the demand of NP appointments at their own care process. This is in contrast to appointments at DB or CHIR's surgery department who mostly treat CP appointments. Here, we find appointments such as *ECHO_PD, ECHO_GD*, *X_RAY_PD* and *X_RAY_GD* with high standard deviations relative to their weekly average demand. Appointments with relatively low weekly demand have a high standard deviation, commonly higher than their weekly average demand. Their demand tends to be distributed sporadically.

Table 2.3.5 Average demand per week and standard deviation (variability of the demand) for each appointment and appointment type. Cells may contain up to four values, from left to right: Elective, Extern, Emergency, Cancellation. The grand total (all appointment types) can be found in the last cell of the columns. N: 114.715 appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

			Weekly Averages & Standard Deviations									
			Total Average Demand					Total Standard Deviation				
CHIR	**CHIR_THK**	**Poli**	2.5			1.0	3.5	2.0		0.2	1.3	2.8
	CHIR_Overig(1)	**Poli**	2.3			0.1	2.4	3.5			0.3	3.6
	CHIR_Overig(2)	**Poli**	6.5		0.2	4.8	11.5	4.2		0.5	3.1	6.3
	CHIR_algemeen	**Poli**	20.3		0.1	4.5	24.9	11.0		0.4	3.0	13.3
	CHIR_KNO	**Poli**	5.4			0.8	6.3	3.3		0.2	1.0	3.7
	CHIR_ONCO	**Poli**	1.8			0.5	2.3	2.4		0.1	0.9	2.8
	CHIR_ORTHO_NEURO	**Poli**	11.2			1.7	12.9	6.0		0.1	1.6	7.0
	CHIR_URO_LEVER	**Poli**	2.3			0.6	3.0	1.8		0.2	0.9	2.2
	CHIR_THK	**Surgery**	3.5		0.2	1.3	5.0	2.1		0.5	1.3	2.8
	CHIR_Overig(1)	**Surgery**	0.7		0.1	0.1	0.9	0.9		0.4	0.3	1.1
	CHIR_Overig(2)	**Surgery**	4.6		3.6	1.4	9.6	2.5		2.2	1.2	3.7
	CHIR_KNO	**Surgery**	2.6		0.7	1.1	4.4	1.7		1.0	1.1	2.4
	CHIR_ONCO	**Surgery**	1.3		0.1	0.5	1.9	1.1		0.3	0.7	1.5
	CHIR_ORTHO_NEURO	**Surgery**	5.6		0.8	2.1	8.5	2.2		1.0	1.7	3.0
	CHIR_URO_LEVER	**Surgery**	4.2		1.1	1.7	7.0	2.0		1.2	1.4	2.7
	CHIR_OVE	**Surgery**	3.9		0.4	2.1	6.4	1.8	0.1	0.6	1.7	2.6
	CHIR_OOG	**Surgery**	2.9		0.1	0.6	3.6	1.5		0.3	0.8	1.7
General Medicines & INT	**GEDRAG**	**Poli**	1.4			0.5	2.0	0.9			0.7	1.3
	OVERIGEPOLI	**Poli**	14.3		0.4	0.1	14.8	9.2		1.2	0.5	9.9
	VOEDING	**Poli**	0.5				0.5	1.0			0.2	1.0
	CARDIO	**Poli**	12.3		0.9	2.2	15.3	4.1		1.1	1.4	4.9
	NEUR	**Poli**	15.0		0.1	3.2	18.3	9.2		0.3	2.6	10.9
	ONCO	**Poli**	16.2		0.1	2.3	18.6	3.6		0.2	1.7	4.1
	OOG	**Poli**	18.4		2.0	3.4	23.8	4.4		2.8	2.2	6.6
	ORTHO	**Poli**	3.8		0.3	0.6	4.7	3.6		0.7	0.9	4.3
	SPOED	**Poli**			102.5		102.5			47.0		47.0
	VPL	**Poli**	10.3		0.1	0.6	10.9	4.2		0.4	0.7	4.3
	ENDO	**Poli**	7.6		0.2	1.6	9.4	2.5		0.4	1.2	2.9
	DERM	**Poli**	11.0			2.8	13.9	3.8		0.2	1.9	4.6
	GAHE	**Poli**	7.7		0.1	1.9	9.7	2.9		0.2	1.6	3.6
	HEMA	**Poli**	5.9		0.1	1.1	7.0	2.7		0.2	1.2	3.3
	URO	**Poli**	7.3			1.6	8.9	2.4		0.2	1.4	2.9
	ALG_INT	**Poli**	3.7			0.9	4.7	2.6		0.2	1.3	3.5
VBD	**VBD**	**Poli**	26.5		1.5	2.6	30.5	11.0		2.0	1.8	12.6
ANE		**SA**	11.1		1.0	2.4	14.5	3.8	0.2	1.1	2.0	4.6
DB	**RAD**	**Poli**	1.7			0.1	1.8	3.0			0.3	3.0
		Nucl_Diagn	1.6	0.1		0.1	1.8	2.9	0.3	0.2	0.3	3.0
		MRI	7.5	2.4	1.1	3.3	14.2	3.0	1.7	1.1	2.1	4.2
		RTC	10.3		0.1	0.3	10.8	6.0		0.7	1.0	6.0
		CT	12.5	2.0	0.8	3.5	18.8	3.7	1.5	0.9	2.1	5.0
		ECHO_PD	11.8	0.1	0.1	0.3	12.3	6.1	0.3	0.3	0.6	6.3
		ECHO_GD	27.8	2.9	5.0	2.6	38.3	11.0	2.1	3.0	2.6	13.8
		X_RAY_PD	11.6	0.2	0.1	0.2	12.1	6.3	0.5	0.3	0.4	6.5
		X_RAY_GD	18.5	0.2	2.5	0.6	21.8	9.8	0.5	2.1	0.9	11.3
		FLUOR	0.8		0.1	0.1	1.1	1.0	0.1	0.4	0.3	1.2
	Grand Total		358.6	7.8	126.5	63.9	556.9	56.4	3.3	49.5	15.4	101.9
Departments	**CHIR**	**Poli**	52.3		0.4	14.0	66.7	9.1		0.9	4.8	11.5
	CHIR	**Surgery**	29.3		7.0	10.9	47.2	5.8	0.1	3.3	3.8	8.1
	GENERAL MEDICINES & INT	**Poli**	135.4		106.7	22.9	265.0	21.2		47.1	6.9	59.2
	VBD	**Poli**	26.5		1.5	2.6	30.5	11.0		2.0	1.8	12.6
	ANE	**SA**	11.1		1.0	2.4	14.5	3.8	0.2	1.1	2.0	4.6
	DB		104.1	7.8	9.9	11.1	132.9	31.8	3.4	5.0	5.6	38.0

On-time arrival distributions

The on-time arrivals of owners and patients for appointments have been reported as impactful on the hospital's daily progression, with in particular at the outpatient clinic in the morning. See Section 1.4.7 for more information on the reported impact.

Since there are only substantial production numbers available for outpatient clinical consults with reliable on-time arrivals and the main interests lies here for on-time arrival distributions, we plotted only those and observed normal distributions at all outpatient clinical consults. In Figure 2.3.10 the on-time arrival distributions can be found for care processes *VBD_Poli, ENDO_Poli*, OOG_*Poli* and *URO_Poli* for both NP (left graphs) and CP arrivals (right graphs) and serve as examples.

The distinction made between NP and CP appointments for on-time arrival is relevant because several employees at the front desk emphasized the differences between these two. NP appointments are generally more and more often delayed than CP appointments.

In Table 2.3.6, the results of on-time arrival analysis can be found. A full detailed table with skewness, interquartile ranges, upper and lower bounds and more information can be found in Appendix L, an explanation of what data has been used in the analysis is also given in the appendix.

We observe close to only positive on-time arrival means. These represent average delays of the on-time arrival of patients and owners. The mean of these delays vary between appointments. Employees at the front desk estimated the average delay to be 15 minutes for outpatient clinical consults, with extremes up to 60 minutes with not many patients arriving on-time. These estimations are in-line with our results.

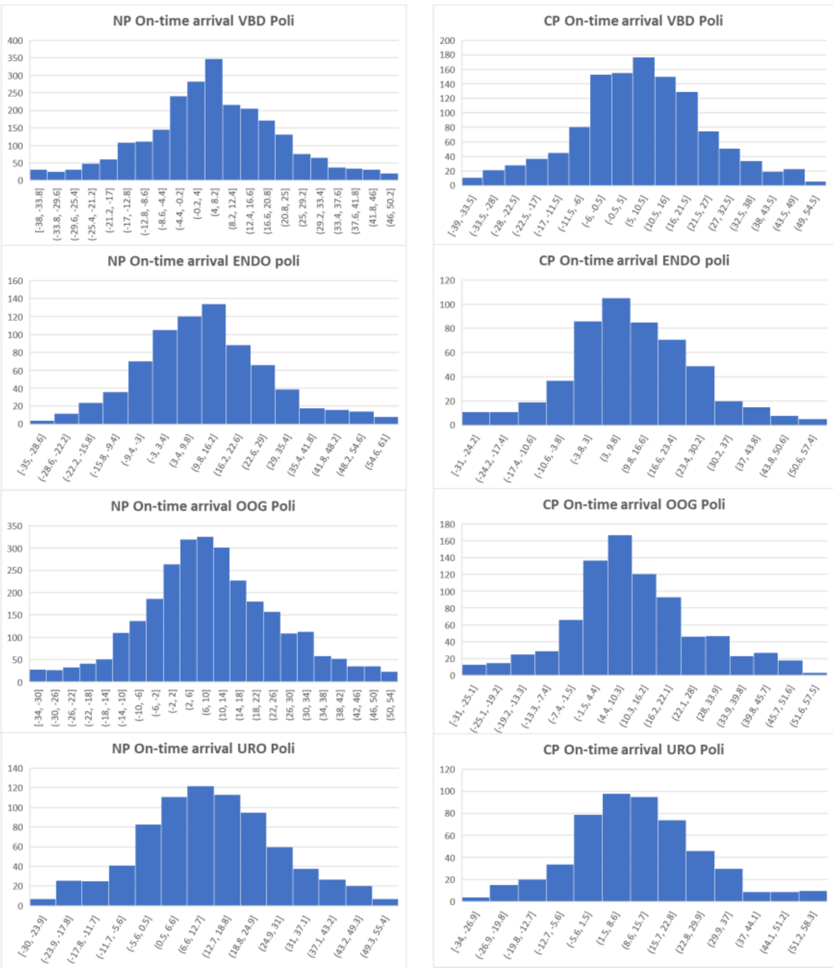

Figure 2.3.10 Examples of the on-time arrival distributions of NP patients (left graphs) and CP patients (right graphs). Extremes have been excluded. N: 8.392 appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

			Total occurrence	Total NP	Total CP	ALL Recorded arrival time	ALL Mean	ALL std.dev	NP Recorded arrival time	NP Mean	NP std.dev	CP Recorded arrival time	CP Mean	CP std.dev	Reliable ALL	Reliable NP	Reliable CP
CHIR	CHIR_THK	Poli	719	472	247	424	1:35	21:37	327	1:30	18:47	94	16:05	1:27			
	CHIR_Overig(1)	Poli	476	386	90	310	-6174.387	4:42	168	-5522.033898	21:57	140	-7042.55639	15:20			
	CHIR_Overig(2)	Poli	2365	820	1545	1104	22:26	9:10	272	11:19	20:41	829	17:56	21:53			
	CHIR_algemeen	Poli	5051	2197	2854	3683	5:06	14:29	1773	15:05	9:27	1895	17:32	10:56			
	CHIR_KNO	Poli	1302	262	1040	1071	6:47	14:14	247	8:19	8:15	818	22:11	9:25			
	CHIR_ONCO	Poli	473	268	205	340	21:10	21:41	217	7:44	12:28	120	16:58	16:17			
	CHIR_ORTHO_NEURO	Poli	2632	1140	1492	1901	17:25	16:08	893	18:40	14:00	1008	2:36	4:31			
	CHIR_URO_LEVER	Poli	610	306	304	443	17:10	12:47	251	11:33	7:11	190	23:00	3:51			
	CHIR_THK	Surgery	1022	245	777	451	11:39	2:04	135	20:50	3:38	314	9:01	1:39			
	CHIR_Overig(1)	Surgery	192	22	170	65	22:09	5:06	5	0:00	9:13	60	0:00	10:34			
	CHIR_Overig(2)	Surgery	1985	191	1794	529	0:35	17:56	45	11:28	18:32	485	9:50	1:07			
	CHIR_KNO	Surgery	900	65	835	424	9:57	5:10	28	0:46	6:20	394	12:49	22:50			
	CHIR_ONCO	Surgery	379	11	368	221	9:33	4:21	7	17:08	5:58	215	13:40	7:34			
	CHIR_ORTHO_NEURO	Surgery	1746	138	1608	709	6:56	4:26	61	2:17	3:04	652	9:08	16:30			
	CHIR_URO_LEVER	Surgery	1439	125	1314	569	10:22	21:29	55	12:24	21:34	511	14:47	1:48			
	CHIR_OVE	Surgery	1288	825	463	753	6:47	4:54	553	2:31	10:00	188	21:36	22:28			
	CHIR_OOG	Surgery	724	197	527	528	14:10	18:52	162	23:42	1:07	365	13:09	16:49			
Internal Medicines & INT	GEDRAG	Poli	396	359	37	266	1:15	18:27	256	21:00	21:08	10	0:00	2:49			
	OVERIGEPOLI	Poli	3040	2654	386	2566	4:29	19:48	2247	13:02	0:30	290	10:47	12:52			
	VOEDING	Poli	97	86	11	66	13:05	4:32	63	17:08	13:04	3	0:00	17:07			
	CARDIO	Poli	3140	2104	1036	2082	4:46	2:24	1541	14:48	4:52	567	2:58	21:22			
	NEUR	Poli	3737	2370	1367	2199	1:59	10:04	1697	9:15	22:18	483	13:32	2:52			
	ONCO	Poli	3836	899	2937	3056	16:42	5:10	743	5:38	1:28	2305	4:50	0:32			
	OOG	Poli	4859	3416	1443	3676	0:18	4:17	2821	0:06	2:16	855	0:50	9:47			
	ORTHO	Poli	972	479	493	620	13:09	23:46	341	16:19	5:18	274	9:17	9:33			
	SPOED	Poli	21910	19682	2228	18941	15:17	21:32	17329	16:31	15:09	1562	-5.18466899	7:59			
	VPL	Poli	2248	801	1447	1854	12:06	12:43	649	16:10	23:08	1215	22:15	1:38			
	ENDO	Poli	1908	1008	900	1287	0:53	6:43	751	19:34	11:41	531	3:34	2:23			
	DERM	Poli	2837	1191	1646	1871	10:36	15:45	844	15:06	18:05	1039	6:21	5:53			
	GAHE	Poli	1980	1043	937	1319	0:15	8:50	782	12:22	20:02	548	21:02	7:43			
	HEMA	Poli	1443	516	927	1061	9:16	20:10	406	19:43	12:24	655	1:38	20:13			
	URO	Poli	1821	961	860	1319	23:01	10:33	780	3:41	4:09	539	20:10	23:31			
	ALG_INT	Poli	947	516	431	587	3:16	20:11	370	3:49	14:05	211	8:31	7:56			
VBD	VBD	Poli	6225	3196	3029	3635	10:55	16:37	2418	21:40	15:40	1240	4:25	4:59			
ANE		SA	2945	146	2799	1069	20:20	16:29	37	17:30	4:28	1032	8:22	22:34			
DB	RAD	Poli	352	152	200	123	16:58	18:55	50	18:40	17:07	84	22:57	13:38			
		NuclDiagn	352	0	352	123	16:58	18:55				123	16:58	18:55			
		MRI	2911	676	2235	1747	2:39	3:02	557	22:31	21:16	1161	2:40	13:16			
		RTC	2231	18	2213	1323	6:54	12:15	13	6:32	15:09	1312	3:39	13:13			
		CT	3843	821	3022	1779	4:44	13:10	292	22:41	1:34	1481	8:37	9:43			
		ECHOPD	2495	1658	837												
		ECHOGD	7806	989	6817	2553	9:50	2:25	1526	17:55	6:20	1027	10:46	19:07			
		XRAYPD	2444	1792	652												
		XRAYGD	4418	249	4169	664	0:34	0:03	313	-2819.42492	21:17	351	4:30	11:12			
		FLUOR	219	24	195	75	14:24	11:19	13	16:36	17:05	62	19:21	21:48			

Table 2.3.6 On-Time arrival results (total/NP/CP appointments, total/NP/CP reported arrival times with means and standard deviations in minutes on the on-time arrival). The last three columns report the reliability of the data of all, NP and CP on-time arrival data. Negative mean arrival rate are presented in red in seconds (due to the limitations in the data analyses program). N: 8.392 appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

According to the Head of the patient administration (Department of telephony, case managers and front desk) a current measure is in place where patients are requested to arrive 10 minutes in advance of their appointment at which administrative tasks may take place. The effectiveness of this measure is unknown, but we conclude that delays of patient arrivals is problematic for the operationalisation.

Check-in time at front desk

The check-in times of NP and CP appointments at the front desk have been reported by employees to be different in duration. We observed the arrival of owners and patients at front desk for two mornings to find potential bottlenecks (e.g. queues that delay appointments). The check-in times for a total of 48 NP appointments and 56 CP appointments have been recorded. Additionally, three employees at the front desk have been requested to make a estimation of the check-in time of NP and CP patients. For the check-in times, the results are presented in Table 2.3.7. The average queue time was estimated to be roughly 4 minutes on average without major congestions.

	Average	Standard deviation	Lower bound	Upper bound	Distribution
NP	8 min	5 min	2 min	20 min	Normal dist.
CP	2 min	3 min	1 min	6 min	Normal dist.

Table 2.3.7 results of the check-in time analysis. N: 48 NP appointments, 56 CP appointments, T: Monday 3-2-2020 and Friday 7-2-2020, from 9:00-11:30, Source: Observations and recordings on check-in times at UKG's front desk.

2.3.4 Summary

In the previous sub-sections, we have answered research question 5: *How does the demand for resource capabilities look like?*. A summary of the results of the whole section is provided in Table 2.3.8 (CHIR's outpatient clinical consults), Table 2.3.9 (CHIR's surgeries), Table 2.3.10 (General Medicines' outpatient clinical consults), Table 2.3.11 (INT's and DERM's outpatient clinical consults) and Table 2.3.12 (DB's appointments, and grand totals and averages). We have summarized our main observations for each sub-section below.

In these tables, the following information can be found in the columns (from left to right):

- *Average Weekly demand,* this is the average weekly demand recorded over the four year period.
- *Standard Deviation weekly demand,* this is the average deviation recorded over all weekly demands. We may think of it as the average deviation of the demand's mean.
- *NP appointments,* this is the percentage of NP appointments as a fraction of all the appointments.
- *Single NP appointments*, this is the percentage single NP appointment (thus, a clinical pathway consisting of one appointment) as a fraction of all appointments.
- *Average path length*, this is the average path length (number of successive appointments) of clinical pathways starting with this appointment.
- *Standard deviation of cancellations*, this is the standard deviation recorded over weekly demands for only cancelled appointments. This describes whether there is a constant number of cancellations or the number of cancellations fluctuates greatly.
- *Percentage of Cancellations,* describes the percentage of all appointments that are cancellations.
- *Percentage of Cancellations that is NP,* describes the percentage of cancellations that are NP.
- *Percentage of Cancellations that is single NP appointments,* describes the percentage of cancellations that are single NP appointments (clinical pathway consisting of only one NP cancellation).
- *Percentage of Appointments that is OVB,* this is the percentage of all appointments that is classified as OVB (with reservation).
- *Percentage of appointments that is One-Stop-Shop,* this is the percentage of all appointments that is classified as One-Stop-shop.
- *Most frequent successive appointments...,* this is a selection of the most frequent successive appointments for the appointment. The percentages represent the fraction of all the appointments with the succeeding appointment.
- *Most frequent prior appointments…,* this is a selection of the most frequent prior appointments for the appointment. The percentages represent the fraction of all CP appointments that had the prior appointment.
- *Common duration of appointments*, this is a selection of the most common appointment durations recorded for both NP and CP appointments (read from left to right). Less but frequent common durations are presented within brackets.

In Section 2.3.1 we made the main observations and conclusions about **the production numbers**:

- We analysed 114.715 appointments (63.8% Elective, 1.4% Extern, 23.4% Emergency, 11.4% Cancellation).
- With the appointments, we designed 61.977 clinical pathways (54.0% NP, 46.0% CP).
- Most emergencies arrive at *SPOED_Poli* (81.7%).
- Most extern appointments arrive at *MRI* (30.4%), *CT* (24.9%) and *ECHO_GD* (36.9%). Remaining patients arrive other DB appointments (7.8%).
- Most cancellations of NP appointments (5.2%) of all appointments occur at outpatient clinical consults (roughly 10% of all outpatient clinical consults). Most cancellations of CP appointments (6.2% of all appointments), happen at surgeries (10% to 25% of the all surgeries), *MRI* (19.3%), *CT* (17.3%) and *SA* (15.5%). Cancellations of CP appointments at outpatient clinical consults commonly lay around 3% to 8% of the total appointments at these outpatient clinical consults.
- Most outpatient clinical consults have more NP appointments (average of 65.0%) than CP appointments. Most of the clinical pathways at the outpatient clinical consults consist of single NP appointments.
- Roughly 40% of the outpatient clinical consults are part of a clinical pathway consisting of only cancellations. We conclude that this demand was either non-existent or it was treated at other veterinarian clinics.
- Surgeries and appointments at DB have high rates of OVB appointments. In particular *MRI* (56.4% of all appointments), *CT* (48.1%) and *ECHO_GD* (23.9%) have high rates.
- Surgeries and appointments at DB have high rates of One-Stop-Shop appointments. In particular *MRI* (60.9%) and *CT* (65.1%) have high rates.
- Many appointments are succeeded by the same kind of appointment (mostly between 8% to 60% of the CP appointments).
- Many of CHIR's outpatient clinical consults are succeeded by surgeries at the same discipline (commonly 6% of all appointments). Subsequently, many of the surgeries are succeeded by outpatient clinical consults at the same discipline (commonly between 8% to 12% of all appointments).

In Section 2.3.2 we made the main observations and conclusions about **cancellations**:

- We analysed 114.715 and identified 13.049 cancellations (11.4% of all appointments). Cancellations are correctly cancelled in 65.7% of the time. Cancellations at the Echo's, X-Rays and Fluor are almost always incorrectly cancelled (between 94.5 and 100%). For other cancellations at DB and Surgeries at CHIR this lies between 22.4% and 73.9%. Incorrectly reported cancellations are difficult to identify. It would be valuable to standardise the reporting of cancellations throughout the hospital.
- Roughly 1/3th was identified with a known reason, another 1/3th was identified with a commented reason and 1/3th of the cancellations could not be identified by a reason. There is no finetuned system to report the reasons behind a cancellations. This is troublesome to identify and understand the motives behind cancellations.
- 'Moved', 'Another time', 'Owner cannot come' and 'Another clinic' are very frequent reasons (roughly 20% to 50% of the time) behind cancellations at non-DB appointments. We

conclude that this is caused by long waiting times in days and inefficient patient appointment planning processes (e.g. cost and date confirmation causes many adjustments to appointments times and dates). Reducing the waiting time for appointments and improve the patient appointment planning processes is expected to reduce the number of cancellations.

- ‘Via consult’ is the most frequent reason (roughly between 12% to 40% of the time) behind cancellations at DB. Most of the cancellations happen on a short-notice and cause short-term inefficiencies. Eliminating the scheduling ‘with reservation’ and thereby reducing these inefficiencies is promising to be very beneficial.

In Section 2.3.3 we made the main observations and conclusions about **the patient arrival process**:

- A steady increase in the total cancellations over the four year period, but constant in its proportion to all appointments. A decrease in the total external patients over the four year period at *MRI* and *ECHO_GD* (30% and 50% resp.). And a close to constant increase in the total elective patients over the four year period (roughly 2000 patients a year).
- We observe a yearly periodic cycle where demands drops drastically around new year in weeks 1 and 52 with the exception of emergency arrivals that increase drastically in this period.
- There is no obvious monthly and weekly seasonality observed.
- There is a clearly observable (week)daily and hourly seasonality. Hourly arrival distributions for *SPOED_Poli* are strongly correlated with weekdays. For other patient arrivals, this is not the case.
- Patient arrival rates for outpatient clinical consults peak on Mondays. Arrival rates decrease over the midweek and peak on Friday again. Emergencies peak in weekends (mornings and evenings). Emergencies peek in the midweek in the afternoon until midnight (19:00-24:00).
- The demand variability is reported and observed to be high in relation to the average weekly demand. This weekly demand is normally distributed over the weeks and for some appointments it is sporadic. Reducing the variability may have significant benefits to the hospital and may reduce short-term inefficiencies that is associated with variability in the demand.
- On-time arrivals are normally distributed and their mean is always positive, this refers to delays in the on-time arrivals. For many outpatient clinical consults, this delay is around 15 minutes.
- Check-in time at front desk is no major congestion for the operationalisation. Delayed arrivals of patients and owners are. No strong measures are in place to reduce these delays.

Table 2.3.8 Summary of the information presented in Section 2.3 for CHIR's outpatient clinical consults. N: 114.715 appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

			Average Weekly demand	Standard Deviation weekly demand	NP appointments	Single NP appointments	Average length pathway	Standard deviation of cancellations	Percentage cancellations	Percentage of cancellation that is NP	Percentage of cancellations that is single NP cancellation	Percentage of appointments that is OVB	Percentage of appointments that is One-Stop-Shop	Most frequent <u>successive</u> appointments after the appointment (in percentage as a fraction of <u>all appointments</u>)	Total appointments	Most frequent <u>prior</u> appointments before the appointment (in percentage as a fraction of <u>all CP appointments</u>)	Total CP appointments	Common duration of appointments
CHIR	**CHIR_THK**	**Poli**	3.5	2.8	74.5%	36.9%	1.9	1.3	27.7%	73.4%	41.2%	6.0%	3.3%	**CHIR_THK** (El: 35.7%, Can: 12.5%)	719	**CHIR_THK_Poli** (El: 7.7%) **CHIR_THK** (El: 30.6%, Can: 5.1%) **DERM_Poli** (El: 5.5%)	183	15
	CHIR_Overig(1)	**Poli**	2.4	3.6	49.6%	34.7%	1.5	0.3	2.7%	38.5%	23.1%	4.2%	12.6%	**X_RAY_GD** (El: 11.1%) **CARDIO_Poli** (El: 5%)	476	**CHIR_ORTHO_NEURO_Poli** (El: 4.6%) **X_RAY_GD** (El: 79.2%)	240	5 (10)
	CHIR_Overig(2)	**Poli**	11.5	6.3	42.9%	24.4%	2.0	3.1	41.2%	67.5%	45.6%	7.2%	5.7%	**CHIR_OVERIG(2)_Poli** (El: 18.3%)	2365	**CHIR_Overig(2)_Poli** (El: 32.0%, Can: 5.9%) **CHIR_Overig(2)** (El: 5.3%, Em: 3.0%) **SPOED_Poli** (Em: 7.9%) **SA** (El: 5.9%)	1350	45, 25, 30, 15
	CHIR_algemeen	**Poli**	24.9	13.3	48.6%	16.6%	3.1	3.0	17.9%	51.2%	22.9%	6.4%	3.7%	**CHIR_algemeen_Poli** (El: 15.1%, Can: 4.5%) **SA** (El: 7.1%) **CT** (El: 10.1%)	5051	**CHIR_algemeen_Poli** (El: 29.3%, Can: 8.7%) **CHIR_ORTHO_NEURO** (El: 5.2%) **ECHO_GD** (El: 6.0%) **X_RAY_GD** (El: 7.2%)	2595	45, 25 (30, 15)
	CHIR_KNO	**Poli**	6.3	3.7	22.7%	3.9%	4.7	1.0	13.4%	18.9%	6.3%	1.7%	1.5%	**CHIR_KNO_Poli** (El: 48.2%, Can: 8.1%) **SA** (El: 7.5%)	1302	**CHIR_KNO_Poli** (El: 62.5%, Can: 10.5%) **CHIR_KNO** (El: 5.8%) **SA** (El: 5.9%)	1007	45, 25
	CHIR_ONCO	**Poli**	2.3	2.8	63.8%	18.6%	3.5	0.9	22.6%	69.2%	37.4%	6.6%	3.8%	**CHIR_ONCO_Poli** (El: 7.4%) **CHIR_ONCO** (El: 6.8%) **SA** (El: 12.8%) **CT** (El: 19.5%, Can: 5.3%) **ECHO_GD** (El: 5.9%)	473	**CHIR_ONCO_Poli** (El: 20.5%, Can: 5.3%) **CHIR_ONCO** (El: 18.7%) **CT** (El: 4.7%) **ECHO_GD** (El: 5.3%) **X_RAY_GD** (El: 5.8%)	171	45 (25)
	CHIR_ORTHO_NEURO	**Poli**	12.9	7.0	45.5%	15.8%	3.1	1.6	13.4%	37.3%	15.3%	4.9%	3.7%	**CHIR_ORTHO_NEURO_Poli** (El: 7.4%) **CHIR_ORTHO_NEURO** (El: 5.1%) **SA** (El: 12.9%) **MRI** (El: 6.8%) **CT** (El: 8.%) **X_RAY_GD**(El: 7.6%)	2632	**CHIR_ORTHO_NEURO_Poli** (El: 13.7%, Can: 5.9%) **CHIR_ORTHO_NEURO** (El: 13.7%) **SA** (El: 6.0%) **X_RAY_GD** (El: 25.5%)	1435	45 (25, 5, 30)
	CHIR_URO_LEVER	**Poli**	3.0	2.2	55.7%	24.6%	2.3	0.9	20.5%	56.0%	28.8%	9.2%	2.6%	**CHIR_URO_LEVER_Poli** (El: 5.9%) **CHIR_URO_LEVER** (El: 12.6%) **SA** (El: 6.2%) **ECHO_GD** (El: 12.5%)	610	**CHIR_URO_LEVER_Poli** (El: 13.3%, Can: 5.6%) **CHIR_URO_LEVER** (El: 14.8%) **ECHO_GD** (El: 35.2%)	270	45 (25)

Table 2.3.9 Summary of the information presented in Section 2.3 for CHIR's surgeries. N: 114.715 appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

			Average Weekly demand	Standard Deviation weekly demand	NP appointments	Single NP appointments	Average length pathway	Standard deviation of cancellations	Percentage cancellations	Percentage of cancellations that is NP	Percentage of cancellations that is single NP cancellation	Percentage of appointments that is OVB	Percentage of appointments that is One-Stop-Shop	Most frequent <u>successive</u> appointments after the appointment (in percentage as a fraction of <u>all appointments</u>)	Total appointments	Most frequent <u>prior</u> appointments before the appointment (in percentage as a fraction of <u>all CP appointments</u>)	Total CP appointments	Common duration of appointments
CHIR	CHIR_THK	Surgery	5.0	2.8	32.6%	24.6%	1.6	1.3	26.4%	35.9%	27.0%	12.5%	55.8%	**CHIR_THK_Poli** (El: 5.5%) **CHIR_THK** (El: 5.4%)	1022	**CHIR_THK_Poli** (El: 37.3%, Can: 13.1%) **CHIR_THK** (El: 8.0%, Can: 3.5%) **GAHE_Poli** (El: 6.5%)	689	120, 90
	CHIR_Overig(1)	Surgery	0.9	1.1	10.4%	3.6%	3.9	0.3	12.0%	13.0%	4.3%	17.2%	57.8%	**CHIR_algemeen_Poli** (El: 7.5%) **CHIR_Overig(2)** (El: 4.7%) **ECHO_GD** (El: 4.2%) **X_RAY_GD** (El: 5.7%)	192	**CHIR_algemeen_Poli** (El: 22.7%) **OOG_Poli** (El: 7.0%) **SPOED_Poli** (Em: 12.7%) **ECHO_GD** (El: 9.3%)	172	45, 30
	CHIR_Overig(2)	Surgery	9.6	3.7	10.4%	6.1%	2.0	1.2	14.2%	12.8%	5.7%	14.8%	40.1%	**CHIR_algemeen_Poli** (El: 6.1%) **CHIR_Overig(2)** (El: 4.0%, Em: 4.2%)	1985	**CHIR_Overig(2)_Poli** (El: 4.9%) **CHIR_algemeen_Poli** (El: 6.7%) **CHIR_Overig(2)** (El: 4.5%, Em: 4.7%, Can: 2.9%) **SPOED_Poli** (Em: 30.1%) **CT** (El: 6.8%)	1779	180, 120, 150, 30
	CHIR_KNO	Surgery	4.4	2.4	8.2%	4.7%	2.0	1.1	24.7%	6.3%	3.2%	24.3%	45.0%	**CHIR_algemeen_Poli** (El: 6.8%) **CHIR_KNO_Poli** (El: 6.4%) **CHIR_KNO** (El: 3.8%, Can: 5.4%)	900	**CHIR_algemeen_Poli** (El: 10.2%) **CHIR_KNO_Poli** (El: 6.4%) **CHIR_KNO** (El: 4.1%, Can: 5.9%) **SPOED_Poli** (Em: 12.5%) **CT** (El: 21.1%, Can: 7.5%)	826	90, 60, 120, 180
	CHIR_ONCO	Surgery	1.9	1.5	3.4%	1.6%	4.5	0.7	25.9%	4.1%	1.0%	13.2%	13.5%	**CHIR_algemeen_Poli** (El: 15.6%%) **CHIR_Overig(2)** (El: 5.3%) **CHIR_ONCO_Poli** (El: 8.4%) **CHIR_ONCO** (El: 5.8%, Can: 8.4%)	379	**CHIR_algemeen__Poli** (El: 11.7%) **CHIR_ONCO_Poli** (El: 8.7%) **CHIR_ONCO** (El: 6.0%, Can: 8.7%) **CT** (El: 24.0%, Can: 3.6%) **ECHO_GD** (El: 4.9%)	366	180 (150, 240, 98)
	CHIR_ORTHO_NEURO	Surgery	8.5	3.0	9.1%	3.8%	2.8	1.7	25.1%	11.9%	5.5%	18.4%	21.2%	**CHIR_algemeen_Poli** (El: 7.7%) **CHIR_ORTHO_NEURO_Poli** (El: 11.2%) **CHIR_ORTHO_NEURO** (El: 4.1%, Can: 7.7%) **X_RAY_GD** (El: 8.8%)	1746	**CHIR_ORTHO_NEURO_Poli** (El: 8.5%) **CHIR_ORTHO_NEURO** (El: 4.5%, Can: 8.5%) **SPOED_Poli** (Em: 10.7%) **SA** (El: 5.1%) **MRI** (El: 10.3%) **CT** (El: 8.4%) **X_RAY_GD** (El: 14.2%)	1587	240, 260, 180, 150
	CHIR_URO_LEVER	Surgery	7.0	2.7	9.9%	4.9%	2.2	1.4	24.2%	14.1%	5.2%	26.6%	27.1%	**CHIR_algemeen_Poli** (El: 6.2%) **CHIR_URO_LEVER** (Em: 3.5%, Can: 5.8%) **ECHO_GD** (El: 6.5%)	1439	**CHIR_Overig(2)_Poli** (El: 6.0%) **CHIR_algemeen_Poli** (El: 7.4%) **CHIR_URO_LEVER_Poli** (El: 5.9%) **CHIR_URO_LEVER** (El: 3.9%, Can: 6.5%) **SPOED_Poli** (Em: 14.3%) **CT** (El: 5.8%) **ECHO_GD** (El: 6.6%)	1296	180, 150, 240, 90
	CHIR_OVE	Surgery	6.4	2.6	68.7%	55.5%	1.3	1.7	32.6%	66.0%	42.1%	5.6%	6.4%	**CHIR_OVE** (El: 3.6%, Can: 10.3%)	1288	**CHIR_OVE** (El: 11.7%, Can: 33.0%) **SPOED_Poli** (Em: 6.7%) **VPL_Poli** (El: 8.9%) **ECHO_GD** (El: 4.2%)	403	120, 60, 150, 90
	CHIR_OOG	Surgery	3.6	1.7	27.9%	19.1%	1.6	0.8	16.6%	20.8%	11.7%	9.4%	14.9%	**CHIR_OOG** (El: 4.6%, Can 3.7%) **OOG_Poli** (El: 19.5%)	724	**CHIR_OOG** (El: 6.3%, Can: 5.2%) **OOG_Poli** (Em: 61.1%, Em: 3.8%) **ECHO_GD** (El: 9.2%)	522	90, 75 (60, 120)

Table 2.3.10 Summary of the information presented in Section 2.3 for General Medicines outpatient clinical consults. N: 114.715 appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

General Medicines

		Average Weekly demand	Standard Deviation weekly demand	NP appointments	Single NP appointments	Average length pathway	Standard deviation of cancellations	Percentage cancellations	Percentage of cancellations that is NP	Percentage of cancellations that is single NP cancellation	Percentage of appointments that is OVB	Percentage of appointments that is One-Stop-Shop	Most frequent successive appointments after the appointment (in percentage as a fraction of all appointments)	Total appointments	Most frequent prior appointments before the appointment (in percentage as a fraction of all CP appointments)	Total CP appointments	Common duration of appointments
GEDRAG	Poli	2.0	1.3	96.2%	93.7%	1.0	0.7	27.0%	96.3%	93.5%	3.5%	0.3%		396	**GEDRAG_Poli** (El: 46.7%, Can: 13.3%)	15	90, 75 (60, 120)
OVERIGEPOLI	Poli	14.8	9.9	86.7%	81.5%	1.1	0.5	0.9%	50.0%	32.1%	8.1%	1.7%		3040	**OVERIGEPOLI_Poli** (El: 24.8%) **SA** (El: 12.9%) **ECHO_GD** (El: 7.7%) **X_RAY_GD** (El: 11.4%)	404	10, 15, 30
VOEDING	Poli	0.5	1.0	91.8%	83.5%	1.1	0.2	6.2%	#####	66.7%	41.2%		**VOEDING_Poli** (El: 5.2%)	97		8	60
CARDIO	Poli	15.3	4.9	70.5%	51.4%	1.6	1.4	14.2%	76.0%	64.9%	11.9%	4.7%	**CARDIO_Poli** (El: 8.4%)	3140	**CARDIO_Poli** (El: 28.5%) **SPOED_Poli** (Em: 17.9%) **ECHO_GD** (El: 5.2%) **X_RAY_GD** (El: 6.8%)	927	60 (30, 90)
NEUR	Poli	18.3	10.9	68.1%	30.3%	2.0	2.6	17.8%	72.4%	40.5%	8.5%	3.0%	**NEUR_Poli** (El: 13.8%) **MRI** (El: 24.6%, Can: 5.3%)	3737	**NEUR_Poli** (El: 43.1%, Can: 5.1%) **SPOED_Poli** (Em: 8.7%) **MRI** (El: 12.8%, Can: 5.8%)	1193	25, 15 (30)
ONCO	Poli	18.6	4.1	26.1%	9.0%	5.4	1.7	12.5%	40.1%	28.1%	2.9%	1.6%	**ONCO_Poli** (El: 51.6%) **CT** (El: 6.6%) **ECHO_GD** (El: 4.2%)	3836	**ONCO_Poli** (El: 69.7%, Can: 5.3%) **CT** (El: 4.8%) **ECHO_GD** (El: 5.4%)	2836	
OOG	Poli	23.8	6.6	73.7%	51.7%	1.6	2.2	14.3%	68.0%	60.1%	7.2%	5.2%	**CHIR_OOG** (El 6.6%) **OOG_Poli** (El: 12.2%)	4859	**CHIR_OOG** (El: 11.1%) **OOG_Poli** (El: 46.5%, Em: 4.0%, Can: 6.2%) **VBD_Poli** (El: 6.7%)	1276	30
ORTHO	Poli	4.7	4.3	53.3%	37.6%	2.1	0.9	12.6%	35.2%	21.3%	2.4%	3.9%	**ORTHO_Poli** (El: 30.7%) **CHIR_ORTHO_NEURO_Poli** (El: 5.1%)	972	**CHIR_ORTHO_NEURO_Poli** (El: 6.2%) **ORTHO_Poli** (El: 65.6%, Em: 4.4%, Can: 6.4%)	454	45, 30 (60)
SPOED	Poli	102.5	47.0	89.3%	72.8%	1.5					2.2%	2.1%	**SPOED_Poli** (Em: 5.5%)	21910	**SPOED_Poli** (Em: 51.7%) **ECHO_GD** (El: 8.8%, Em: 2.8%) **X_RAY_GD** (El: 3.8%, Em: 1.3%)	2345	30 60
VPL	Poli	10.9	4.3	36.3%	13.2%	3.3	0.7	5.1%	60.5%	46.5%	5.0%	2.4%	**VPL_Poli** (El: 47.9%) **ECHO_GD** (El: 12.4%)	2248	**VPL_Poli** (El: 75.2%) **ECHO_GD** (El: 15.1%)	1433	30, 10, 15

Table 2.3.11 Summary of the information presented in Section 2.3 for INT's and DERM's outpatient clinical consults. N: 114.715 appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

Group	Specialty	Type	Average Weekly demand	Standard Deviation weekly demand	NP appointments	Single NP appointments	Average length pathway	Standard deviation of cancellations	Percentage cancellations	Percentage of cancellations that is NP	Percentage of cancellations that is single NP cancellation	Percentage of appointments that is OVB	Percentage of appointments that is One-Stop-Shop	Most frequent <u>successive</u> appointments after the appointment (in percentage as a fraction of <u>all</u> appointments)	Total appointments	Most frequent <u>prior</u> appointments before the appointment (in percentage as a fraction of <u>all CP</u> appointments)	Total CP appointments	Common duration of appointments
INT & DERM	ENDO	Poli	9.4	2.9	57.7%	26.2%	2.2	1.2	16.8%	68.2%	38.3%	8.7%	3.3%	**ENDO_Pol**i (El: 17.9%) **CT** (El: 14.3%)	1908	**ENDO_Poli** (El: 42.4%, Em: 2.6%, Can: 7.1%) **SPOED_Poli** (Em: 5.3%) **CT** (El: 5.9%) **ECHO_GD** (El: 4.6%)	807	15, 30 (45, 60, 25, 45)
	DERM	Poli	13.9	4.6	48.1%	26.8%	2.2	1.9	20.5%	64.6%	47.9%	5.3%	4.2%	**DERM_Poli** (El: 31.2%, Can: 5.6%) **SA** (El: 5.5%)	2837	**DERM_Poli** (El: 60.1%, Can: 10.7%) **SA** (El: 5.5%)	1473	45 (60, 30)
	GAHE	Poli	9.7	3.6	56.6%	28.2%	2.3	1.6	20.0%	57.3%	39.1%	9.4%	6.6%	**GAHE_Poli** (El: 9.4%) **SA** (El: 7.7%) **ECHO_GD** (El: 11.1%)	1980	**SPOED_Poli** (Em: 6.0%) **GAHE_Poli** (El: 21.7%, Can: 6.2%) **HEMA_Poli** (El: 5.1%) **SA** (El: 4.4%) **ECHO_GD** (El: 17.7%)	860	25 (60, 30)
	HEMA	Poli	7.0	3.3	39.6%	18.3%	2.6	1.2	15.3%	49.8%	32.1%	7.1%	2.2%	**HEMA_Poli** (El: 26.8%) **ECHO_GD** (El: 6.9%)	1443	**SPOED_Poli** (Em: 11.9%) **HEMA_Poli** (El: 44.4%, Can: 5.3%) **ECHO_GD** (El: 6.3%)	872	25 (30)
	URO	Poli	8.9	2.9	56.8%	29.3%	2.3	1.4	18.1%	57.4%	39.5%	10.0%	3.8%	**URO_Poli** (El: 10.2%) **ECHO_GD** (El: 13.7%)	1821	**SPOED_Poli** (Em: 7.1%) **URO_Poli** (El: 23.5%, Can: 6.2%) **ECHO_GD** (El: 24.2%, Em: 4.2%, Can: 2.4%)	786	25 (30, 60)
	ALG_INT	Poli	4.7	3.5	59.1%	31.6%	2.1	1.3	19.7%	59.4%	41.7%	11.1%	4.9%	**ALG_INT_Poli** (El: 4.4%) **ECHO_GD** (El: 10.0%)	947	**SPOED_Poli** (Em: 9.3%) **HEMA_Poli** (El: 9.0%) **ALG_INT_Poli** (El: 10.9%) **ECHO_GD** (El: 15.2%) **X_RAY_GD** (El: 4.4%)	387	25 (30)
VBD	VBD	Poli	30.5	12.6	53.5%	36.9%	1.9	1.8	8.5%	65.5%	50.9%	3.2%	4.0%	**VBD_Poli** (El: 33.7%)	6225	**VBD_Poli** (El: 72.4%, Em: 5.5%, Can: 4.2%)	2892	45, 30
ANE		SA	14.5	4.6	5.2%	2.5%	2.8	2.0	16.2%	4.4%	1.9%	21.2%	80.4%	**X_RAY_GD** (El: 6.2%)	2945	**CHIR_algemeen_Poli** (El: 12.9%) **CHIR_ORTHO_NEURO_Poli** (El: 12.2%) **DERM_Poli** (El: 5.6%) **GAHE_Poli** (El: 5.4%)	2791	45, 30, 60

Table 2.3.12 Summary of the information presented in Section 2.3 for DB's appointments and the grand totals and averages at the bottom row. N: 114.715 appointments, T: *From 1-1-2016 up to and including 31-12-2019*, Source: *Vetware report 'OK verslagen'*.

			Average Weekly demand	Standard Deviation weekly demand	NP appointments	Single NP appointments	Average length pathway	Standard deviation of cancellations	Percentage cancellations	Percentage of cancellations that is NP	Percentage of cancellations that is single NP cancellation	Percentage of appointments that is OVB	Percentage of appointments that is One-Stop-Shop	Most frequent <u>successive</u> appointments after the appointment (in percentage as a fraction of <u>all appointments</u>)	Total appointments	Most frequent <u>prior</u> appointments before the appointment (in percentage as a fraction of <u>all CP appointments</u>)	Total CP appointments	Common duration of appointments
DB	RAD	Poli	1.8	3.0	43.5%	0.0%	3.6	0.3	5.1%	5.6%	0.0%	23.3%	40.6%	**Nucl_Diagn** (El: 92.3%)	352	**ENDO_Poli** (El: 7.0%) **SA** (El: 6.5%) **Nucl_Diagn** (El: 21.6%) **RTC** (El: 40.2%)	199	15
		Nucl_Diag	1.8	3.0	0.0%	0.0%	0.0	0.3	4.8%	0.0%	0.0%	23.3%	#####	**SA** (El: 20.2%) **RAD_Poli** (El: 12.2%) **RTC** (El: 21.9%)	352	**RAD_Poli** (El: 92.3%, Can: 4.8%)	352	15, 30
		MRI	14.2	4.2	25.3%	21.5%	1.4	2.1	22.9%	15.5%	11.3%	56.4%	60.9%	**CHIR_ORTHO_NEURO** (El: 5.6%) **NEUR_Poli** (El: 5.3%)	2911	**CHIR_algemeen_Poli** (El: 4.1%) **CHIR_ORTHO_NEURO_Poli** (El: 8.3%) **NEUR_Poli** (El: 42.3%, Can: 9.1%) **SPOED_Poli** (Em: 12.7%)	2175	75, 90, 60, 120
		RTC	10.8	6.0	0.9%	0.2%	###	1.0	3.2%	2.8%	0.0%	0.1%	10.4%	**RTC** (El: 79.1%) **ONCO_Poli** (El: 6.1%)	2231	**RTC** (El: 79.7%, Can: 2.4%)	2212	30 (15, 20, 25)
		CT	18.8	5.0	21.4%	17.0%	1.5	2.1	18.8%	8.3%	5.1%	48.1%	65.1%	**CHIR_KNO** (El: 4.5%)	3843	**CHIR_Overig** (El: 3.5%, Can: 2.5%) **CHIR_algemeen_Poli** (El: 16.9%, Can: 3.5%) **CHIR_ORTHO_NEURO_Poli** (El: 7.0%) **ONCO_Poli** (El: 8.4%) **SPOED_Poli** (Em: 5.0%) **ENDO_Poli** (El: 9.0%, Can: 1.5%) **VBD_Poli** (El: 6.6%)	3020	45, 60, 30
		ECHO_PD	12.3	6.3	71.2%	52.5%	1.4	0.6	8.2%	73.2%	5.6%	6.8%	9.5%	**ECHO_PD** (El: 8.9%) **X_RAY_PD** (El: 15.5%)	2495	**ECHO_PD** (El: 30.7%, Can: 1.5%) **X_RAY_PD** (El: 60.9%)	719	30, 45 (60, 75)
		ECHO_GD	38.3	13.8	50.1%	38.3%	1.5	2.6	6.8%	42.1%	29.2%	23.9%	24.9%		7806	**CHIR_algemeen_Poli** (El: 4.8%) **SPOED_Poli** (Em: 13.7%) **VPL_Poli** (El: 7.1%) **GAHE_Poli** (El: 5.6%) **URO_Poli** (El: 6.4%, Can: 1.1%) **ECHO_GD** (El: 5.9%, Em: 1.4%, Can: 1.1%) **X_RAY_GD** (El: 6.5%, Em: 1.4%)	3897	30 (45, 15, 60)
		X_RAY_PD	12.1	6.5	69.6%	45.0%	1.5	0.4	2.8%	56.8%	52.1%	5.1%	10.5%	**ECHO_PD** (El: 17.9%)	2444	**ECHO_PD** (El: 52.2%, Can: 1.1%)	742	30, 20, 15, 45
		X_RAY_GD	21.8	11.3	40.8%	21.8%	2.0	0.9	2.7%	33.3%	19.2%	6.2%	31.7%	**ECHO_GD** (El: 5.7%) **X_RAY_GD** (El: 4.2%)	4418	**CHIR_algemeen_Poli** (El: 5.8%, 1.1%) **CHIR_ORTHO_NEURO_Poli** (El: 7.6%, Can: 1.6%) **CHIR_ORTHO_NEURO** (El: 5.8%, Can: 1.7%) **SA** (El: 7.0%, Can: 1.1%) **ECHO_GD** (El: 9.6%, Em: 2.2%) **X_RAY_GD** (El: 7.1%)	2617	15 (25, 30)
		FLUOR	1.1	1.2	29.2%	12.3%	2.0	0.3	1.5%	22.2%	24.3%	19.6%	29.7%	**ECHO_GD** (El: 5.5%) **X_RAY_GD** (El: 8.7%)	219	**CARDIO_Poli** (El: 23.9%, Em: 1.3%, CanL 1.3%) **SPOED_Poli** (Em: 8.4%) **GAHE_Poli** (El: 6.5%, Can: 1.3%) **SA** (El: 7.1%, Can: 1.9%) **ECHO_GD** (El: 9.7%, Em: 1.3%) **X_RAY_GD** (El: 9.7%)	155	90, 30, 240
Grand Total			556.9	101.9	55.3%	67.9%	1.9	15.4	15.2%	45.7%	27.7%	10.7%	14.5%		114715		52738	

2.4 Key Performance Indicators

To establish a set of Key Performance Indicators (KPIs) to comprise the stakeholders objectives and evaluate alternative solutions in terms of performance, several conversations were held with employees from various departments and UKG's vision and business strategy was taken into account. This section will give an answer to research question 5: *How is the tactical planning of resources evaluated on its performance?*

Hospital Waiting Times (HWT)

Many human hospitals use *Throughput* or the *Length of Stay* as KPIs to evaluate the efficiency and unobstructedness of their patient flow. The KPIs cover both the efficiency of the hospital's treatments and the waiting time experienced by patients. As we are not interested in the efficiency of treatments, we only value the second part: the experienced waiting times.

From the moment an owner enters the hospital with their patient until their treatment starts, the owner of the patient experiences *Hospital Waiting time (HWT)* recorded in seconds. While this waiting time may only partially be perceived as waiting by the owner, e.g. when the owner arrives early it might not be bothered with waiting until the actual time of the appointment, it is still experienced as stressful for the patient. In the future, a KPI may be developed to measure the perceived waiting time by categorising and weighting different kind of waiting times. For now, we do not make any distinction between different types of waiting times.

We calculate the HWT for each appointment with the following formula:

$$HWT\ in\ seconds = Arrival\ time\ of\ patient - appointment\ time\ of\ patient$$

Appointment delays

If the patient is delayed or the patient flow is obstructed by another reason, it most likely to result in a delayed appointment. If some patients are delayed, it may delay other appointments and the obstructed patient flow is expressed by longer HWT's. However, if many of the patients are delayed, the daily routine is simply shifted forward by some time where most patients are treated still with acceptable HWT's. While this obstructed patient flow may not perceived by the patients as problematic, it can be experienced as very chaotic and inefficient by employees. Therefore, we want to reduce the number of delayed appointments as much as possible. Another objective is to provide a well-balanced workload with friendly and sufferable work conditions. If this implies a delay of most appointments, this will go hand in hand with the need of many ad-hoc tasks. To measure this obstructiveness from employees perspective, we measure the *average delay of delayed appointments*, the *average delay of all appointments*, *fraction of all appointments delayed*.

The above mentioned KPIs are calculated with the following formulas:

$$Average\ delay\ of\ delayed\ appointments\ in\ seconds = \frac{\sum_{i=N} Start\ time\ appointment\ i - scheduled\ start\ time\ of\ appointment\ i}{n}$$

$$Average\ delay\ of\ all\ appointments\ in\ seconds = \frac{\sum_{i=M} Start\ time\ appointment\ i - scheduled\ start\ time\ of\ appointment\ i}{m}$$

$$Fraction\ of\ all\ appointments\ delayed = \frac{n}{m}$$

Here, *M* is the set of finished appointments, *N* is a subset of *M* with finished delayed appointments, *m* is the total number of finished appointments and *n* is the total number of delayed appointments.

Appointment Waiting Times (AWT)

Another KPI is used to describe waiting times:: *Appointment Waiting Times (AWT)* recorded in days. This KPI is designed to cover the enormous value patients put in fast access to care. Many departments strive for a maximum desired or acceptable AWT for specific treatments and urgencies. Some expectation management is performed by the departments and can be described as follows:

- An owner expects an available appointment date for an outpatient clinical consult within one to three days. This is highly dependent on the urgency perceived by and preference of the owner. If the demand is created on the Friday or Saturday, most owners expect an available place for a consult the next Monday.
- CHIR strives to provide a treatment slot for surgeries within one week from the moment the demand is observed. For some surgeries, in particular less complex ones, an available treatment slot is desired the same day of the consult. The demand for surgeries is highly dependent on the AWT with many external veterinarian clinics facilitating shorter AWTs.
- Owners expect an as complete diagnosis as possible on the day of their consult. This is covered by the One-Stop-Shop principle and, according to many specialists, expected by many owners. Therefore, DB strives to treat patients on the same day of their consult and report the results within 24 hours.

The lower the average AWT, the higher the patient satisfaction. Additionally, longer AWT's have been reported to be correlated with more cancellations and less clientele as owners have time to consider other clinics that are cheaper or provide earlier treatment possibilities. Hence, we measure the *fraction of the appointments scheduled within acceptable AWT*.

We calculate the AWT for each appointment with the following formula:

$$\begin{aligned} AWT\ in\ days = {} & Scheduled\ treatment\ day\ of\ the\ appointment \\ & - First\ day\ from\ which\ the\ owner\ of\ the\ patient\ wanted\ to\ receive\ the\ care \end{aligned}$$

The fraction of the appointment scheduled within the acceptable AWT is calculated by:

$$Fraction\ of\ the\ appointments\ scheduled\ within\ acceptable\ AWT = \frac{n}{m}$$

Here, *m* is the total number of appointments and *n* is the number of appointments scheduled within the acceptable AWT (acceptable if AWT of appointment is smaller or equal to the acceptable AWT).

One-Stop-Shop satisfaction

Many owners expect a one-day diagnosis (or treatment) known as One-Stop-Shop. One-Stop-Shop is most common with owners visiting for an outpatient clinical consult in combination with a treatment at DB (e.g. a MRI). The appointment availability for One-Stop-Shop appointments is measured by counting *the fraction of One-Stop-Shop appointments treated as One-Stop-Shop from the total number of One-Stop-Shop appointments*.

We calculate this KPI for each <u>kind</u> of appointment (e.g. CHIR_THK_Poli) with the following formula:

$$Fraction\ of\ One-stop-shop\ satisfied = \frac{n}{m}$$

Here, *m* is the total number of One-Stop-Shop appointments and *n* is the number of One-Stop-Shop appointments treated as One-Stop-Shop (= treated on the same day of the previous appointment).

Capacity Utilisation

The utilisation of allocated resources is important to guarantee cost-efficient and affordable treatments. There is a strong trade-off between capacity utilisation and waiting times (Both AWT and HWT) that are in relation to the number of availability of appointment slots. Creating buffers of appointments or overscheduling capacity will increase the waiting times but may be beneficial for a more optimal use of the available capacity as appointments may be combined and a demand for the capacity is more certain. A goal is to find the optimal balance within this trade-off by aligning the demand for and supply of capacity with respect to the performance on the discussed KPIs.

At DB, the treatment costs for medical operations are based on last year's operating costs and production numbers. High production numbers are necessary to make certain treatments financially accountable. With the high number of cancellations and the mismatch in demand and supply between departments, DB experiences many gaps in their schedule.

For CHIR, the price of surgeries is highly dependent on the required materials and labour time. The operating costs for ORs is high, currently surgeons complain about the inefficient operationalization of the ORs. Surgeons frequently have to wait for proceedings performed by anaesthetists pre- and post-operative. Currently, ANE is the bottleneck for CHIR in terms of productivity at the ORs. However, many cancellations and gaps in the appointment planning can be observed at CHIR.

Capacity utilisation is measured for each care process with the following formula:

$$Capacity\ utilization = \frac{Total\ time\ occupied\ by\ treatments}{(Total\ opening\ time - Total\ break\ time)}$$

Balanced Workload

Employees prefer a balanced workload throughout their working hours with minimal peak workloads and a smooth unobstructed patient flow. Cancellations, the absence of patients and owners, and other deviations in the planning require ad-hoc tasks that aggregate the chaos, load of the experienced workload and decreases the productivity. Minimizing deviations in the planning and facilitating mechanics and measurements to deal with deviations is key for the patient flow and employees' well-being.

The workload is measured hourly for each individual weekday by monitoring the occupancy rate at care processes, the reception and the whole hospital. In addition to this, the obstruction of a care process in case of an ANE shortage is measured by hourly monitoring this obstructiveness for each weekday. We use the following formula:

$$Hourly\ workload = Hourly\ occupancy\ rate = \frac{Total\ time\ occupied\ by\ treatments\ in\ seconds}{3600}$$

The hourly workloads are used to calculate the balanced workload. We divide the maximum hourly workload that can be found (at some hour at some weekday) and divide it by the average workload of the week (for opening hours only).

Scoring system for the KPIs

In order to use the KPIs to evaluate alternative solutions or evaluate the performance of the 'as-is' situation, we may use a scoring system. We made many efforts to understand how some KPIs may be more vital to UKG than others (e.g. by weighting KPIs) and how to quantify scores (e.g. numerical, subjective, binary). Nevertheless, we encounter many obstacles in this process as a clearly defined business strategy and vision is lacking and the parts that are clearly defined are not univocally implemented in the operationalisation of the hospital. The undeveloped interest in comparing performance metrics at the UKG is understandable. The humane healthcare is under constant peer criticism of insurance companies and accreditation programs and the demand for transparency is high. UKG is little affected by these factors and is less developed in its facilities to measure and monitor KPIs. Yet, in order to come up with a useable scoring system, we consulted many employees to quantify the KPIs with performance goals and bottom-line performance boundaries. Most disciplines perform some expectation management for the KPIs, in particular for the KPI (acceptable) *AWT*. Most disciplines were also able to provide some estimation of a minimum performance on specific KPIs.

In Table 5.2.1, the boundaries and performance goals are quantified for all care processes and appointments. In the table, from the first red column on the left to the last red column on the right, we find the KPI boundaries:

1. Maximum *percentage AWT not satisfied* (thus, the fraction of the appointments not scheduled within the acceptable AWT)
2. Minimum *capacity utilisation* (for care processes).
3. Maximum *percentage of delayed appointments of all appointments* (for appointments).
4. Maximum average *HWT* (for care processes).

Adjacent to the boundaries, the first yellow column on the left to the last column on the right, we find the performance goals:

5. *Appointment Waiting Time* (*AWT*, for appointments).
6. *Capacity Utilisation* (for care processes).
7. *Balanced Workload* (for care processes).
8. *Hospital Waiting Time (HWT,* for care processes).
9. *Average Appointment Delays* (for care processes).
10. *One-Stop-Shop satisfaction* (for appointments).

In SectionProblem-solving method 3.3, we elaborate on how we use these KPI performance boundaries and goals in the solving phase.

Chapter 3 Theoretical background

In this chapter we give answer to the research question 6: *What solution approaches can be considered and used to solve the research problem?* and 7: *What models, heuristics, algorithms and/or methods may be used to guide the design and evaluation of improvements in the tactical allocation of resources and patient appointment planning processes?*

First an introduction and discussion of the problem's field and characteristics and how they stand in relation to existing literature in provided in Section 3.1. Simultaneously, we select a suitable modelling approach. The systematic approach to search and select literature can be found in Appendix T.

Next, we discuss several topics in Section -o with the aim to provide a theoretical understanding of the information that was used in the development of alternative solutions. For example, we discuss the act of Variability buffering.

In Section 3.3 we explain the problem-solving method used to guide the solving phase and take note of the important aspects that should be taken into consideration. At the end of this section, a set of alternative solutions is presented that is used to develop applicable solutions to the problem.

In Appendix V we present a discussion of the problem characteristics and solving phase from an economic point of view. This discussion was enacted after a discussion with an expert in econometrics and finance with a doctorate in topics such as Game Theory and Mathematical Modelling.

3.1 Problem characteristics, modelling approaches and modelling solution

Over the last decades, operations research is becoming increasingly more prevalent in the area of health service operations as they are becoming considerable more complex [1] and are progressively more characterized as enterprise-based operations instead that of health community-based operations [2]. Customers are becoming more critical and the healthcare's environment is becoming increasingly more competitive. Instead of optimizing the efficiency of resource usage, a shift towards organizing services from a customer perspective can be observed [3]. Patients are expecting equal, accessible and high quality care with high standards in waiting times, convenience (of the appointment planning systems) and hospitalization durations. This sought-after balance between services for the patients and efficiency for the provider(s) require stakeholders to make challenging trade-offs and other decision. In response, the need for new applications and tools to support decision making processes in the field of health service operations is filled by operations research.

Animal health service operations are both less and more complex when compared to humane. In animal health service operations, Insurance companies are less integrated, core processes are controlled by the organization itself and operated by hired employees instead of controlled by 'freelancing' specialists, and the standards of quality are less controlled and assessed by, e.g., accreditation programs. This simplifies the political struggle contained by the many conflicting interests between stakeholders and makes the organizational structure of animal health service operations to be more characterizes as that of industrial services. On the contrast, the relative high uncertainty and urgency that is associated with the patient flow aggregates the complexity of the healthcare system and complicates the efficient use of resources. Additionally, the extra level of ownership (pet owners) introduces a different ‘customer’ perspective as we know it in humane. Some of these differences from humane are: more aversion towards hospitalization of the patient (1), associated higher customer value for one-day diagnosis (2), more price-based and authorized decision making in the follow-up treatment of patients by owners (3) and relatively short (acceptable) waiting times for a diagnosis and the start of clinical treatment (4).

Operations research is widely applied to problems in the area of patient admission planning and tactical resource allocation in the healthcare [4]. The problem setting faced in this research can be described by a number of care processes (treatment units, e.g. consults or diagnostics) operated by (multiple) disciplines (*ONCO, THK, DB, ANE*, etc.) where patients with various clinical pathways (set of successive treatments) arrive to be scheduled on and served by these care processes and disciplines. Treatments are restricted to (a set of) care processes at which they can be treated and care processes are also constrained (e.g. by the hospital’s opening hours and the minimum number of treatment slots if operated). Uncertainties in the development and arrival of clinical pathways and other stochastic elements in the system are present. We aim to develop a more efficient and effective tactical resource allocation and patient admission planning by improving on the discussed KPIs. Generally, a number of shared and limited available resources like materials, facilities and devices can identified. The only resource type in the problem setting in this study that is identified to be constrained in its availability is treatment time (and slots).

Many of the discussed problem characteristics can be found in the classic job shop scheduling optimization problem. Here, a number of n jobs $J_1, J_2 \dots J_n$ (clinical pathways) with different processing times must be scheduled at a particular time on a number of m machines (care processes operated by disciplines). A job may be build-up of several operations O_1, O_2 … O_k (treatments). By adding a precedence constraint, operations within a job must be processed in a given order and only one operation in a job can be processed at the time. Commonly, the optimization objective is to minimize the maximum make span of process stations [ref to operations research book]. Since Job shop scheduling is NP-hard, heuristic algorithms can be used to design feasible and find (local, near) optimal solutions. While job shop scheduling contains the decision to schedule which operation when and where, our model deals with the additional decision to open which machine, when and for how long.

The presence of variable elements (e.g. non-elective patients (emergencies), unexpected treatments and fluctuations in the demand of elective patients) combined with the connectiveness of care processes that comes with clinical pathways results in a chain of resources that is embedded in a complex network of care processes. The variability in the supply and demand for resources in this network facilitates the bull-whip effect greatly [5]. We have observed the impact of this effect in the long waiting times, poor capacity utilisation, capacity shortages and the unbalanced workload. As we deal with a complex network of care processes, the optimization of isolated care processes (e.g. high capacity utilisation of operation rooms) can result in congestion at other healthcare processes (e.g. long waiting times for MRIs) and result in a suboptimal solution [10]. Instead, a wide-chain optimization approach for a (sub)set of interconnected healthcare processes is required to improve the flow of patients and reduce the impact on the overall chain [6,10].

One solution method that focusses on a more wide-chain optimization can be found in the development of a master surgical schedule (MSS) with block schedules for the department of surgery.

In humane hospitals, the Department of Surgery is often identified as the most influencing department for the workload for downstream departments and as the engine of the hospital [11, 12]. In [11], four stages for the planning and scheduling of ORs are identified:

"*The multiple stage process is used by many hospitals and starts with the long term allocation of OR time to the surgical specialties. This allocation, referred to as Stage 1, is a strategic decision that reflects patient demand patterns and the priorities defined by hospital management. From this strategic decision a MSS is developed which divides OR time (aggregated into blocks) amongst the specialties, known as stage 2. The specific assignment of patients to OR blocks within the MSS is commonly referred to as Stage 3. A fourth stage "addresses the monitoring and control of the OR activities" on the day of surgery."*

In the animal healthcare setting however, the department of surgery is not considered as the most expensive department and the primary department influencing the workload downstream. Rather Radiology and Anaesthesiology who are involved in roughly 80% of clinical pathways are at the core of the hospital. High resource availability in terms of treatment slots and time at these departments is important to maintain an unobstructed patient flow. However, Radiology's workload is highly dependent on other departments such as the outpatient clinic. How generally ORs influence the workload experienced by the Intensive Care Unit and are the most expensive, in this study the outpatient clinic influences the workload at Radiology while Radiology is the most expensive. This makes the development of block schedules for surgical specializations not the problem. Additionally, at what OR a surgery is performed is not considered as a hard-constraint in our problem. Only a hand full of surgeries must exclusively be performed by a specialist. Also, shared resources like ORs, equipment and devices are not perceived as problematic by specialists. Nevertheless, we may divide the available treatment time or slots available at Radiology among upstream departments or we may develop a MSS with block schedules for the outpatient clinic to analyse the workload at downstream departments.

A major limitation to this approach is the lack of consideration of variability-related phenomena embedded in the system, like the bullwhip effect. On strategic level, demand patterns can reflect the minimum required amount of resources that should be allocated to a care process. However, such a strategic decision struggles to take into account the variability in demand and supply for these resources. To cope with these fluctuations, solution methods require dynamic solutions (e.g. the re-allocation of resources) to reduce the impact of variability-related phenomena on a system. Many proposed models to develop a MSS or similar resource allocation plans assume 'steady state' given the schedules are cyclical for a long period of time. While our problem has characteristic of 'steady state' given the production schedule is a cyclical long-term plan restricted to change, we observe dynamic elements. For instance, disciplines may choose to close operation rooms, appointments may be cancelled, rescheduled to the next day and be replaced by other appointments, and surgeries may be postponed if an emergency arrives.

Paper [4] proposes a dynamic solution designed as a Mixed Integer Linear Program (MILP) that facilitates the mid-term re-allocation of resources based on newly acquired and previously missing information. However, since the clinical pathways of our patients become 'known' only a few hours to days in advance of their treatment, the proposed solutions to re-allocate resources are not applicable to our problem. Another model is Resource-Constrained (Project) Scheduling (RC(P)S) which deals with constrained availability in resources, the allocation of successive jobs and the variability in process times of jobs and available resources. Even with high certainty, this problem is NP-hard and therefor commonly solved by mathematical programming or simulation models [9].

In literature, models for resource allocation and patient admission planning are broadly categorized as analytical or simulation based [13]. Analytical models simplify the complex nature that is generally associated with health care systems. Examples of such analytical models are discussed in papers [11, 14]. While analytical models are more tractable, the simplification is less than ideal [16]. Simulation models are widely used to solve dynamic problems with finite planning horizons [4,10,15]. On the contrast, Analytical models and Mathematical Programming (MP) have proven to be suitable options to deal with steady state problems with infinite planning horizons. Queueing theory is often used to simulate queues to analyse waiting times but struggles where simulation models shine: the possibility of an imbalance between supply and demand and highly stochastic complex systems [15].

The development of simulation models is relatively more time consuming compared to that of analytical models. However, simulation models are able to capture the broad scope of complex system mechanics [11] and study unpredictable complicated consequences of actions [13]. Also, simulation models are able to evaluate the performance of alternative solutions and non-existing systems on many different objective functions, can provide visual insights, and are visually appealing and convincing. There are many variabilities within our system which adds to the complexity and stochasticity. Comparable systems are widely approached by discrete-event simulations that facilitate the implementation of stochasticity and provides a well-integrated approach [6]. For instance, flow probabilities, treatment durations and timings can be associated with successive care processes and disciplines and used to design and evaluate patient flows [7]. The design and use of clinical pathways in a network of resources to coordinate and realign care processes has been shown successful to cope with fluctuation-related phenomena (length of stay, waiting times, capacity utilisation) [8].

Summarizing, the resource allocation and patient admission planning problem of the current study has characteristics of a classic job shop scheduling problem with precedence constraint. The system is highly stochastic and therefor approached dynamically. Discrete-event simulation models have proven to be successful at covering the broad scope of complex (dynamic) stochastic systems that deal with variability-related phenomena. In conclusion, the use of an experimental discrete-event simulation model to study the job shop scheduling problem, evaluate alternative solutions (and explore non-existent systems) and to simulate variability-related phenomena is considered as a suitable modelling solution. This modelling approach is therefor used to solve the problem through simulation based optimisation, considering we can not predict interactions and their outcomes due to the complexity of the system at hand.

3.2 Information on alternative solutions

Previously, we coined the terms 'Bullwhip effect' and 'Portfolio effect'. In this section, those and other topics will be elaborated on to provide the theoretical background information that is used to developed most of the alternative solutions. We elaborate on the practical application of the Bullwhip effect, Portfolio effect and Variability buffering (Section 3.2.1). Then, we discuss the trade-off between *AWT* and *Capacity utilization* experienced in the system (Section 3.2.2). This is followed by a discussion of the practical use of using multiple service stations, the inefficiencies associated with breaks and short opening times, and how we may take into account (the mix of) appointment durations (Section 3.2.3). At last, we discuss how we may deal with short-term inefficiencies that come with the cancellation of appointments (Section 3.2.4).

3.2.1 Bullwhip effect, Portfolio effect and Variability buffering

The Bullwhip effect refers to increasingly variability in the supply (capacity) as a response to shifts in variability in the demand (appointments) as one moves further up in the supply chain (moving down in the clinical pathways). Our complex network of resources suffers greatly from the bullwhip effect causing many short-term inefficiencies at in particular downstream care processes like *CT* and *ECHO_GD*. By reducing variability in the demand, we may reduce the bullwhip effect's impact on the performance of the system.

It is most beneficial to reduce this variability somewhere upstream the chain of successive processes. In our system, we find the upstream processes to be the care process with many NP appointments (most of the outpatient clinical consults) and the ones the precede many other care processes. Reducing the variability in the demand at these care processes may greatly reduce the variability in the demand experienced at downstream processes. To illustrate this effect, Figure 3.2.1 visualises the bullwhip effect in two situations: One situation (on the left) at which the variability in the demand is high and the negative impact of the bullwhip effect is experienced greatly downstream, and another situation (on the right) where the variability in the demand at the outpatient clinic is reduced and the impact of the bullwhip effect is experienced less.

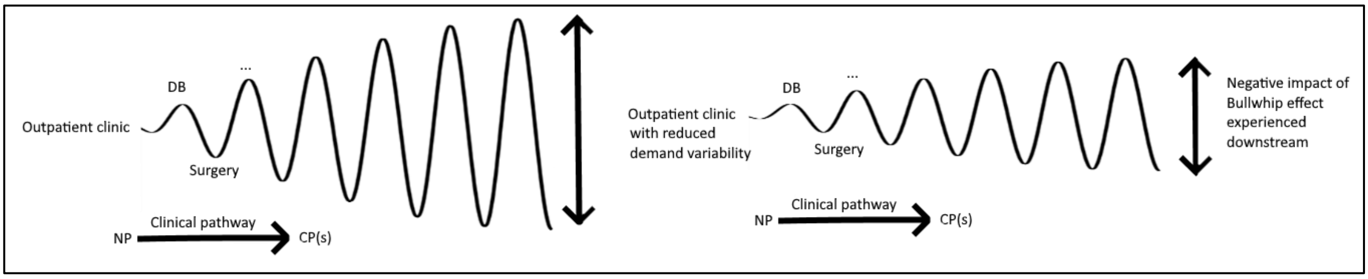

Figure 3.2.1 Illustration how the reduction in the variability of the demand upstream has a positive effects on the variability in the demand experienced downstream. As a result, the negative impact of the bullwhip effect (e.g. short-term inefficiencies) can be reduced.

We may reduce the variability in the demand by exploiting the portfolio effect. The portfolio effect is an investment term that describes the reduction in risk by introducing more diversity to the portfolio. The more diversity added, the less risk taken. In short, if we take two care processes and consider both their demand variability and we cluster them (into one portfolio), then we perform so called 'Variability buffering'. The total demand variability of the portfolio is less in comparison to the individual sum of both care processes' demand variability. Obviously, if we cluster two care processes and thus their demand while their demand is not shared (treated at each other's care process), there is no effect. However, if we consider the two care processes with a shared downstream care process, they indirectly share some of their demand. To illustrate this, in Figure 3.2.2 we presented the top three most preceding care processes at *CT* with ficticious demand patterns. *ONCO_Poli* has a low demand variability while *CHIR_Algemeen_Poli* and *ENDO_Poli* have both a high demand variability. If we combine all of them, most of the variability can be reduced at *CT*. However, we may be limited in the combinations we can make. If this is the case, it is advisable to combine the care process that have similar demand variabilities as they cancel each other out the most. In our example, we therefore prefer to combine *CHIR_Algemeen_Poli* and *ENDO_Poli*. Obviously, the variability in the demand will

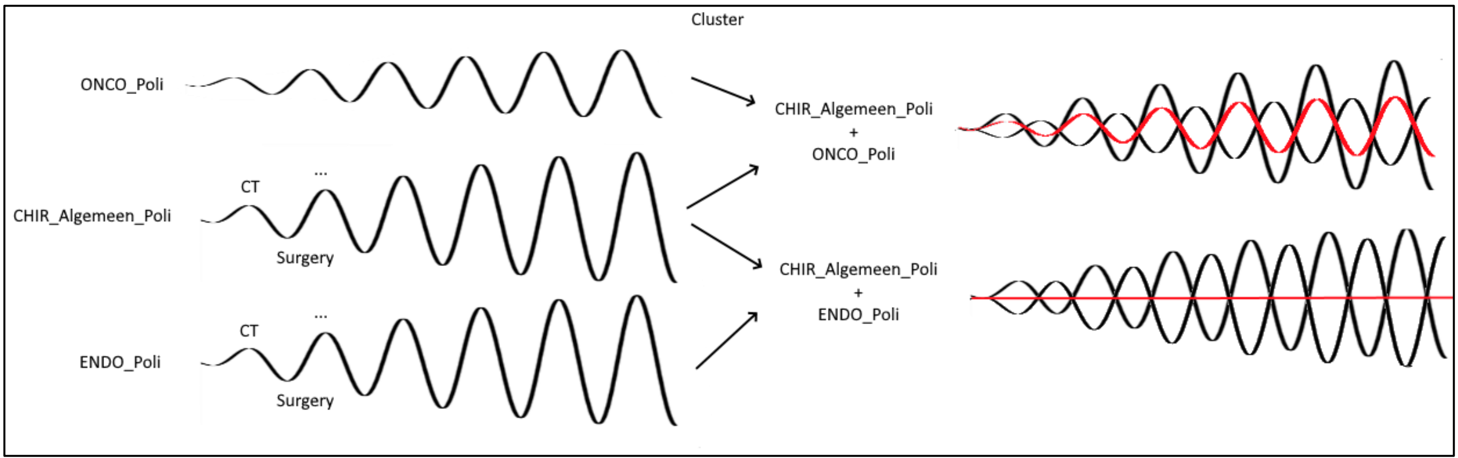

Figure 3.2.2 Illustration how the clustering of care processes can reduce the variability in the demand experienced downstream.

not cancel each other out perfectly as we depicted in the figure if we use a more realistic random demand pattern.

The use of Variability buffering is also applicable to individual care processes. If a care process is opened less frequently it can buffer appointments over a longer period. We may consider each day we can buffer patients as an asset that is added to the portfolio. The more assets added to portfolios and the less number of different portfolios, the lower the total variability in the demand. For example, when we open 2 times in a week on Monday and Wednesday, we may buffer for 5 days and then for 2 days. If we open only once on Monday, we may buffer the patients throughout the whole week. See Appendix BB for an elaborated example of this effect.

To summarise our discussion on the Bullwhip effect, Portfolio effect and Variability buffering:

- The Bullwhip effect introduces short-term inefficiencies.
- To reduce the impact of the bullwhip effect, we may reduce the variability in the demand.
- We can reduce the variability in the demand by:
    - Cluster care processes that treat the same kind of demand (e.g. surgeries at ORs).
    - Clustering care processes that share the same succeeding care processes (see relationship diagrams in *Appendix G*).
    - Buffering appointments as long as possible by opening less frequently.
- Reducing the variability in the demand is most beneficial
    - at upstream processes with many preceding downstream processes.
    - at care processes that share the same variability.
    - at care processes that have high variability.

3.2.2 Trade-off between *AWT* and *Capacity utilization*

There exists a strong trade-off between *AWT* and *Capacity utilization* when we turn our attention to the alternative solutions for our production schedule. Alternative solutions that may improve the performance on *AWT*, whether it is on the boundary *Maximum percentage AWT unsatisfied* or on the performance goal *Acceptable Average AWT,* will almost always negatively affect the performance on the *capacity utilization* and vice versa. A better performance on *Maximum percentage AWT unsatisfied* and *Acceptable Average AWT* stands in relation to higher capacity availability. Higher capacity availability can be achieved by, e.g., widening the opening times, opening at shorter intervals and more frequently, or opening more service stations. These measures come at a cost. For example, wider opening times can increase the capacity availability through facilitating quick access to a lot of care, but we may frequently end up with an excess supply of capacity. This negatively effects the *Capacity utilization*. Another measure was to open on more days. This can increase the capacity availability in a similar way to the previous example, but also increases the total demand variability as we perform less Variability buffering. The increased total demand variability causes more short-term inefficiencies which affects the *Capacity utilization*.

Concluding, in the optimalisation of the production schedule we try to specifically anticipate on this trade-off.

3.2.3 Multiple service stations, gaps and breaks, and duration of opening times and appointments

We may open multiple service stations at the same time (if possible) to supply a great amount of capacity in a short period of time. It can be beneficial to open multiple service stations for care processes with high demand, many cancellations and many delayed appointments. With more service stations, there is more flexibility to deal with these cancellations, delays and other deviations. For instance, when one service station is finished earlier, it may start treating a patient scheduled at and arrived for another opened station.

Opening with more service stations or for more weekdays will result in shorter opening times. Shorter opening times reduces the number of combinations of appointments we may schedule together. For instance, if we open for 90 minutes and we regularly have appointments of 30 and 60 minutes, we may schedule one 30 and 60 minute appointment or three 30 minutes appointments. If we open 120 minutes, we can schedule three combinations (4x30 or 2x60 or 2x30 and 1x60). Thus, the longer we open a care process, the more combinations we can schedule. Simultaneously, we reduce the number of gaps at the end of the opening time if we open less often. Additionally, we discussed the positive effects on the total variability of the demand if we buffer the demand by opening less frequent.

We advise to open care process for a period of time that facilitates a great number of combinations of appointment durations. We suggest to consider what combinations of appointments and their durations can be scheduled at certain times (e.g. in a period before or after a break) and schedule appointments in such a way that most combinations remain open. This may decrease the occurrence of gaps at the end of or during the day.

3.2.4 Cancellations

Cancellations cause many short-term inefficiencies. However, aside from exploiting the portfolio effect in a similar way as we do in the above, it is challenging to reduce the negative impact of cancellations on *capacity utilization* and other KPIs. Previously, we argued how a decrease in the *Average AWT* will likely reduce the number of cancellations, but there is no telling in how much this may be. To further deal with cancellations specifically, it can be promising to:

- Introduce short-term flexibility measures (e.g. a walk-in care process or day-admission for patients) that reduces the negative impact of cancellations during the operationalisation.
- Introduce changes to the patient appointment scheduling processes (e.g. *No OVB*) which reduces the number of cancellations scheduled upfront.
- Introduce long-term flexibility measures (e.g. overschedule capacity) to allow flexibility at operational level.
- Look into the motives (reasons) behind cancellations and try to understand how they may be reduced. Previously, we proposed to improve the patient appointment planning processes to reduce cancellations with reasons 'moved' and 'Owner cannot come' and 'another time'

3.3 Problem-solving method

The problem solving phase in this study aims at optimizing the system's performance by improving the tactical resource allocation and patient appointment planning. In Chapter 1, we introduced our methodology to guide this optimalisation process. We arrived at phase 4: *formulation of alternative solutions* where we develop a set of alternative solutions.

In Chapter 4, a set of what-if scenarios will be presented. They have been based on our conclusions drawn in Chapter 2. The what-if scenarios will focus to improve the patient appointment planning processes. For example, we explore the non-existence system where scheduling 'with reservation' is eliminated.

In Chapter 2, we also drawn the conclusion that the production schedule is far from optimal and has many flaws as it is not demand-driven. Our hypothesis is that we can substantially improve the system by making drastic changes with as little effort as possible to the production schedule by making it more demand-driven. Here, we aim to optimize the allocation of resources.

Table 3.3.1 summarises the set of alternative solutions that is considered in the development of the what-if scenarios and alternative solutions for the production schedule. The alternative solutions are divided into four main categories and further distinction is made between solutions introducing change to the allocation of resources and solutions introducing change to the patient appointment planning. We also consider in the development of alternative solutions the topics discussed in our literature review from Section 3.1 (e.g. we consider to reduce the negative effects imposed by the bullwhip effect or exploit the portfolio effect). Furthermore, we try to not violate policy-related constraints by discussing the feasibility of the developed alternative solutions employees. For example, we may not consider unrealistic working hours by opening a care process for one hour, then close it for six hours and open it again for one hour.

After we developed a set of alternative solutions, we evaluate their performance on the KPIs discussed in Section 2.4. This will be done by the use of experimental simulation and be executed in the following steps:

1. *We develop and quantify a set of performance <u>boundaries</u> and <u>goals</u> for the KPIs. The boundaries will represent a bottom-line acceptable performance of the system if no boundary is violated. We are interested in such a performance of the system since the 'as-is' situation is far from optimal. We expect an imbalance in trade-offs between and unacceptable poor*

performances of KPIs. Furthermore, we argue that the system becomes more sensitive to (trade-offs imposed by) the what-if scenarios and other alternative solutions when the system is more tightly constrained by, e.g., the opening times. We also do not want to develop a system that is unrealistic, e.g. with great amounts of overtime. The compliance with boundaries is intended to ensure the feasibility of the final system we come up with.

2. *We introduce alternative solutions that will, most likely, lift the violation of boundaries. We do this in the following steps:*
    a. *The <u>what-if scenarios will be evaluated</u> on their performance compared to the 'as-is' situation. We select the set of what-if scenarios that have proven to (contribute to) lifting of violated boundaries.*
    b. *We <u>evaluate changes to the production schedule</u> that will require the least effort and will most likely lift the violation of boundaries. If this turns out to be not the case, we undo the change. Else, we accept the change. If a bottom-line acceptable performance of the system is achieved, we stop. Else, we continue by introducing more changes.*
3. *When we have a system with a bottom-line acceptable performance, we make a prioritization of the performance goals by consulting employees.*
4. *We will optimize one performance goal after the other. We do this by introducing alternative solutions that will most likely contribute to the performance on the KPI. We do this in the following steps. Alternatives solutions can be both based on what-if scenarios as well as changes to the production schedule.*

If a boundary is violated in the execution of step 4, we either reject the alternative solution that was introduced and caused the violation or we accept and lift the violation by introducing more alternative solutions. The same counts in case the performance on a previous achieved or optimized performance goal is substantially affected by an introduced alternative solution.

Categories	Allocation of resources (production schedule)	Patient appointment planning
Decrease or increase the available resources. *(This can be both long-term and short-term solutions)*	*1) Decrease or increase the total opening time.* *2) Decrease or increase the number of stations opened at the reception or any other care process.* *3) Decrease or increase the number of available ANE personnel to save cost or prevent the obstruction of treatments.*	
Decrease or increase the productivity or efficient use of resources.	*1) Increase the number of available ANE personnel to eliminate the preparation time (recovery time) required for each patient at the CT and MRI.* *2) Eliminate or reduce the need for certain medical operations, e.g. eliminate pre-anaesthetic examinations for already examined patients or non-complex sedations performed by ANE.*	*1) Create gaps between appointments to take into account the preparation tasks required for ANE to prepare patients to be treated at the MRI or CT.* *2) Reduce the creation of gaps by overscheduling resources.*
Increase or decrease flexibility (measures) to be used to deal with variability in the demand for and the availability of resources. *(How resources are presented to demand, operationalized and deal with short-term inefficiencies)*	*1) Supply resources at specific weekdays or intervals when the demand is urgent or the need is higher.* *2) Increase or decrease the buffering of demand to reduce or increase the demand variability, e.g. by buffering patients over a period of time by opening on a less frequent interval (this reduces the total standard deviation of the demand).* *3) Increase or decrease the employability or use of resources, e.g. open care processes to a wider range of appointments or appointments may be scheduled on a wider range of care processes (e.g. by increasing the staff's employability or reducing the quality of care (standards).* *4) Distribute opening times.*	*1) Use walk-in rooms to cope with deviations in the operationalization of the schedule.* *2) Restrict resources to be used by specific patient groups to separate the interaction of uncertain care from certain care. E.g. schedule extern patients in off-peak hours.* *3) Create buffers between appointments to deal with deviations and prevent the aggregation of negative outcomes of deviations.* *4) Create buffers of patients to fill up gaps, e.g. with day and night admission.* *5) Schedule patients with high probability of succeeding care (e.g. OVB appointments) early, to provide more time to serve unforeseen demand.*
Decrease the variability in the demand for and supply of resources. *(May reduce variability-related phenomena and partially resolve short-term inefficiencies)*	*1) Exploit the portfolio effect by clustering appointments within the same time window or care processes on the same day.* *2) Balance the workload to prevent the aggregation of deviations.* *3) Cater to the delays caused by owners and patients. E.g. by supplying resources at moments were the variability of demand is minimal.* *4) Cater to the delays caused at the clinic.*	*1) Cluster patients and exploit the portfolio effect (e.g. cluster patients with similar standard deviations in their appointment times)* *2) Reduce or eliminate the cancellation of appointments (discharging of capacity), e.g. eliminate the scheduling with OVB.* *3) Reduce or eliminate the need for and costs of set standards, e.g. reduce were possible the use of One-Stop-Shop treatments.* *4) Cater to the delays caused by owners and patients. E.g. by introducing a day or night admission in order for patients and owners to arrive on time for their appointments.* *5) Schedule uncertain demand at times were it minimizes the impact or where the demand becomes more certain. E.g. schedule CP in the mornings prior to NPs as they are delayed less frequently.*

Table 3.3.1 Proposed alternative solutions.

Chapter 4 Model

To comply with stakeholders objectives and to meet the interests of management, a set of validity criteria for the simulation model are drafted to enhance the successfulness of the project. First, the patient flow and patient appointment planning processes must be representative for the current situation. Section 4.1 describes the core functionality of the patient flow: how a patient with a clinical path will progress through the simulation, including a discussion of the patient appointment planning processes, and how the timings of appointments are taken into account (e.g. time between appointments, time between scheduling moments, time until an appointment after scheduling it, etc.). Next, the model must be robust, meaning it should exclude and include the necessary elements required to connect and meet research and operational interests in one model. The model should also be reproducible. To enhance this reproducibility and because many corrections, approximations and assumptions have been made with in particularly to the historical data, Section 4.2 is dedicated to the discussion of the data preparation. Finally, the model should facilitate experimentations (e.g. evaluating different what-if scenarios and operational changes). An explanation of the (non-) experimental decision variables is provided in Section 4.3. The assumptions made and a summary of the model can be found in Section 4.4.

This chapter will give an answer to research question 8: *Which planning and management processes should be taken into account to evaluate alternative solutions? What (care) processes should be in- and excluded?* If the reader is not interested in the model's structure and the design decisions made, it is advised to continue reading at Section 4.4.

4.1 Model structure

In this section we explain how we handled the clinical pathways, the timing of appointments, the flow of patients, the patient appointment planning processes and the arrival of patients in the simulation model.

4.1.1 Structure of clinical pathways

For each appointment the following information is available and used on the appointment times and dates:

1. Start day of appointment (in Vetware: DatumVan)
2. Start time of appointment (in Vetware: TijdVan)
3. End day of appointment (in Vetware: DatumTot)
4. End time of appointment (in Vetware: TijdTot)
5. Day of making (in Vetware: DatumAfspraakGemaakt)
6. Day of cancellation (in Vetware: DatumAfgezegd, not always recorded)
7. Patient arrival time (in Vetware: TijdGekomen)
8. Processing time (in Vetware: Behandeltijd)

This information is used in the simulation model to guide the patient flow. The timing of appointment is important to simulate a realistic patient flow. To illustrate this, take patients with RTC treatments in their clinical pathway. This is one of the more plannable clinical pathways where a patient will visits the hospital for a number of days, day after day. The timings concerned with this set of successive appointments should be taken into account. Furthermore, the appointments for an RTC patient are commonly scheduled in clusters or all at the same time. This should also be taken into account. Another example is a patient that seeks an outpatient clinical consult with a diagnosis treatment at DB (e.g. a MRI) and expects One-Stop-Shop. This set of appointments should be scheduled together on one day to take into account One-Stop-Shop and may be scheduled at the same scheduling moment. There are many more scheduling rules embedded within the clinical pathways information regarding timings. In order simulate an as realistic patient appointment planning process, we take into account these timings and meanwhile eliminate as many dependencies the timings have as a result of the past production schedule. For instance, an appointment that was scheduled 5 days in advance on the first available suitable care process. This does not imply that the simulation model should schedule the appointment from 5 days and onwards.

A representation of the scheduling of two successive appointments in a clinical pathway is visualized in Figure 4.1.1Figure 4.1.1. Here, the first two appointments of a clinical pathway is presented, where the second appointment is scheduled after the first appointment.

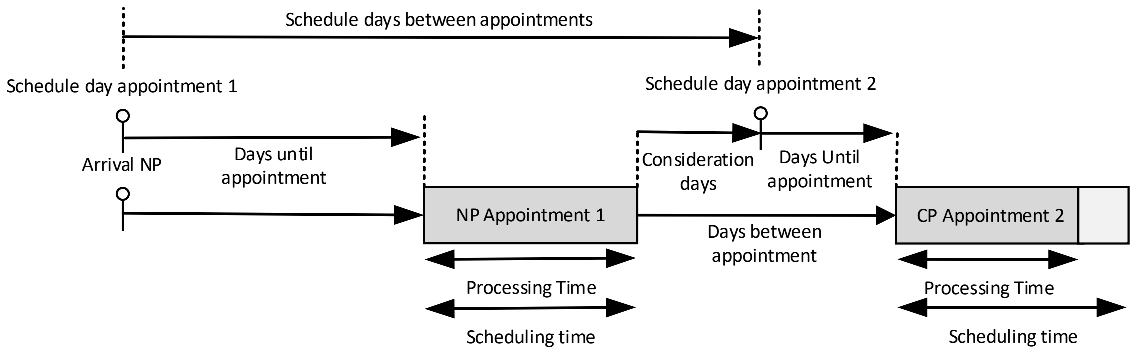

Figure 4.1.1 Example of appointment timings of two successive appointments (appointment 1 is scheduled, executed, then appointment 2 is scheduled and executed)

Other clinical pathways may have a set of appointments scheduled before the first appointment is executed. For instance, the first and third appointment are scheduled together, after the first appointment, the second appointment in the clinical pathway is scheduled. A day after the second appointment is scheduled, the third appointment is cancelled and the same day a fourth appointment is scheduled as a replacement of the third appointment. At the end of the fourth appointment, an emergency appointment will occur roughly a week from then. After the emergency appointment, the patient will consider whether it wants a surgery. It has a number of considerations days before a new appointment is scheduled.

No matter the complexity of the scheduling sequence or appointment types of appointments, we always want to make sure the scheduling sequence is managed correctly. Therefore, four timings are designed that may not be violated at any moment if we are concerned with the execution and scheduling of appointments:

- *UntilAppointmentTime,* referring to the recorded number of days between the day of scheduling the appointment and the day at which the appointment was scheduled to be treated on.

- *ConsiderationTime*, referring to the time in days between the execution of one appointment, and the scheduling moment of one of any successive appointment.
- *ScheduleTimeBetween,* referring to the time in days between the scheduling moment of one appointment, and the scheduling moment of one of any successive appointment.
- *AppointmentTimeBetween,* referring to the time in days between the finishing of one appointment, and the start of one of any successive appointment.

4.1.2 Patient flow

The flowchart in Figure 1.4.2 describes the basic patient flow of an arbitrary patient from the point of arrival in the simulation up until its departure. The patient is created at one of the patient arrival flows (See Objects: *Source*) through poison distributions. The patient is accepted to the simulation or removed by the thinning procedure discussed in Section 4.1.4 (See Method: *Thinning*). The patient receives one of the Clinical Pathways associated with the patient arrival flow through an empirical distribution. Any additional information associated with the selected clinical pathway (processing times, scheduling times, appointment names, treatment types, appointment types, timing of appointments/scheduling moments) are linked to the patient (See Method: *NewPatient*). If the patient is an emergency, it is directly send to the hospital's waiting room (See Buffer: *WaitingRoom2*). Else, the patient arrives at the patient appointment planning process that is discussed in Section 4.6. After scheduling the appointments, we generate moments in time at which scheduled cancellations should be cancelled (See Method: *AppointmentCancellation*). After the appointments are scheduled for the patient and if the next appointment is elective or extern, the patient will wait at home (See buffer: *WaitingAthome*). Else, the appointment is a cancellation and is temporarily stored until it is called again (See Buffer: *CancellationInProgress*). Patients waiting at home will be called to the hospital at their appointment time plus/minus their on-time appointment (See Method: *CallPatient*). Arriving patients will enter the waiting room (See Buffer: *WaitingRoom*) and check in with their check-in time at the front desk (See parallel-process: *Reception*) after which they enter the waiting room again (See Buffer: *WaitingRoom2*). Emergency, elective and external patients will be send to their care process (treatment location) for their treatment if it is/becomes available. An emergency patient may be placed in one of the two buffers for outpatient clinical consults (See Buffer: *Em_CHIR*_Poli) or surgeries (See Buffer: *Em_CHIR*_OR) performed at CHIR as they may be treated by any of the opened care processes. Patients with cancellations as their next appointment will skip the appointment. After finishing the treatment or skipping the appointment, the patient will be drained if it was the last appointment of the clinical pathway. In case the patient did not finish their clinical pathway, the patient will be temporarily stored in one of three buffers for a number of days equal to the *consideration time* (See Buffers: *EmergencyInProgress, ElectiveInProgress, CancellationInProgress*). Emergencies will arrive on the selected day within an hour following the emergency arrival distribution. Once the patient is called again, it will be sent back to the start of the appointment planning or is directly routed to the hospital in case of an emergency.

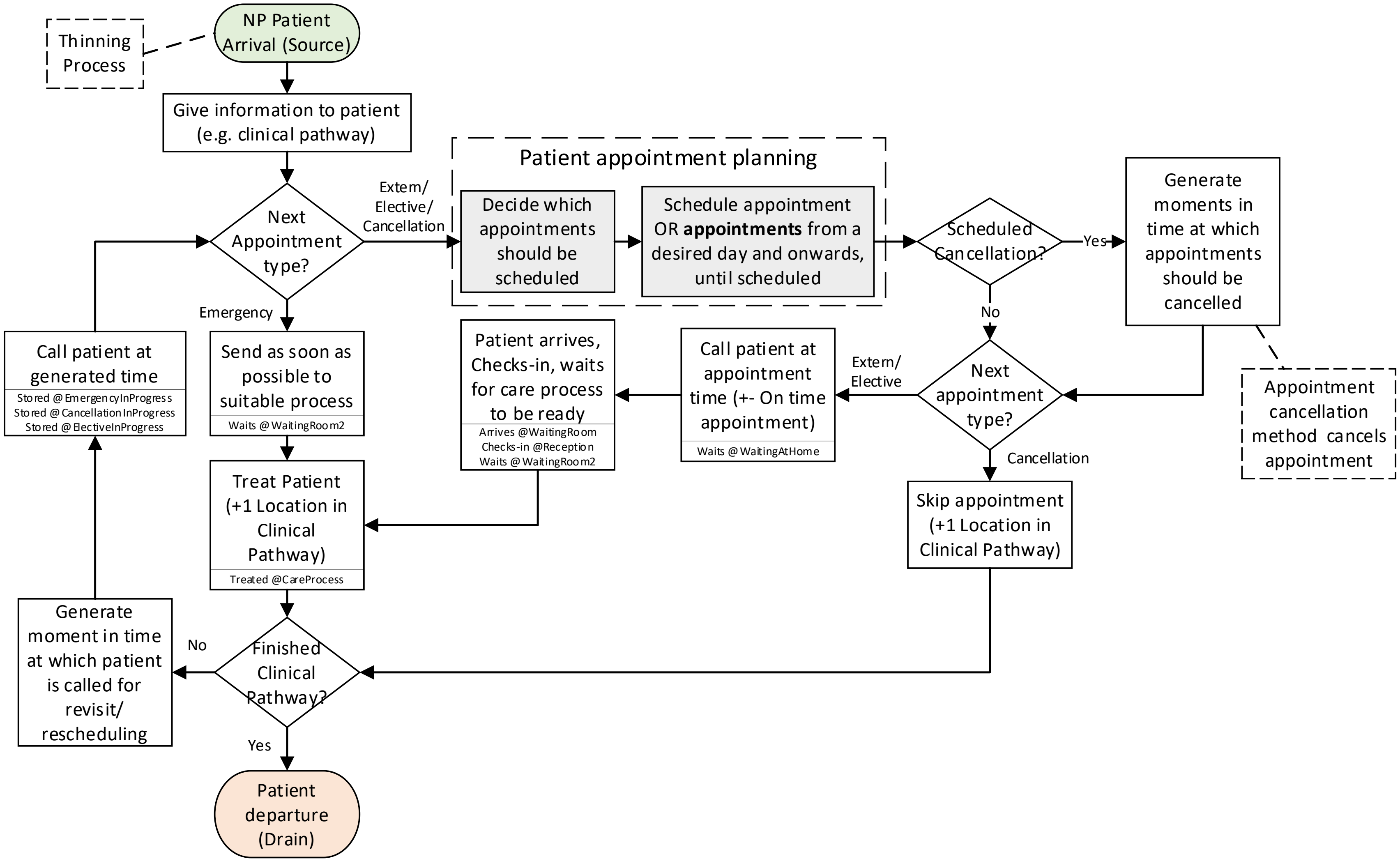

Figure 4.1.2 Flow(chart) of patient(s) with clinical pathways through the simulation model.

4.1.3 Patient appointment planning

In Figure 4.1.2 in Section 4.1.2, the patient appointment planning is located at the two grey marked action elements. This area is magnified in Figure 4.1.3 and elaborated on next.

When a patient wants to plan an appointment, we check the first upcoming appointment. This appointment may have been scheduled already in combination with one of the previous appointments. In this case, we can skip the patient appointment planning for the patient. In any other case, we will schedule the upcoming appointment and, if necessary, more appointments for the patient.

For each appointment succeeding the upcoming appointment in the clinical pathway, we figure out whether we must schedule the appointment. An appointment may be scheduled if:

- It has <u>the same</u> recorded scheduling moment as the first next appointment of the clinical pathway OR it has a recorded scheduling moment prior to the minimum day at which the upcoming appointment of the clinical pathway may be scheduled at.
- The appointment is not of appointment type Emergency.
- The appointment is not scheduled yet.

After identifying the appointments that must be scheduled, the first next appointment is scheduled. The start day of scheduling (schedule day) is the day at which the patient is willingly to be scheduled from. This is considered as the Until Appointment Time (in days). The current simulation day with the added until appointment time is schedule day at which we start scheduling the first next appointment. For the appointment, we check at which care processes the appointment may be scheduled. For each identified care process and each service station of each care process (e.g. when two outpatient clinical rooms are opened for at one care process), we check whether

- the service station is opened on the schedule day
- there are any available appointment slots left
- the appointment fits at the care process (it does not violate opening and break times)

If the constraints are satisfied, we check whether the found appointment time is the earliest time found yet. If this is true, we store the appointment start time, slot, care process and service station as the best yet. If false, we go to the next care process until we check all care processes.

If the appointment did not fit on any of the care processes, one day is added to the schedule day and the process starts over for the next schedule day. If the appointment fitted on one or several care processes, the care process with the earliest appointment time is selected. The appointment is then scheduled on the selected care process with the associated service station, appointment time and slot. One slot is subtracted from the available appointment slots at the selected service station. Additionally, a number of days will be added to the schedule day to make sure appointments are scheduled with a desirable time in between. This time is known as the *between appointment time*.

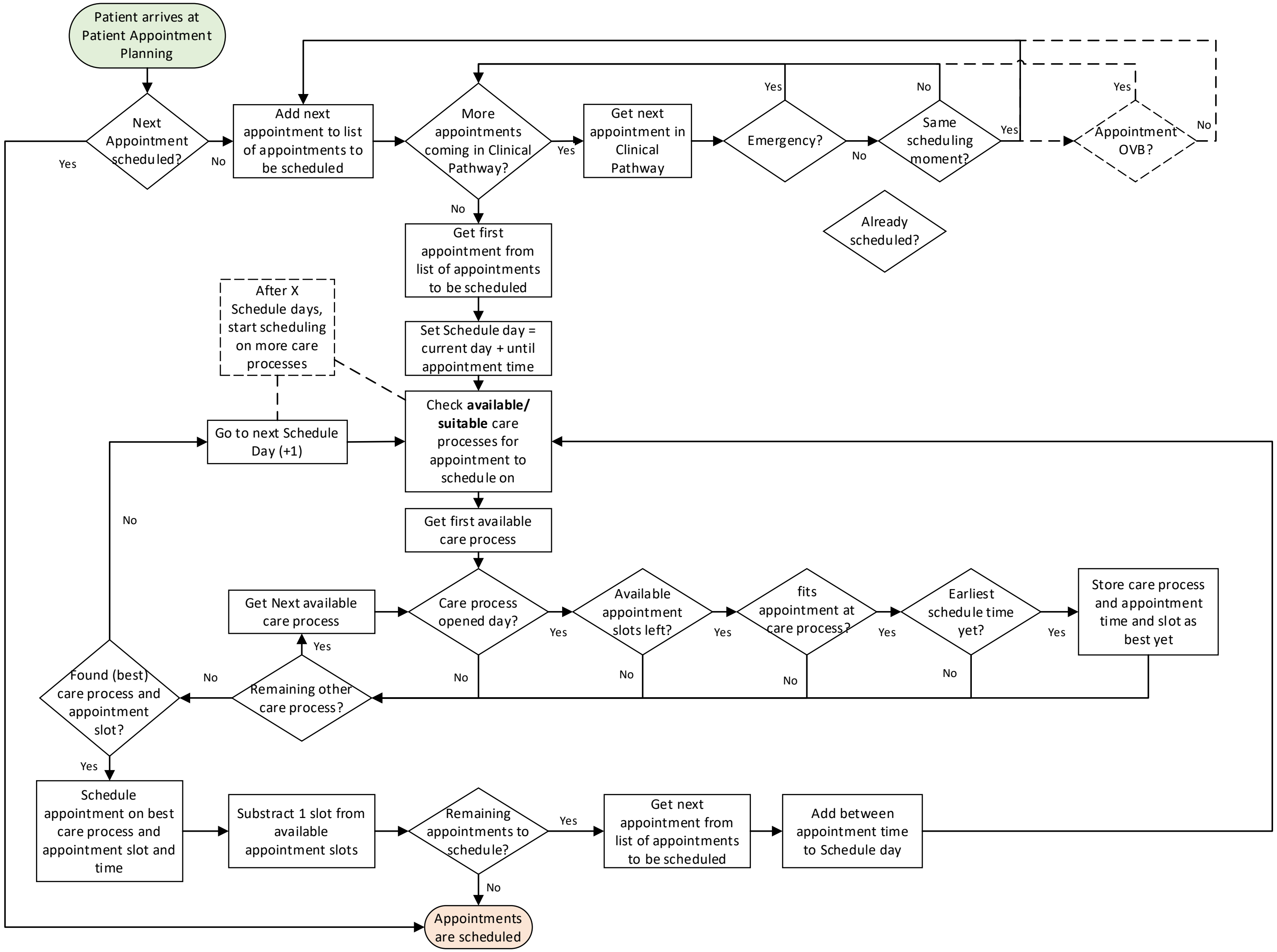

Figure 4.1.3 Modelled core processes of the patient appointment planning. Two example what-if scenarios are represented by dotted elements and arrows.

4.1.4 Thinning procedure

We clustered appointments into 9 different patient arrivals sensitive to weekdays and time of day. The patient arrival for Emergency outpatient clinical consults at *SPOED_Poli* has a correlated seasonality for weekdays and time of day. Each patient arrival may let new patients arrive with each a limited set of NP appointments. To illustrate this: the patient flow for elective outpatient clinical consults may only generate patients and assign a clinical pathway starting with an NP appointment that is an outpatient clinical consult with the appointment type Elective. The selection process for clinical pathways is based on the empirical distribution (probabilities are based on the frequency at which a clinical pathways occurred in the data). As the patient arrivals are very sporadic, we allow sporadic arrival that may be associated with the use of an empirical distribution (thus, there is no lower or upper bound in the patient arrival for specific clinical pathways).

A thinning procedure (many patients arrive, some patients will be allowed to the simulation model) will be used to adjust the patient arrival rates to the current weekday and to the hour of the current day. This does not imply that we reject patients to enter the hospital to retrieve care, but we ensure the patient arrival will be stochastic and follows the same distributions found in Section 2.3.3. The average weekly demand arrives each hour and every new arrival is accepted by a probability equal to what would arrive in that hour as a fraction of the weekly total arrivals (depending on weekday and hour of day. For instance, 40 patients arrive each week on average. On Monday, in some given hour interval, 2% of all patients in that week will arrive. We accept every new arrival with this probability.

4.2 Data preparation

In the previous section we discussed the model's main structure. In this section we discuss the extensive data preparation performed on the input data and the assumptions made on the input data. We discuss the identification and classification of appointments, the design and identification of clinical pathways, and the adjustments and assumptions made to appointment timings, and processing and scheduling times.

4.2.1 Appointments

Clinical pathways describe a set of appointments related to each other and each may have different appointment types (e.g. emergency or cancellation). For a representative patient flow, the design and use of realistic and representative clinical pathways with reliable associated information is necessary. Clinical pathways are, in contrast to humane care, more diverse and unique in the veterinary care. At first, the use of flow probabilities from one treatment to another with the advantage to generate an endless number of random, unique and realistic clinical pathways was thought to be a promising approach. Nevertheless, the appointments within the generated clinical pathways had non-logical associated information such as very high or low processing times. We concluded that with the many unique and diverse clinical pathways we are dealing with, it was unrealistic to follow an approach that assumes similarities in the base information between clinical pathways. Instead, we used the historical data of the **4 year period** between 1-1-2016 up to and including 31-12-2019 (present time) that is concerned with a total of **114.715 appointments** to identify all the unique clinical pathways and use this as the input for the simulation model. The data extracted from Vetware in this 4 year period is considered as reliable, as little to no changes in the methods of storing and collecting data were introduced. Before 1-1-2016, many changes to the hospital's structure were introduced that affects the reliability of the data.

We decided to **not** design a network of resources and disciplines with the aid of clinical pathways that were identified based on their medical operations. For instance, if a patient with a tumour arrives at the hospital, we may expect a variety of clinical pathways with specific medical operations which could tell us something about the expected amount of resources required to treat this patient and the timing of this. In humane care, there are clearly designed clinical pathways for specific treatments based on protocols that enhance equal, high quality, plannable and safe care. Sometimes, the treatment of a patient can be completely scheduled in advance with a high certainty. We discussed earlier how clinical pathways in the animal care are very unpredictable, have high uncertainty and varies from patient to patient. Therefore, we seek for a low level design that could tell us something worthy about the types of patients and clinical pathways, as well as the resources expected for these patients and clinical pathways. Furthermore, Vetware does not provide the suitable information if we would want to design clinical pathways by clustering patients based on their medical operations. For a consult, surgery or other treatment, several medical operations may be registered with the treatment and a patient report is developed. However, the core medical operation or the main treatment characteristic cannot be extracted without reviewing each patient report individually.

4.2.2 Identification of clinical pathways

On the basis of a set of well-considered criteria validated many times over with various employees, we came up with a final design for clinical pathways. A clinical pathway begins with a first appointment. This appointment is considered as the New Patient (NP) appointment. Any appointment related to this NP is registered as a Control Patient (CP) appointment.

The steps and criteria to identify NP and their associated CP appointments are:

1. Perform a multi-level sort on the appointments by prioritizing patient number (in Vetware: diernummer), followed by appointment date (in Vetware: DatumVan) and then appointment time (in Vetware: TijdVan)
2. Classify the first appointment for each unique patient number as a 'NP'.
3. Classify the remaining appointments on the basis of the appointment's comment fields. T
    a. If the comment field contains 'CP', 'Control' or 'follow-up', then we register the appointment as being part of an existing clinical pathway. We classify the appointments by 'CP'.
    b. If the comment field contains 'NP' or 'New patient', then we register the appointment as being the start of a new clinical pathway. We classify the appointments by 'NP'.
4. For not yet classified <u>consults</u>, we use the information provided by the invoices whether the consult is irregular (CP) or regular (NP). The correctness of this classification is high, according to several employees and users of Vetware.
5. For not yet classified appointments, we consider a new clinical pathway to start if two successive appointments registered with the same patient number are scheduled for over 40 days from each other.

It was impossible to employ the so called 'case numbers' registered with each appointment describing which clinical pathway an appointment is part of. The intended use of case numbers was created to link a unique number to each unique clinical pathway. Unfortunately, many appointments are registered by new case numbers while they are part of already existing clinical pathway.

We do not classify an emergency appointment in a clinical pathway as the start of a new clinical pathway and thereby combine the elective and emergency patient flow. One may want to classify emergency appointments as the start of a new clinical pathway since emergencies in humane care are commonly the start of an actual new clinical case as the prevention for dangerous complications of past-treatments is relatively high. In veterinary care, we observe the opposite. There is a common behaviour among owners who contact for elective care when the urgency is already (too) high. As a result, the elective outpatient clinical consult is cancelled and the owner arrives at the emergency department when the urgency has increased and the owner recognized this. Owners tend to wait out the symptoms until the urgency is perceived as concerning high.

From the **114.715 appointments** a total of **61.997 clinical pathways** have been identified and designed. Here, a total of 104 appointments classified as CP were excluded when prior appointments of their clinical pathway happened before 1-1-2016 and were missing.

4.2.3 Classification of appointments types, OVB and One-Stop-Shop

Appointments in clinical pathways are classified by one of the four main appointment types:

1. **Elective**, appointments for (plannable) internal patients
    - 73.224 appointments (63.83% of all appointments)
    - 33.269 Clinical pathways (53.68% of all clinical pathways)
2. **External**, appointments for external patients
    - 1.621 appointments (1.41% of all appointments)
    - 1.439 Clinical pathways (2.32% of all clinical pathways)
3. **Emergency**, appointments for emergency cases
    - 26.821 appointments (23.38% of all appointments)
    - 21.306 Clinical pathways (34.38% of all clinical pathways
4. **Cancellation**, appointments that have been identified as cancelled
    - 13.049 appointments (11.38% of all appointments)
    - 5.963 Clinical pathways (9.62% of all clinical pathways

Appointments are also classified by whether they are *OVB* (scheduled with reservation) or not. This classification is based on the comment field supplemented with each appointment where *OVB* is mentioned. If an appointment is classified as OVB, it is scheduled with reservation with a lack of certainty whether the appointment is necessary or not.

Appointments are also classified by whether they may be considered One-Stop-Stop appointments or not. An appointment is considered One-Stop-Shop if it is executed the same day as the previous appointment.

The other criteria used to classify appointments by appointment types are discussed in Appendix M.

4.2.4 Identification and selection of disciplines

As the time did not allow to include all the departments in the simulation model and we were interested to include only the necessary level of detail that would make the simulation realistic and usable, we started drawing boundaries at which disciplines to include, exclude and elaborate. At the core of our root problem lies DB as the supporting department. It was only logical to identify which department and disciplines were dependent on/connected to DB and vice versa. We inspected the departments CHIR, ANE and the outpatient clinic and concluded that all of these had appointments scheduled at DB.

In consultation with head of Radiology, specialist medical Oncology and two surgeons, we concluded that this level of detail captures the core of the network and could almost answer a question like: *if a patient is visiting for an outpatient clinical consult at CHIR, what resources can be expected at other disciplines at their treatment location(s) in order to treat this patient?* However, an additional level of detail had to be introduced to CHIR. If a discipline that is not CHIR request a surgery on an OR, this discipline is registered with the operation while it is executed by some specialization within CHIR with the assistance of ANE. Unfortunately, the build-in hierarchy in Vetware does not facilitate the direct classification of outpatient clinical consults and operations at CHIR into specializations. The production schedule cannot be followed as a guideline to classify surgeries into specializations, since ORs are not routinely occupied by the same specializations and surgeries of a specific specialization are frequently performed by other specializations. These specializations are very important for our network. To illustrate this, consider surgeries with the surgical specialization Orthopaedics and neurology. This specialization will require the MRI much more frequent than, for example, surgical specialization Dentistry. Within CHIR, nine surgical specialisations were identified.

Each discipline can have none to several own treatment locations. For instance, CHIR has both outpatient clinical consults at consult rooms and surgeries at ORs while medical oncology only has outpatient clinical consults at one consult room. Each unique treatment location or (surgical) specialisation is considered as a separate care process.

The full identification and selection procedure of disciplines and care processes can be found in *Appendix 1*. Here, the background information on each discipline can be found too.

4.2.5 Classification of appointments into disciplines

Classification of outpatient clinical consults at CHIR

The classification steps undertaken to classify outpatient clinical consults and surgeries into one of the surgical disciplines is described in Appendix N.

From the 13.628 consults at CHIR (incl. THK consults and cancellations, excluding OOG consults), a total of 10.869 (79.8%) consults are classified based on invoices.

After classification on the basis of the production schedule and filtering on the comment fields with key words, a total of 11.663 (85.6%) consults were classified. The remaining 1965 (14.4%) unclassified consults are classified by *CHIR_OVERIG(2)_Poli*, most of which are cancellations (86%).

Classification of surgeries
A total of 7266 surgeries have been analysed. 2149 (29.6%) surgeries are classified by the aid of previously classified consults. Another 2348 (32.3%) surgeries are classified on the basis of the production schedule. Another 2312 (31.9%) surgeries are classified by filtering the description field on a set of words. A remaining 456 (6.3%) surgeries were still unclassified. Description fields of these surgeries commonly describe short, simplistic or emergency surgeries. That is why we classify them as *CHIR_OVERIG(2).*

Classification of outpatient clinical consults at Internal medicine and else
Consults are classified into disciplines according to the schedule of rooms at which consults are booked. Most disciplines have an individual schedule for outpatient clinical consults. However, the schedule at Internal Medicines (INT) is shared by ENDO, GE/HEP, UR/NEF, HEMA, ALG-INT on outpatient clinical consult rooms INT-1, INT-2 and INT-3. They do follow a weekly production schedule with the following disciplines on the following rooms:

- ENDO: Monday on INT-2, Thursday on INT-2
- GAHE (GE/HEP): Monday on INT-1, Wednesday on INT-1
- URO (UR/NEF): Tuesday on INT-1, Thursday on INT-1
- HEMA: Tuesday on INT-2, Wednesday on INT-2
- ALG-INT: Monday on INT-3

These consults are classified with this production schedule and the remaining consults are classified with invoices in a similar way as we did with CHIR's consults. The remaining consults are mostly ALG-INT and classified by this.

4.2.6 Classification of appointments into treatment types

As previously presented, each discipline can have none to several own treatment locations. We consider each treatment location as an individual care process. At these treatment locations, a specific type of treatment can be executed. The different treatment types are:

- Poli (Outpatient clinical consult)
- Medical Surgery
- SA (Service Anaesthesiology)
- MRI
- CT
- RTC
- Nucl_Diagn (Nuclear diagnostics)
- X_RAY_GD (X-Ray for GD)
- X_RAY_PD (X-Ray for PD)
- ECHO_GD (X-Ray for GD)
- ECHO_PD (X-ray for PD)
- FLUOR

Most disciplines have only a treatment location for *Poli*. DB is the only discipline with treatment locations *MRI, CT, RTC, Nucl_Diagn, X_RAY_GD, X_RAY_PD, ECHO_GD_, ECHO_PD* and *FLUOR*.

Disciplines at CHIR have *Poli* or *Surgery*, sometimes both, sometimes only one of the two. Disciplines with no treatment location, will treat their patients at other discipline's treatment locations. For instance, PD requires MRI treatments. Other disciplines may schedule their patients at similar treatment locations used by other disciplines. For instance, surgical specialty CHIR_OVERIG(2) may be scheduled at other ORs if they are not operating on a specific day. Such scheduling rules disciplines specific and will later on be discussed.

4.2.7 Appointment timings

As some of the timings of appointments are dependent on the current or past production schedule in place, we remove as much dependencies as possible. We can reduce the dependencies by considering the following information we know about the general expectations of an owner:

- Owners with their patients want to visit as soon as possible for outpatient clinical consults starting from the next day.
- Owners with their patients want to visit as soon as possible for MRI, CT, Rontgen or ECHO starting at the same day.
- If the *UntilAppointmentTime* exceeds a week, thus more than 6 days, the owner is not able or willing to visit earlier for the appointment than this OR a minimum number of days between two successive appointments is necessary.
- If the *UntilAppointmentTime* is less than a week but longer than a day, e.g. 4 days, it is most likely that the owners wanted to visit as early as possible but the production schedule did not facilitate this.

Based on this information, several assumptions are made on the *UntilAppointmentTime* to estimate the most representative time at which a patient wanted their appointment at its earliest:

- If the *UntilAppointmentTime* is equal or less than 1 day **AND** the treatment is an MRI, CT, Rontgen or ECHO, the *UntilAppointmentTime* is set to 0 days. Similar for these treatments, if the *UntilAppointmentTime* is between 2 to 7 days it is set to 1 day.
- If the *UntilAppointmentTime* is between 1 and 7 days **AND** the treatment is outpatient clinical consult, Nucl_diagn or Surgery, the *UntilAppointmentTime* is set to 1 day.
- If the *UntilAppointmentTime* is greater than a week (thus more than 6 days), the *UntilAppointmentTime* is rounded down to weeks. For instance, if the *UntilAppointmentTime* is valued at 8, 14 or 24 days, it is rounded down to 7, 14 and 21 (1, 2 and 3 weeks) respectively.

If the *UntilAppointmentTime* is adjusted, the *AppointmentTimeBetween* is adjusted in an equal matter. However, the *AppointmentTimeBetween* must stay equal or greater than 0, as appointments must be processed in the order described by the clinical pathway. The *ConsiderationTime* is considered as representative. However, we assume for NP that they have no ConsiderationTime, as they already have decided that they want the appointment and no prior appointments are of importance. The *ScheduleTimeBetween* is not adjusted, even when the *UntilAppointmentTime* was adjusted, as we only use this to determine which appointments were scheduled together or in close proximity of each other to cluster their scheduling moments.

4.2.8 Processing and scheduling times

The time we schedule appointments with is different from the actual processing time. Unfortunately, actual processing times are rarely recorded for outpatient clinical consults. In many cases, the processing time is set equal to the schedule time. The processing time is equal to the recorded appointment start and end time.

For 399 (5.5% of all) surgeries at CHIR, the comment field contains a description of the 'norm' time scheduled with. We filtered these times and set them as scheduling times. The norm times for each appointment's surgical operation may be found in Vetware, unfortunately it was impossible to automate this in the data preparation for all appointments. According to Anaesthetists, most processing times of surgeries are corrected after the surgery. In this case, the actual processing time is known, but a scheduling time is missing. If it is other way around, if surgeries are not corrected on their processing time, we only know the scheduling time. Therefore the accuracy of processing and scheduling times for surgeries is questionable. For appointments at the MRI and CT, appointment times are also adjusted to the actual processing time that was experienced. Fortunately, we can round these processing times up or down to standard slot times used in the scheduling of appointments to approximate the scheduling times.

For 193 (15.4% of all) appointments at VBD, the comment field contains a description of 'opname' (admission to the hospital). Their schedule time has been set to zero, as we do not intend to deal with these appointments.

For 9.113 (9.4% of all) appointments recorded with processing times of zero. For 2.785 (30.5%) of these appointments, we are concerned with (incorrectly reported) cancellations. For 4.772 (52.4%) of the 9.113 appointments with zero processing times, we are concerned with emergencies of which 4.315 appointments occurred at *SPOED_poli*. We observed incorrectly scheduled appointments in the agenda. For the remaining 1556 (17.8%) appointments, we sampled tons of appointments and checked them on correctness. Many appointments are quick examinations of a group of animals (e.g. laboratory animals and guide dogs from KNGF). We expect little to no impact on the simulation model by keeping the processing and scheduling time on zero for these appointments. For the 2.785 cancelled appointments, we keep the processing time on zero but generate scheduling times based on a simplistic approach: For each kind of treatment we find for both NP and CP appointments the top four most occurred processing times. Many treatments have peaks in their frequency at 2, 3 or 4 processing times. Clinical consults and treatments at DB have a set of fixed scheduling times for different treatments. A CP consult is commonly shorter (10/15/20/25min) than an NP consult (25/30/45/60min). We use the occurrence frequencies of the four processing times to construct a cumulative probability and use a uniform distribution to draw a number between 0 and 1 for each appointment. Based on whether they are CP or NP, the drawn number and the treatment of the appointment, it will receive a processing time from the tables that can be found in Appendix O**.** We use the exact same method to provide the 4.772 emergency appointments with processing and scheduling times.

4.3 Decision variables

We discussed the model's structure and the data preparation in the previous two sections. In this section, we discuss the (non-) experimental decision variables (including what-if scenarios) that can be adjusted in the simulation model to simulate the 'as-is' situation and experiment with.

Aside from the restrictions embedded in the discussion of the patient flow (Section 4.1.2) and the patient appointment planning (Section 4.1.3), the simulation model has other restrictions such as opening times, processing times and break times.

For the optimization of and experimentation with the production schedule and the patient appointment planning processes, a number of decision variables are available that may be altered. They can be altered at the dashboard displayed in Appendix S.

For each care process, we have the following decision variables:

- Opening time for each weekday (See Table: *Opening_Times*).
- Closing time for each weekday (See Table: *Closing_Times*).
- Break times for each opened service station (See Table: *Break_Times*).
- Number of service stations for each opened weekday (See Table: *Service_Stations*).
- Number of appointments slots for each opened weekday (See Table: *Appointment_Slots*).
- Minimum scheduling time for an appointment to count the appointment as an appointment slot (See Table: *Scheduling_Restrictions*, Column *MinTimeForSlotNumber*).
- Break times after an appointment is finished on the care process, before a new appointment starts (See Table: *Scheduling_Restrictions*, Column *TimeAfterAppointment*).
- Minimum scheduling time for an appointment to trigger the break time after an appointment from above (See Table: *Scheduling_Restrictions*, Column *MinTimeForTimeAfterAppointment*).
- A time penalty to prepare an appointment on the care process before it can start (recovery time). This is used to simulate the tasks of ANE to prepare an appointment e.g. transporting the patient (See Table: *Scheduling_Restrictions*, Column *RecoveryTime*).

For each appointment, we have the following decision variables:

- After how many unsuccessful schedule days a set of One-Stop-Shop appointments may be scheduled individually. The number of days provided in the settings are applied to the **second** appointment of the set of One-Stop-Shop appointments (See Table: *Scheduling_Restrictions*, Column *DropOneStopShop*).
- After how many unsuccessful reviewed schedule days an appointment may be scheduled on a set of additional care processes (See Table: *Scheduling_Restrictions*, Column *StartSchedulingOnOtherRooms*).
- On which care process appointments may be scheduled (See Table: *App_On_Stations*)
- On which additional care process appointments may be scheduled <u>after</u> a given number of unsuccessful reviewed schedule days (See Table: *App_On_Stations2*)
- A time penalty between one appointment (left column) and a successive appointment (top row) in a clinical pathway (See Table: *App_Time_Between*)

Additional global decision variables (constants):

- The earliest time after which an appointment can be scheduled after the request for an appointment arrived (not applicable to emergencies, because they are not scheduled). This is set to two hours as specialists consider this as the minimum time at which they can handle changes to their schedule. (See Global Variable on Dashboard: *EarliestTime*).
- Non-emergency patients that are still waiting for their treatment are send home after a certain time. This is set to 18:30 in the afternoon, as many care processes are not strictly committed to regular closing times (16:30) and delays are common. (See Global Variable on Dashboard: *SendHomeAfter*). Note that, if a patient is already being treated, the appointment will be finished before the patient is send home.
- Patients may only check-in after and before a certain time. This is set to 8:00 and 17:30 respectively. Some care processes will receive their patients at this latest hour, and many care processes regularly start their shift earlier than the reported opening time. (See ShiftCalender: *OpeningHours*).
- For cancellations with no registered cancellation time, a global variable is available to determine at which fraction of the remaining time until the scheduled appointment the cancellation should take place. This is set to 0.7 after analysing the timings of reported cancellations. Most of them are cancelled at two-third of the time between the scheduling day and day of the appointment. However, it is very dependent on the appointment (See Global Variable: *CancelAfter*).

The Decision variables for ANE are:

- Working shift (Starting/ending) for regular opening hours. We are not interested in non-regular opening hours, but require at least one anaesthetist to perform emergencies there. Also, ANE is guided by other disciplines opening times and therefore the shift times are set to 24/7 for now (See ShiftCalender: *ANE_Shift*)
- A roster with the number of anaesthetists available per weekday (See Table: *ANE_Roster*).

The decision variables that facilitate the patient appointment planning processes and are used by the what-if scenarios are:

- Scheduling with reservation can be turned off and on for care processes (See Checkbox on Dashboard: *OVB)*. If the checkbox is turned off, appointments identified as OVB are not scheduled as OVB but scheduled after its preceding appointment. The user can decide for which care processes this should apply to (See Table: *Scheduling_Restrictions*, Column *No OVB*).
- Care processes can be turned into walk-in rooms where appointments are scheduled on the care process while neglecting the maximum number of appointment slots available. Furthermore, if the patient is already at the hospital, it is directly scheduled and send to the care process (See Checkbox on Dashboard: *Walk-In*). The user can decide for which care processes this should apply to (See Table: *Scheduling_Restrictions,* Column *Walk-In*).
- The walk-in setting may be extended by a setting that neglects both scheduling time and appointment slots restrictions. Appointments are then scheduled all together in the morning when the care process opens or as soon as possible for when a patient is already at the hospital (See Checkbox on Dashboard: *Walk-In Morning*).

- We can schedule appointments of appointment type *Extern* in off-peak times (morning and afternoon) and restrict other non-emergency appointments to not be scheduled within these off-peak times (See Checkbox on Dashboard: *RestrictedAppointmentTypes*).
- For the above setting, the morning off-peak end time and afternoon off-peak start time can be set (See Table: *SchedulingRestrictions*, Columns *MorningOffPeakEndTime* and *AfternoonOffPeakStartTime*).
- The number of days in advance for which these off-peak rules should apply can be set too (See Table: *SchedulingRestrictions,* Column *ScheduleRestrictedDays*). For instance, if this is valued on 2 days, elective patients may be scheduled in off-peak times if they are tried to be scheduled on the next day or the day after that. In a similar way, extern patients may be scheduled outside off-peak times if we try to schedule them the next day or the day after that.
- Day admissions of patients can be turned on for care processes. Patients are requested to arrive at certain time if they fit within/after/before a time interval (three time intervals are available). For example, when the times are 9:00:00, 11:00:00 and 12:00:00, patients with an appointment at 11:30:00 will be requested to arrive at 11:00:00 and patients with an appointment at 8:30:00 will be requested to arrive at the opening time of the care process. (See Checkbox on Dashboard: DayAdmission, See Table *Scheduling_Restrictions*, Columns *AdmissionTime1, AdmissionTime2, AdmissionTime3*).
- There are settings available for night admissions of patients. Patients are dropped at the hospital at the start of the day (00:00:00) if they have an appointment starting before a certain time, e.g. before 10:30:00. They will be processed from the moment the care process opens (See Checkbox on Dashboard: *NightAdmission*, See Table *Scheduling_Restrictions*, Column *LatestNightAdmission*).
- We can request patients to arrive earlier for their appointment time (See Checkbox on Dashboard: *ArriveEarlier*). The time that is deducted is equal to the mean delay time that is associated with the appointment (see Table: *On_Time_Arrival* for means). In addition to this deducted time, additional time may be deducted for a NP and CP patient to take into account the check-in time and queue waiting time at the reception (See Global variables on Dashboard: *ExtraEarlyNP* and *ExtraEarlyCP*).
- A setting is available to add an extra anaesthetist at the DB and CT (See Checkbox on Dashboard: *ExtraANEDB*). If this setting is on, a time will be subtracted from the scheduling and processing times for appointments at the CT and MRI (See global variable on Dashboard: *SubtractIntroOutroForANE*). The time represent the time that can be deducted from appointments at CT and MRI if an extra ANE is present to support with preparing and finishing tasks for appointments.
- We can overschedule capacity at care processes by making appointments overlap each other. This was complex to implement flawless, therefor we simply deduct time from the scheduling time and keep the processing time the same (See Table: *SchedulingRestrictions*, Column *OverscheduledMinutes*).

What-if scenarios

We developed a set of what-if scenarios that were carefully selected in consultation with employees. We considered the expected effort to implement them and the expected benefits they may bring. Each of the what-if scenarios will fit within the discussed alternative solutions from Table 3.3.1. The scenarios are presented in Table 4.3.1 with their expected effects.

What-if scenario	Description	Expected outcome
No OVB	Appointments classified as OVB are not scheduled in advance, only when they are up next (e.g. after the consult).	*Reduction in short-term inefficiencies, as cancellations on a short-notice (e.g. via outpatient clinical consult) are reduced. A possible reduction in one-stop-shop satisfaction as less OVB appointments may not fit on the same day when they appear.*
No One-Stop-Shop	Appointments classified as One-Stop-Shop are not scheduled like One-Stop-Shop but simply scheduled one after the other.	*Reduction in the appointment waiting times and One-Stop-Shop satisfied, as we schedule One-stop-shop appointments not in pairs but individually.*
Restricted Extern	Extern appointments are scheduled in off-peak hours (afternoon or morning). The off-peak hours becomes accessible to other appointments types some period before the actual day. Similar, non-off-peak hours become accessible to extern appointments in the same period before the actual day.	*Improved workload balance, as we utilise off-peak hours more. If scheduled in the morning, we also expect fewer and shorter appointment delays and shorter hospital waiting times, as external patients are almost never cancelled.*
Walk-in	Care processes become walk-in rooms. Patients may immediately move on to the queue if they are already present at the hospital and the number of available appointments slots is neglected. Furthermore, we schedule appointments with scheduling times of zero.	*Shorter hospital HWT but shorter AWT and higher one-stop-shop satisfaction, as gaps (e.g. created by cancellations) are filled by the walk-in mechanic. However, we may also expect longer HWTs and delays, because many appointments are still scheduled at certain times.*
Walk-in Plus	Similar to Walk-in. But appointments that are still scheduled days in advance are now scheduled at the moment the care process will be opened and are treated also as walk-in appointments.	*Similar effect as Walk-in, but we expect many appointments to be delayed (since all of them are scheduled at the opening time). Therefore, we shall focus on the effects the scenario has on the HWTs.*
Walk-in Basic	Similar to Walk-in. But appointments are scheduled with their original scheduling time.	*Similar effect as Walk-in.*
Extra ANE DB	An extra Anaesthetist is present at DB. We subtract 10 minutes from each appointment at CT and MRI, as the expected reduction in time for each appointment is estimated to be this. The recovery time for appointments is removed (previously set to 20 minutes to, e.g., call, prepare and transport the next patient).	*We expect less and shorter appointment delays, as the time in between appointments is removed. We expect this substantially reduces the gaps in the schedule and improves the capacity utilisation if we shorten the opening times accordingly.*
Gaps for DB	Instead an extra Anaesthetist at DB, we take into account the time required time between appointments at the Ct and MRI. Gaps of 20 minutes are scheduled between appointments.	*Increase in AWT we schedule additional gaps in the schedule. But it may balance the workload and reduces the duration and number of delays.*
Earlier Arrival	All owners are requested to arrive earlier for their appointment. The earlier requested arrival time is equal to the **mean** plus 34% of the **standard deviation** of the on-time arrival that is associated with the appointment (distinction between NP and CP is made).Additional time for NP and CP appointments can be added to take into account the check-in tasks.	*We expect substantial decreases in the number and duration of delayed appointments. It may affect the HWT, as we treat patients with First-come-first-served heuristic and some patients with late appointment times may arrive earlier than other patients with earlier appointment times.*
Day-admission	Owners with patients are expected at the beginning of the time interval in which their appointment takes place. We can set three time intervals, e.g.: 8:00-10:00, 10:00-12:00, 12:00-closure.	*We expect many patients to arrive on-time for their appointment, reducing the number of delayed appointments. Nevertheless, it is expected to substantially increases the HWT, as most patients have to wait for their appointment. On the other hand, if there is a cancellation, it is highly likely another patient is available for their appointment.*
Night-admission	owners will drop off their patient on the day before the appointment day if their appointment is before a time in the morning.	*We expect significant increases in the HWT, but they are not experienced by the owner as we expect the owner will pick-up their pet the next day after the treatment. A substantial*

		improvement is expected on the number and duration of delayed appointments and workload balance.
No limited slots	we remove the number of available slots to evaluate which care processes are constrained by this. In practice, many care processes do not live up to this constraint.	*We expect that the capacity utilisation is significantly increased for care processes constrained by the maximum number of available appointments slot.*
Overscheduled capacity	*We schedule appointments overlapping each other by subtracting a time from the scheduling times.*	*We expect an increased capacity utilisation for care processes treating demand with many cancellations. However, we also expect longer HWT and delays, and more delays at times when no appointment is cancelled.*
Broader employability	*We reduce the number of days before an appointment may be scheduled on a wider range of care processes. This is applicable to the outpatient clinical consults at INT and CHIR, as well as most surgeries at CHIR.*	*We expected a reduction in AWT as appointments can be treated quicker at other care processes. We expect no reduction in other performances.*

Table 4.3.1 Description of the what-if scenarios with their expected improvements on KPIs

4.4 Assumptions and model summary

The developed simulation model consist of the following **core functionalities**:

- Patient flow for clinical pathways of patients through care processes, waiting rooms, reception, and waiting at home.
- Stochastic patient creation for 9 patient arrivals (extent (1), elective (2), emergency (3), cancellations (2)) with own weekday and hourly arrival distribution
- Stochastic patient arrival with normal distributed on-time arrivals. Distinction in NP/CP.
- Stochastic patient check-in with normal distributed check-in times. Distinction in NP/CP.
- Patient appointment planning process that:
    - Respects timings of appointments (consideration time, time between appointments…)
    - Scheduling of several appointments at once
    - Scheduling at several service stations
    - Scheduling with One-Stop-Shop
    - Scheduling first-come-first-served and ASAP
    - Respecting breaks, maximum number of appointment slots, time between appointments
    - Scheduling and cancelling cancellations
    - Scheduling on multiple care processes
    - And more…
- Simulation that treats emergencies as emergencies.
- Set of care processes supported by Anaesthetists.
- Weekly routinely Production schedule with opening times, service stations, fixed breaks and more.
- Wide range of decision variables to experiment with, and to guide and optimize the patient flow, allocation of resources and patient appointment planning.
- Experimental environment designed to perform experiments with statistical significant results.

- Recording of many statistics processed into tables and graphs. Used to monitor and evaluate progression of the simulation and identify bottlenecks.

The developed simulation model has the following **model assumptions**:

- In practice, most appointments are scheduled FCFS (observed at and according to Case Managers, employees from Telephony and front desk). However, there are many exceptions made (e.g. if the urgency is high). It is impossible to imitate the exact patient appointment planning processes, considering it depends on experience and intuition. We have validated the modelled patient appointment planning processes multiple times to be sure to capture the core of the reality.
- Model does not consider:
    - Holidays
    - Labour capacity (except ANE to little extent)
    - Some care processes (e.g. nursing ward and most care processes of Paard)
    - Non-regular opening hours (except for *SPOED_Poli*)
    - Ad-hoc tasks and other unreported activities.
    - Admission of patients to the hospital for multiple days or specific activities like feeding the admitted patients at VBD_Poli.
- Variability in processing times (treatment times) is taken little into account as (reliable) data and quantitative information is missing. Distributions of the variability of processing times are therefore unknown. However:
    - Outpatient clinical consults durations are considered as relatively consistent (if the executive employee sticks to the schedule).
    - Surgeries are very variable in their duration.
    - Some surgeries received a different scheduling time than processing time, if processing time was adjusted after the surgery by ANE and a standard time was reported).
    - Appointments at DB are less variable in duration. They are consistently delayed by belayed personnel and patients.
    - Appointments at DB are succeeded by additional medical operations (e.g. ECHO succeeding a CT). These additional medical operations either:
        - Scheduled at SA.
        - Executed within the appointment duration.
        - Executed outside the appointment duration, but the appointment time is adjusted by ANE afterwards.
        - Not executed, but scheduled at the correct care process as an appointment.
- On-time arrivals are very sensitive to the time of day due to traffic and other factors. We are not concerned with these factors.
- In practice, highly specialised complex surgeries and other appointments types (e.g. consults at INT) can only be treated by a specific care process. We prioritise to treat appointments of a discipline at this discipline, but allow many appointments to be scheduled at other care processes. In the future, we may identify and constraint appointments to be treated only by specific care processes.

- NP appointments are IMMEDIATELY scheduled after they contact the hospital (arrive at the model). Therefore, the time of scheduling is considered to be equal to the arrival time of the demand. This is true for most outpatient clinical consults and emergencies as they want to receive care as soon as possible. It is also true for appointments that require a confirmation of the appointment date and an agreement on a cost estimation by the owner. They are either immediately scheduled, cancelled and moved, or scheduled after the owner agreed on the cost estimation and appointment date. This is not true for external patients, they are scheduled by the clinic whenever it suits the current schedule and thus not upon the first contact.
- Due to the limited time, we failed to resolve the following:
    - Emergencies are only prioritised over elective patients at surgeries at CHIR. They cannot interrupt ongoing appointments or be prioritised over other already arrived patients.
    - We cannot monitor overtimes and how well breaks between appointments and fixed breaks are respected.

4.5 Summary

In Section 4.1 we discussed how we handled clinical pathways, the timing of appointments, the flow of patients, the patient appointment planning processes and the arrival of patients in the simulation model.

Next in Section 4.2 we discussed the data preparation in which we designed **61.997 clinical pathways**, identified tens of disciplines and came up with a final selection of 31 disciplines with 42 care processes (and 3 disciplines with no care processes), and classified **114.715 appointments** by appointments types, treatment types and the disciplines. Most of the results are presented in Chapter 2, Section 2.3.1. In the same sub-section, we explained how we adjusted the appointment timings to make them as independent as possible from the past production schedule that was in place and how we corrected processing times and introduced and valued scheduling times.

Then in Section 4.3 we discussed the decision variables and presented the what-if scenarios based on these variables.

We finished with Section 4.4 by summarising the model and discussing the model assumptions made on the data and practical (real) situation.

Chapter 5 Experiments & Results

This chapter will answer research question 9: *How do the alternative solutions contribute to the performance on KPIs? What are valuable and meaningful solutions?*. This is done by first discussing the experimental set-up (warm-up period, number of replications, 'as-is' situation settings, etc.) in Section 5.1. Next, Section 5.2 presents and discusses the performance results of the 'as-is' situation. Successively, in Section 5.3 we present and evaluate on the results for the proposed alternative solutions for the allocation of resources (production schedule) that we found through simulation based optimization. At last, we present and discuss the experimental results for the alternative solutions to the patient appointment planning processes (what-if scenarios) Section 5.4.

Experimental results can be found in Appendix R. Recommendations based on the (interpretation of) the results can be found in the Chapter 6.

During the research, we ran into other findings during the (data) analysis of the 'as-is' situation that were not (strongly) related to the core problem. These findings are presented in Appendix V occasionally supplemented with the problem description and/or proposed solution(s).

5.1 Experimental set-up

In Section 2.4 we introduced the KPIs to measure the performance of the system and in Section 3.3 we discussed how the KPIs will be used to evaluate the performance of the 'as-is' situation and alternative solutions. The quantified boundaries and performance goals on the KPIs for all care processes and appointments can be found in Table 5.2.1.

The settings of the 'as-is' situation can be found in Appendix P with an brief explanation. The experimental and non-experimental decision variables are discussed in Section 4.3 and can be consulted in case of haziness (e.g. haziness about the what-if scenarios). The production schedule of the 'as-is' situation can be found in Table 2.2.1.

For the experiments, we start collecting data results after a warm-up period of 966 days when the system enters typical 'normal' running conditions. To produce statistically significant (maximal margin of error less than 2.5%), the minimum number of replications is found to be 5 replications with 10 years running time each. We will experiment with 20 replications with 10 years running time each as the run speed of the model is quite fast. We further elaborate on the use and estimation of a warm-up period and minimum number of replications in Appendix Q.

5.2 Performance of the 'as-is' situation

The performance results of the 'as-is' situation are presented in Table 5.2.1 with the use of conditional formatted cells to indicate violated boundaries (red coloured cells) and unachieved performance goals (yellow coloured cells). Most of the problems identified in the problem identification and Chapter 2 can be found back in the performance results. These observations increase the validity of the simulation. Some examples are:

- Far from optimal production schedule with poor performance on capacity utilisation and AWT as the schedule is not demand driven and uses overcapacity as a flexibility measure to cope with variabilities.
- Many delayed appointments due to the unaccounted for delay in on-time arrivals.
- Unbalanced workload throughout the week and days (see Figure 5.2.1). Daily peak workloads between 10:00-12:00 with in particular experienced at DB and outpatient clinical consults

The system is complex and we can only guess with the information discussed in the previous chapters what interactions may take place and what outcomes can be expected from employing an alternative solution. After all, this is why we use experimental simulation and simulation based optimization. What-if scenarios and changes to the production schedule interact with each other. For instance, if we overschedule capacity or eliminate scheduling with reservation, we may in response shorten the opening times. For the above reasons, and to keep it manageable and orderly, we first aim to exploit changes to the production schedule to gain substantial improvements. Later-on, we evaluate the what-if scenarios on both the obtained optimised situation and the initial ‘as-is’ situation.

Table 5.2.1 Performance boundaries and goals for KPIs for care processes and appointments. Step-wise approach can be found at the top of the table.

<table>
<tr><th colspan="2"></th><th>Priority steps -></th><th colspan="4">1. Boundaries</th><th>2. AWT</th><th>3. Capacity Utilization</th><th>4. Balanced workload</th><th>5. HWT</th><th>6. Appointment Delays</th><th>7. One-Stop-Shop satisfaction</th></tr>
<tr><th colspan="2"></th><th>KPI for -></th><th>Appointments</th><th>Care Process</th><th>Care Process</th><th>Care Process</th><th>Appointments</th><th>Care Process</th><th>Care Process</th><th>Care Process</th><th>Care Process</th><th>Appointments</th></tr>
<tr><th colspan="2"></th><th>Care Process, Appointment or Both</th><th>Maximum percentage AWT unsatisfied (in %)</th><th>Minimum Capacity Utilization (in %)</th><th>Maximum percentage of delayed appointments (in %)</th><th>Maximum average HWT (in seconds)</th><th>Acceptable average AWT (in days)</th><th>Capacity Utilization (in %)</th><th>Balanced workload</th><th>Average HWT (in seconds)</th><th>Average delay time (in seconds)</th><th>Percentage of satisfied One-Stop-Shop (in %)</th></tr>
<tr><td>CHIR_THK</td><td>Poli</td><td>Both</td><td rowspan="46">15.0%</td><td rowspan="8">60.0%</td><td rowspan="46">50.0%</td><td rowspan="26">20 minutes</td><td rowspan="8">4</td><td rowspan="8">80.0%</td><td rowspan="46">Peak workload less than twice the average workload (value less than 2)</td><td rowspan="46">10 minutes</td><td rowspan="46">20 minutes</td><td rowspan="37">N/A</td></tr>
<tr><td>CHIR_Overig(1)</td><td>Poli</td><td>Appointment</td></tr>
<tr><td>CHIR_Overig(2)</td><td>Poli</td><td>Appointment</td></tr>
<tr><td>CHIR_algemeen</td><td>Poli</td><td>Both</td></tr>
<tr><td>CHIR_KNO</td><td>Poli</td><td>Both</td></tr>
<tr><td>CHIR_ONCO</td><td>Poli</td><td>Both</td></tr>
<tr><td>CHIR_ORTHO_NEURO</td><td>Poli</td><td>Both</td></tr>
<tr><td>CHIR_URO_LEVER</td><td>Poli</td><td>Both</td></tr>
<tr><td>CHIR_THK</td><td>Surgery</td><td>Both</td><td rowspan="10">30.0%</td><td>14</td><td rowspan="10">70.0%</td></tr>
<tr><td>CHIR_Overig(1)</td><td>Surgery</td><td>Appointment</td><td rowspan="3">7</td></tr>
<tr><td>CHIR_Overig(2)</td><td>Surgery</td><td>Appointment</td></tr>
<tr><td>CHIR_OVERIG</td><td>Surgery</td><td>Care Process</td></tr>
<tr><td>CHIR_KNO</td><td>Surgery</td><td>Both</td><td rowspan="2">14</td></tr>
<tr><td>CHIR_ONCO</td><td>Surgery</td><td>Both</td></tr>
<tr><td>CHIR_ORTHO_NEURO</td><td>Surgery</td><td>Both</td><td>7</td></tr>
<tr><td>CHIR_URO_LEVER</td><td>Surgery</td><td>Both</td><td rowspan="2">14</td></tr>
<tr><td>CHIR_OVE</td><td>Surgery</td><td>Both</td></tr>
<tr><td>CHIR_OOG</td><td>Surgery</td><td>Both</td><td>7</td></tr>
<tr><td>GEDRAG</td><td>Poli</td><td>Both</td><td rowspan="8">60.0%</td><td rowspan="8">4</td><td rowspan="16">80.0%</td></tr>
<tr><td>OVERIGEPOLI</td><td>Poli</td><td>Both</td></tr>
<tr><td>VOEDING</td><td>Poli</td><td>Both</td></tr>
<tr><td>CARDIO</td><td>Poli</td><td>Both</td></tr>
<tr><td>NEUR</td><td>Poli</td><td>Both</td></tr>
<tr><td>ONCO</td><td>Poli</td><td>Both</td></tr>
<tr><td>OOG</td><td>Poli</td><td>Both</td></tr>
<tr><td>ORTHO</td><td>Poli</td><td>Both</td></tr>
<tr><td>SPOED</td><td>Poli</td><td>Both</td><td>30.0%</td><td>5 minutes</td><td>0</td></tr>
<tr><td>VPL</td><td>Poli</td><td>Both</td><td rowspan="7">60.0%</td><td rowspan="20">20 minutes</td><td rowspan="7">4</td></tr>
<tr><td>ENDO</td><td>Poli</td><td>Both</td></tr>
<tr><td>DERM</td><td>Poli</td><td>Both</td></tr>
<tr><td>GAHE</td><td>Poli</td><td>Both</td></tr>
<tr><td>HEMA</td><td>Poli</td><td>Both</td></tr>
<tr><td>URO</td><td>Poli</td><td>Both</td></tr>
<tr><td>ALG_INT</td><td>Poli</td><td>Both</td></tr>
<tr><td>VBD</td><td>Poli</td><td>Both</td><td rowspan="2">30.0%</td><td>4</td><td rowspan="2">40.0%</td></tr>
<tr><td></td><td>SA</td><td>Both</td><td>999</td></tr>
<tr><td>RAD</td><td>Poli</td><td>Both</td><td rowspan="10">60.0%</td><td rowspan="2">4</td><td rowspan="10">80.0%</td></tr>
<tr><td>RAD</td><td>NuclDiagn</td><td>Both</td><td rowspan="2">90.0%</td></tr>
<tr><td>RAD</td><td>MRI</td><td>Both</td><td>1</td></tr>
<tr><td>RAD</td><td>RTC</td><td>Both</td><td>2</td><td>N/A</td></tr>
<tr><td>RAD</td><td>CT</td><td>Both</td><td rowspan="6">1</td><td rowspan="5">90.0%</td></tr>
<tr><td>RAD</td><td>ECHOPD</td><td>Both</td></tr>
<tr><td>RAD</td><td>ECHOGD</td><td>Both</td></tr>
<tr><td>RAD</td><td>XRAYPD</td><td>Both</td></tr>
<tr><td>RAD</td><td>XRAYGD</td><td>Both</td></tr>
<tr><td>RAD</td><td>FLUOR</td><td>Both</td><td>N/A</td></tr>
</table>

Table 5.2.2 Performance on KPI boundaries (columns with red coloured headings) and goals (columns with yellow coloured headings) of the 'as-is' situation. If cells are coloured, the boundary is exceeded (red) or the goal is not achieved (light yellow). N = n/a, T = n/a, S = output simulation model

	Priority steps ->		1. Boundaries				2. AWT	3. Capacity Utilization	4. Balanced workload	5. HWT	6. Appointment Delays	7. One-Stop-Shop satisfaction
	KPI for ->		Appointments	Care Process	Care Process	Care Process	Appointments	Care Process	Care Process	Care Process	Care Process	Appointments
		Care Process, Appointment or Both	Maximum percentage AWT unsatisfied (in %)	Minimum Capacity Utilization (in %)	Maximum percentage of delayed appointments (in %)	Maximum average HWT (in seconds)	Acceptable average AWT (in days)	Capacity Utilization (in %)	Balanced workload	Average HWT (in seconds)	Average delay time (in seconds)	Percentage of satisfied One-Stop-Shop (in %)
CHIR_THK	Poli	Both	9.7%	39.8%	83.8%	74	1.82	39.8%	1.50	74	1568	30.7%
CHIR_Overig(1)	Poli	Appointment	0.0%				0.32					58.8%
CHIR_Overig(2)	Poli	Appointment	0.0%				0.57					51.2%
CHIR_algemeen	Poli	Both	0.1%	82.0%	89.2%	363	0.48	82.0%	1.78	363	1445	52.5%
CHIR_KNO	Poli	Both	3.8%	61.4%	86.6%	152	1.78	61.4%	1.34	152	1211	26.4%
CHIR_ONCO	Poli	Both	35.3%	22.8%	83.7%	34	2.85	22.8%	1.33	34	1273	16.2%
CHIR_ORTHO_NEURO	Poli	Both	0.0%	46.5%	89.8%	300	0.77	46.5%	1.74	300	1619	28.0%
CHIR_URO_LEVER	Poli	Both	52.7%	54.1%	88.3%	344	4.01	54.1%	1.33	344	1765	16.5%
CHIR_THK	Surgery	Both	0.0%	45.7%	70.3%	708	1.37	45.7%	1.81	708	2043	59.7%
CHIR_Overig(1)	Surgery	Appointment	0.0%				0.43					67.6%
CHIR_Overig(2)	Surgery	Appointment	0.0%				0.53					54.5%
CHIR_OVERIG	Surgery	Care Process		22.3%	83.6%	712		22.3%	2.14	712	1209	
CHIR_KNO	Surgery	Both	0.0%	45.5%	71.5%	399	2.11	45.5%	2.07	399	1056	21.8%
CHIR_ONCO	Surgery	Both	0.0%	64.7%	51.8%	114	3.91	64.7%	1.54	114	540	11.5%
CHIR_ORTHO_NEURO	Surgery	Both	0.7%	35.0%	85.0%	315	0.71	35.0%	1.82	315	1049	58.6%
CHIR_URO_LEVER	Surgery	Both	0.0%	87.6%	67.9%	538	4.29	87.6%	1.36	538	866	7.1%
CHIR_OVE	Surgery	Both	0.0%	79.2%	67.3%	200	3.94	79.2%	1.43	200	713	13.1%
CHIR_OOG	Surgery	Both	0.2%	37.9%	69.2%	147	1.28	37.9%	2.19	147	534	24.0%
GEDRAG	Poli	Both	42.9%	49.2%	90.9%	19	4.16	49.2%	1.66	19	1216	0.0%
OVERIGEPOLI	Poli	Both	0.0%	8.8%	97.9%	124	0.12	8.8%	1.88	124	724	82.2%
VOEDING	Poli	Both	41.1%	10.1%	100.0%	20	3.34	10.1%	1.48	20	528	0.0%
CARDIO	Poli	Both	31.6%	81.4%	91.7%	732	4.20	81.4%	1.33	732	1936	19.0%
NEUR	Poli	Both	0.0%	33.2%	90.7%	388	0.38	33.2%	1.94	388	1676	64.3%
ONCO	Poli	Both	19.0%	78.7%	86.3%	178	2.43	78.7%	1.45	178	1277	17.2%
OOG	Poli	Both	10.4%	51.2%	82.9%	278	1.48	51.2%	1.65	278	1681	42.0%
ORTHO	Poli	Both	0.6%	32.7%	87.7%	260	1.00	32.7%	1.76	260	1613	29.2%
SPOED	Poli	Both	0.0%	66.2%	0.0%	160	0.00	66.2%	3.12	160	0	0.0%
VPL	Poli	Both	0.2%	40.8%	94.4%	358	0.75	40.8%	1.59	358	1212	49.6%
ENDO	Poli	Both	15.4%	69.3%	88.5%	155	2.11	69.3%	1.41	155	1452	43.2%
DERM	Poli	Both	2.9%	54.0%	92.9%	106	1.26	54.0%	1.42	106	1147	41.3%
GAHE	Poli	Both	23.5%	69.3%	90.2%	302	3.05	69.3%	1.47	302	1716	17.6%
HEMA	Poli	Both	19.0%	63.1%	88.3%	255	1.92	63.1%	1.85	255	1404	17.6%
URO	Poli	Both	6.1%	68.0%	91.0%	342	1.60	68.0%	1.54	342	1654	25.1%
ALG_INT	Poli	Both	49.9%	65.5%	92.5%	364	4.47	65.5%	1.77	364	1767	19.9%
VBD	Poli	Both	0.0%	55.4%	88.4%	1141	0.34	55.4%	1.88	1141	1767	69.4%
	SA	Both	0.0%	21.2%	93.4%	1034	0.13	21.2%	1.74	1034	3979	89.5%
RAD	Poli	Both	0.0%	5.5%	100.0%	1225	0.27	5.5%	1.00	1225	1424	58.2%
RAD	Nucl_Diagn	Both	0.0%	1.8%	98.4%	40	0.05	1.8%	1.00	40	14500	91.8%
RAD	MRI	Both	3.9%	34.9%	92.3%	1668	0.22	34.9%	2.05	1668	2623	88.5%
RAD	RTC	Both	2.3%	47.6%	90.6%	581	0.38	47.6%	1.95	581	2229	48.5%
RAD	CT	Both	2.5%	30.0%	95.7%	1369	0.14	30.0%	1.79	1369	3111	90.6%
RAD	ECHO_PD	Both	2.5%	14.0%	100.0%	343	0.33	14.0%	3.45	343	588	92.2%
RAD	ECHO_GD	Both	3.4%	37.5%	100.0%	1332	0.26	37.5%	2.29	1332	721	90.8%
RAD	X_RAYP_D	Both	2.5%	10.0%	100.0%	131	0.32	10.0%	3.77	131	594	93.5%
RAD	X_RAY_GD	Both	3.4%	10.3%	100.0%	293	0.24	10.3%	3.39	293	746	94.7%
RAD	FLUOR	Both	8.7%	3.1%	100.0%	319	0.50	3.1%	1.15	319	1113	78.7%

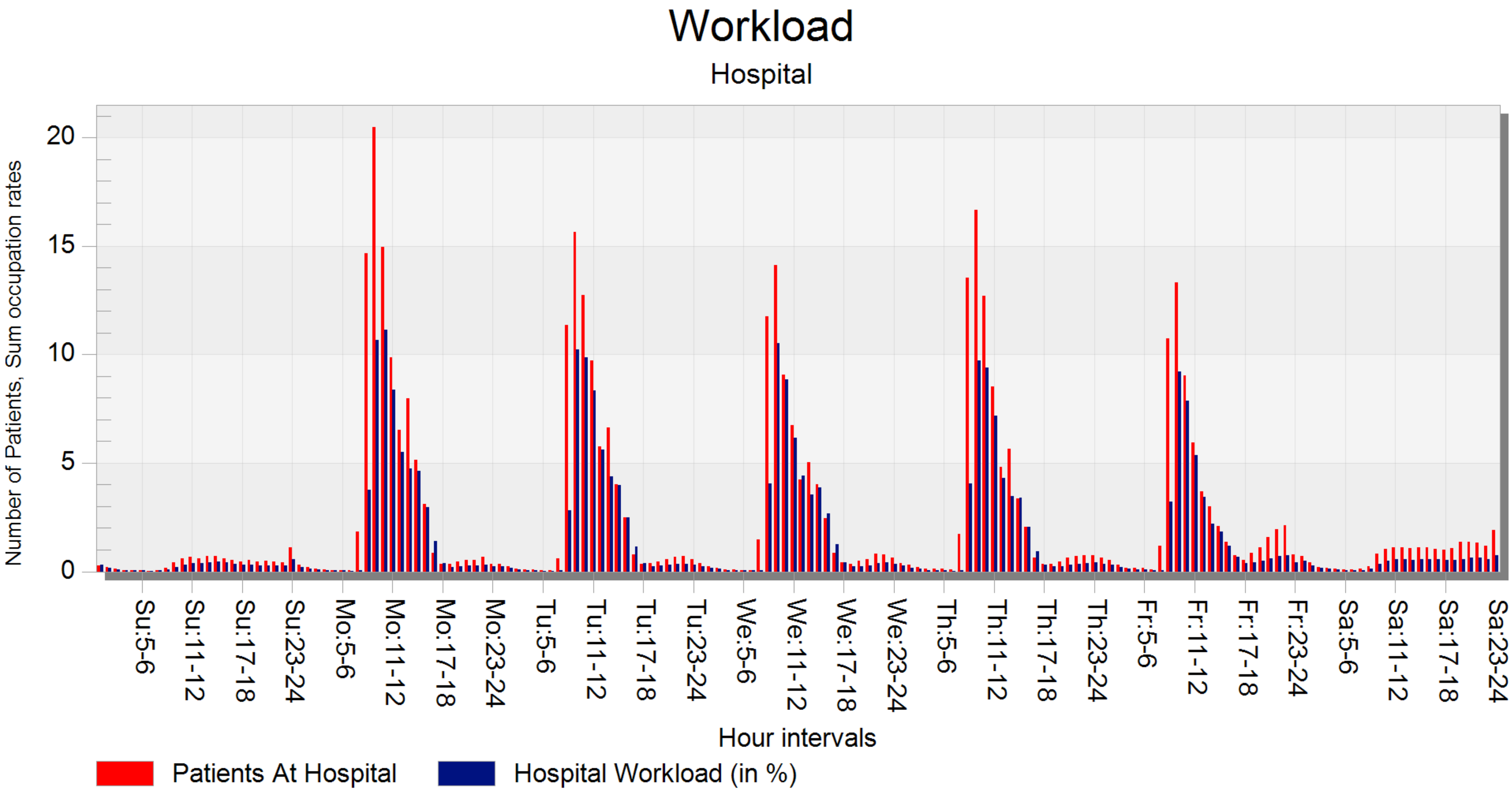

Figure 5.2.1 Hospital's total hourly workload in percentage (%) and number of present patients combined for all **care processes** (excluding reception) per hour per weekday.

5.3 Performance of the optimised production schedule

We optimised the production schedule to a more demand-driven schedule consisting of more univocal schedules. Also, we applied variability buffering of the demand at upstream processes and clustered preceding demand of downstream processes. This was achieved through simulation based optimization. To ensure that the alternative solutions were effortless, we took into account the following:

- We respect the dayparts (mornings and afternoons) at which the outpatient clinical consults are opened.
- We open the care processes that should be opened every day (see Appendix U).
- We respect the breaks between appointments and standard fixed breaks that are present in the 'as-is' production schedule. If a fixed break becomes obsolete (e.g. when we close the care process), we remove it.

The optimalisation of the production schedule took place in the following order:

1. Start with care processes that do not belong to any of three main clusters from the relationship diagrams (see Appendix G, Table_Apx G.1).
2. Optimise the care processes on performance boundaries and then performance goals with the use of the tables presented in Section 2.3.4 and the summary table presented in Appendix U. The alternative solutions are based on the general solutions from Table 3.3.1.
3. Select one of the three clusters from the relationship diagrams (see Appendix G) and optimise the set of care processes belonging to this cluster with the application of variance buffering and other theory discussed Section 3.2.1. Additionally, we use the same information that is also used in step 2. The clusters are optimised in the following order:
    1 Neurology cluster (Appendix G, Table_Apx G.3).
    2 Oncology cluster, (Appendix G, Table_Apx G.2).
    3 Remaining cluster, (Appendix G, Table_Apx G.4).

The performance results of the optimised production schedule with the production schedule itself can be found in Appendix R.

The main results from the use of variability buffering and the development of a more demand driven production schedule consisting of more univocal schedules are:

- A balanced trade-off for most care processes between the made-available capacity and AWT, with fewer and less severally violated boundaries.
- A Reduction in the total made-available capacity by 45% and by 43% for Anaesthesiology-supported care processes achieved by reducing the opening times and number of opened days (see results per care process in
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- Table 5.3.1 in the columns clustered under column header ‘Capacity reduction’)
- A slight decrease in One-Stop-Shop satisfaction by roughly 10%-15% compared to the ‘as-is’ situation in which DB’s care processes were opened complete days.
- Many small increases in unsatisfied AWT by 2%-10% and Average AWT.
- A more balanced workload as capacity is made available whenever it is demanded and the gaps in the planning are reduced.
- Decrease in the percentage of delayed appointments by roughly 10%-20% at most of DB’s care processes and a more balanced workload at the whole hospital as we separated DB’s care processes more from the outpatient clinic. This separation reduces the number of missing or delayed patients for appointment at DB when they are still being treated at the preceding consult. The separation comes at the cost of roughly 10-30 minutes extra HWT for care processes at DB.

Additionally, we draw some topic-specific conclusions in the next sub-sections.

Variability buffering of upstream demand

This appeared to be especially beneficial for care processes with high demand, high variability, many NPs (>50%) and well connected to other downstream care processes. It was less beneficial for care processes with low demand, low variability, relatively long appointments and many revisits (CPs). How beneficial variability buffering is for each care process is based on the care process’ characteristics and is displayed

Table 5.3.1 under column 'Buffering weekday demand'.

Variability buffering for downstream demand

This appeared to be especially beneficial for downstream care processes with many small or few strong connections to other preceding care processes (see

Table 5.3.1, column 'Clustering succeeding demand' for each care process). The implementation of changes to the production schedule based on one of the clusters of the relationship diagram always provided substantial improvements. The clustering of demand downstream resulted in care processes to be specifically opened extra on specific weekdays:

- *ECHO_GD* and *X_RAY_GD* are opened extra on Monday, Tuesday and Thursday.
- *MRI* is extra opened on Thursday and Friday.
- *CT* is extra opened on Tuesday and Thursday.

Towards a more demand-driven production schedule

Making care processes more demand driven appeared to be useful at care processes that are upstream (many NPs) or have no stream with many NPs (see

Table 5.3.1, columns 'No stream (Demand driven)' and 'Upstream (Demand driven)' for each care process). The end of the week appears to be the best moment for these care processes to open (e.g. Friday). An upstream care process with additionally many revisits (CPs) generally requires a second opening day to serve this demand within the acceptable AWT (see

Table 5.3.1, column ‘Revisits). In this case, opening on Monday and Thursday appears to be the best combination with the current demand patterns. As a result, most upstream care processes are opened at Monday and Thursday in case of many revisits or at Thursday and/or Friday (in case of many NPs thus very demand driven).

In addition to care processes with no stream (no connections) there are several care processes that stand in little relation to other care processes. They can be used to distribute the workload throughout the week and in particular distribute the workload at ANE (see

Table 5.3.1, column ‘Flexible’). For example, CHIR_OVE is demand driven and can be opened in a demand-driven matter, but is still relatively flexible in which day it is opened.

Many care processes have little connections to other care processes but should be aligned correctly with other care processes in mind (see

Table 5.3.1, column 'Align'). For instance, it is beneficial to open many surgeries in between the outpatient clinical consult of the same surgical discipline to reduce AWT. Therefore, most *Surgeries* are opened on Wednesday.

Other findings

- Whenever *ECHO_GD* is opened, it is beneficial to open *X_RAY_GD* since they are strongly connected through many succeeding One-Stop-Shop appointments. This is similar to *ECHO_PD* and *X_RAY_PD.*
- *CHIR_Algemeen_Poli* serves general outpatient clinical consults of discipline CHIR and is thereby connected to many outpatient clinical consults and surgeries at CHIR.
- *Service Anesthesia (SA)* is connected to many care processes as preceding and succeeding care process.
- *SPOED_Poli* is very upstream and strongly connected to many care processes as a preceding care process.
- Increasing the opening duration and reducing the occurrence of breaks on an opened day is beneficial for the AWT, as more combinations of appointment with different durations can be scheduled and less gaps before or after breaks, or at the start or end of the opening time occur. This is in particular important for care processes serving appointments of various durations.
- It is beneficial to adjust opening times to the most frequent (combination of) appointment durations and by taking into account the needed in-between appointments.

- Opening multiple service stations simultaneously is beneficial to increase the One-Stop-Shop and AWT satisfaction if many appointments have succeeding one-stop-shop appointments. At both downstream and upstream care processes, fewer appointments are delayed (roughly 5-10%). Slight performance decreases are found at downstream processes in the balanced workload and HWT (roughly extra 5-20 minutes).
- It is challenging to achieve good capacity utilisations for care processes serving only a small average demand that commonly comes with high demand variability. Especially when the care process serves relatively long appointments (45-60 minutes). We either provide overcapacity and violate the capacity utilisation, or reduce the made-available capacity and violate on *Average AWT* and/or *unsatisfied AWT*. It is beneficial to either provide excess capacity and open only once a week to exploit variance buffering of the demand OR opening twice a week distributed over the week with little capacity for shorter *AWT*. These care processes are reported with a cross in
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-
- Table 5.3.1 within the column 'Buffering weekday demand'.

To summarise this section, we conclude that with the proposed alternative solutions substantial improvements can be achieved in *AWT, Capacity utilisation, Balanced workload* and *Delays* at small but acceptable degradations in the performance on *One-Stop-Shop satisfaction* and *HWT.* Simultaneously, we can substantially save on the capacity required by aligning care processes with each other and their demand patterns, and by exploiting variability buffering.

			Variability Buffering					Demand driven					Capacity reduction				
			Buffering Weekday demand	Clustering succeding demand				No Stream (demand-driven)	Upstream (Demand driven)	Revisits	Flexible	Align	Less opened days	As-is (hours)	To-be (Hours)	Reduction (Hours)	Reduction (Hours)
				MRI	ECHO_GD	X_RAY_GD	CT										
CHIR	CHIR_THK	Poli	✓						✓✓		✓		1	1.5	1.0	-0.5	33%
	CHIR_algemeen	Poli	Open every day	✓	✓	✓	✓		✓					24.9	24.9	0.0	0%
	CHIR_KNO	Poli					✓		✓	✓✓	✓			6.0	6.0	0.0	0%
	CHIR_ONCO	Poli	✗				✓✓		✓				-1	6.0	5.0	-1.0	17%
	CHIR_ORTHO_NEURO	Poli	✓	✓✓		✓✓			✓	✓			1	22.5	10.0	-12.5	56%
	CHIR_URO_LEVER	Poli	✗		✓				✓				-1	2.8	3.8	1.0	-36%
	CHIR_THK	Surgery	✓								✓	✓	1	**13.0**	**7.5**	**-5.5**	**42%**
	CHIR_OVERIG	Surgery	✓	✓	✓	✓	✓					✓	3	**54.5**	**15.5**	**-39.0**	**72%**
	CHIR_KNO	Surgery	✓				✓✓				✓	✓	1	**16.0**	**8.0**	**-8.0**	**50%**
	CHIR_ONCO	Surgery									✓	✓		**8.0**	**8.0**	**0.0**	**0%**
	CHIR_ORTHO_NEURO	Surgery	✓✓			✓✓						✓	2	**60.0**	**32.0**	**-28.0**	**47%**
	CHIR_URO_LEVER	Surgery			✓							✓		**8.0**	**8.0**	**0.0**	**0%**
	CHIR_OVE	Surgery						✓	✓✓		✓✓			**7.5**	**5.5**	**-2.0**	**27%**
	CHIR_OOG	Surgery	✓								✓	✓	1	**16.0**	**8.0**	**-8.0**	**50%**
General Medicines & INT	GEDRAG	Poli	✗					✓✓					-1	5.8	7.0	1.3	-22%
	OVERIGEPOLI	Poli	Open every day					✓						37.5	5.0	-32.5	87%
	VOEDING	Poli	✗					✓✓						5.0	1.8	-3.3	65%
	CARDIO	Poli	✓		✓				✓✓				1	17.0	17.0	0.0	0%
	NEUR	Poli	✓✓	✓✓					✓✓				2	26.0	10.0	-16.0	62%
	ONCO	Poli	✓✓		✓		✓		✓	✓✓			2	10.3	10.5	0.3	-2%
	OOG	Poli	✓✓						✓	✓			2	21.5	15.0	-6.5	30%
	ORTHO	Poli	✗					✓						11.8	5.0	-6.8	58%
	SPOED	Poli	Open every day	✓	✓	✓	✓							85.0	85.0	0.0	0%
	VPL	Poli	✓		✓				✓✓				1	12.5	7.0	-5.5	44%
	ENDO	Poli					✓		✓	✓✓				6.3	6.3	0.1	-1%
	DERM	Poli	✓					✓		✓✓			1	22.0	16.0	-6.0	27%
	GAHE	Poli			✓				✓✓	✓				5.3	6.0	0.8	-14%
	HEMA	Poli			✓				✓	✓✓				5.0	5.3	0.3	-7%
	URO	Poli			✓				✓✓	✓				5.3	6.0	0.8	-14%
	ALG_INT	Poli			✓				✓✓					3.3	3.8	0.6	-18%
VBD	VBD	Poli	Open every day					✓		✓✓				38.8	23.8	-15.0	39%
ANE		SA	Open every day	✓	✓	✓	✓		✓					**42.5**	**42.5**	**0.0**	**0%**
DB	RAD	Poli								✓✓	✓		4	12.5	2.0	-10.5	84%
	RAD	Nucl_Diagn								✓✓✓✓	✓	✓	4	40.0	1.8	-38.3	96%
	RAD	MRI	Open every day											**37.8**	**20.0**	**-17.8**	**47%**
	RAD	RTC	Open every day							✓✓✓✓	✓✓			**15.0**	**10.0**	**-5.0**	**33%**
	RAD	CT	Open every day											**38.5**	**15.4**	**-23.1**	**60%**
	RAD	ECHO_PD	Open every day			✓✓								32.5	8.5	-24.0	74%
	RAD	ECHO_GD	Open every day		✓✓				✓					36.0	20.5	-15.5	43%
	RAD	X_RAY_PD	Open every day											35.3	6.0	-29.3	83%
	RAD	X_RAY_GD	Open every day						✓					34.0	7.0	-27.0	79%
	RAD	FLUOR	Open every day									✓	2	42.5	4.8	-37.8	89%
	ANE												160 to 96 dayparts	**317**	**180**	**-136**	**43%**
	Grand Total													931	512	-419	45%

Table 5.3.1 Discussed solutions of Section 5.3 (variability buffering, demand-driven univocal schedule) at the top row with the reported suitability of care processes for these solutions based on their characteristics. In the last columns under 'Capacity reduction', the reduction in capacity is presented (number of less/more opened days, total opened hours in 'as-is' and new 'to-be' situation and reduction of hours in percentage after optimisation).

5.4 Performance of the What-if scenarios

The what-if scenarios are evaluated on both the 'as-is' situation and the new 'to-be' optimised production schedule resulted from Section 5.3. A description and expected outcome of each what-if scenario can be found in Table 4.3.1.

The results of what-if scenarios can be found in Appendix R and consist of:

- Performance results of each what-if scenario applied to both the 'as-is' and 'to-be' situation.
- Performance changes of each what-if scenario in comparison to both situations.
- Performance changes of what-if scenarios in comparison to the 'as-is' situation presented per set of two KPIs.

In addition to the what-if scenarios, we also evaluated the performance changes by varying opening times of outpatient clinical consults in the optimised production schedule. We expect a more balanced workload and fewer delayed appointments. We evaluated '*Overscheduled capacity*' and *'Broader employability'* only in the optimised production schedule because the 'as-is' situation with overcapacity did not provide substantial changes.

We summarise the results with sub-sections for each What-if scenario by discussing the benefits and costs. We also discuss to what care processes the What-if scenario is most effective.

No OVB

Without Scheduling patients 'with reservation' we find slight improvements on HWT (roughly 3 minutes shorter) and the average delay in appointments (roughly 10 minutes shorter) in both the 'as-is' and 'to-be' situation. In both situations, scheduling without 'with reservation' substantially reduces the performance on One-Stop-Shop satisfaction (27.7% at MRI and 19.5% at CT in 'as-is' situation). This can be explained by the fact that appointments with additional OVB appointments are scheduled on times where they can be treated. At roughly half of the OVB appointments the demand appears to be existing.

No One-Stop-Shop

Scheduling appointments without considering that they are One-Stop-Shop concludes in no substantial performance changes. Most likely this can be explained by the reasoning that almost all One-Stop-Shop appointments can fit on the first available day if they are scheduled days in advance.

Walk-in

Walk-in rooms appeared to be most effective for care processes with much variability in the demand that treat many One-Stop-Shop appointments and suffer from many cancellations on a short-notice. Such care processes are *CT*, *MRI*, *ECHO_GD* and *X_RAY_GD*. These care processes require high flexibility to fill gaps in their schedule that can be achieved by treating other patients first or instead.

Three variations of walk-in rooms are tested on the care processes. Performance results are similar in both the 'as-is' and 'to-be' situation. However, if the capacity becomes more scarce (thus, in the 'to-be' situation), the more substantial improvements can be observed.

The 'Walk-in Basic' schedules appointments with the standard scheduling times, but allows patients that are already present at the hospital to be send directly to the care process and be treated at a First-

Come-First-Served heuristic. In both the ‘to-be’ and the ‘as-is’ situation, this reduces the percentage of delayed appointments by 10-20% and HWT by 7-15 minutes. With this walk-in variation, we only send a patients to the care process if we are certain there is capacity available.

In the ‘Walk-in’ variation, we neglect the available capacity at the care process and send any patient that is already present in the hospital to the care process. This may result in overtimes at the care processes. In both the ‘as-is’ and ‘to-be’ situation, we observe occasional overtimes of up to one hour. However, we may treat an additional 7.8-11% One-Stop-Shop appointments the day itself and an extra 1.1-11.8% appointments within the acceptable AWT. This comes at similar performance reductions on average delays and HWT as the previous variation.

In ‘Walk-in Plus’ variation, we additionally neglect the available capacity at care processes for appointments scheduled days in advance. We find this variation to be unrealistic, since we observe overtimes systematically.

Extra Anaesthetists at DB

An extra Anaesthetist can be dedicated to the MRI and CT to support with the introduction and transport of the patient and other tasks. In this situation, an estimate of 20 minutes between appointments and 10 minutes per appointment can be saved. This saves up to 3.9% at the MRI and 5.5% at the CT in capacity in the ‘as-is’ situation (7.1% and 12.9% in the ‘to-be’ situation respectively). An extra Anaesthetist can also support the *ECHO_GD* and *X_RAY_GD*.

Scheduling with gaps at DB

If no extra Anaesthetist supports the *MRI* and *CT*, gaps between appointments can enhance the feasibility of the schedule. This greatly reduces the number of delayed appointments, average delay, and HWT, but comes at drastic performance costs on KPIs such as Average AWT, satisfied AWT and One-Stop-Shop satisfaction. In the ‘as-is’ situation where we provide overcapacity, this is a possible solution. However, in the ‘to-be’ situation where capacity is more scarce, the negative effects are more drastic. An additional 19% of the appointments at MRI and 41.6% at *CT* are not treated within the acceptable AWT. However, we reduce the HWT (roughly 12-50 minutes) and average delay (roughly 5 minutes) since we take into account the time needed for ANE between appointments.

Earlier Arrival

Patients are requested to arrive earlier for outpatient clinical consults equal to the average delay of their appointment plus one standard deviation of the average delay (These values are dependent on care process and type of appointment (CP/NP)). From a theoretical-perspective and since the delays are normally distributed, we may eliminate up to 86% of the delays if we ensure that patients arrive earlier equal to the average delay plus one standard deviation of the delay. An additional 8 minutes for CPs and 11 minutes for NPs are added to take into account check-in related tasks.

In both situations, the percentage of delayed outpatient clinical consults can be reduced by 60-80%. In a similar way and in response to the fewer delays upstream, 30-80% fewer appointments are delayed at downstream processes. In particular the *ECHO_GD* and *X_RAY_GD* are positively affected by fewer delays upstream. In the current situation, an extra 5.2% One-Stop-Shop appointments can be treated the same day and 0.9% appointments can be treated within the acceptable AWT at the *ECHO_GD*. Respectively, this is 8.0% and 1.3% for the *X_RAY_GD*.

The request for patients to arrive earlier has little effect on the HWT. Some patients are still delayed while most patients (commonly >80%) arrive on-time and c

an still be treated quickly. Increasing the extra time at which patients should arrive earlier, will negatively affect the HWT. As upstream care processes become more stream-lined by fewer delays, HWT at downstream care processes increases. Therefore, we find roughly 5 minutes additional HWT at DB's appointments.

Day-admission
With a day-admission owners with patients are requested to arrive at the start of a time-window in which their appointment takes place. We used time windows of roughly 2 hours. The day-admission appeared to be effective at care processes with many delays and cancellations. These care processes are care processes with surgeries at CHIR, the *CT*, *MRI*, *ECHO_GD*, and *X_RAY_GD*. In both the 'as-is' and 'to-be' situation, we find substantial reductions in the delays (40-60%) at minimal cost on additional HWT (4-15 minutes). This is in particular useful to fill gaps in case of short-term cancellations. In return we find shorter waiting times for Emergencies and fewer drastic delays caused by emergencies.

Night-admission
With a night-admission, we admit patients over the night if their appointments starts before a certain time in the morning. We set this time to be 10:30 and experimented on surgeries at CHIR. We find in both situations a reduction in delayed appointments by 4-8% at the costs of additional HWT of 3-7 minutes.

Scheduling extern in off-peak hours
We may schedule certain demand (roughly only 2% of external appointments are cancelled) in off-peak hours separated from or before uncertain demand. From the results in the 'as-is' situation, we conclude that this can distribute the workload more evenly and prevent passing down the negative impact associated with the variability of uncertain demand onto certain demand. In the 'to-be' situation where capacity is scarce, this results in substantially poorer performances.

While we could not any further experiment and explore the benefits on patient discrimination in the patient appointment planning processes due to time and data constraints, it is promising to additional look into:

- Schedule appointments with (high probability of) successive care as early as possible, to leave room to treat unexpected care and to facilitate e.g. appointments at the Radiology to start earlier. On the other hand, schedule other appointments later on the day to reduce on-time delays but also leave room to treat demand potentially arriving on that same day.
- Schedule as many short appointments with low variability in their duration before long appointments with high variability in their duration to reduce appointment delays.
- Applying Variance Buffering to appointment scheduling processes, where appointments of similar variability are clustered together for the least total variability.

Scheduling with overcapacity
We may over-excessively schedule capacity with appointments to anticipate on cancellations, delays or early arrivals. This what-if scenario appeared to be most effective for care processes with many

cancellations on short-term notice and with many appointments during their opening times. These care processes are:

- Surgeries at *CHIR_THK* (common appointment durations of 120/90 minutes and 26.4% cancellations), *CHIR_KNO* (90/60/120/180 minutes, 24.7% cancellations), *CHIR_OVE* (120/60/150/90 minutes, 32.6% cancellations).
- Outpatient clinical consults at *CHIR_Overig(2)* (45/25/30/15 minutes, 41.2% cancellations), *NEUR_Poli* (25/15 minutes, 17.8% cancellations), *OOG_Poli* (30 minutes, 14.3% cancellations), all INT outpatient clinical consults (25 minutes, 15-20% cancellations).
- Appointments at *MRI* (75/90/60/120 minutes, 22.9% cancellations) and *CT* (45/60/30 minutes, 18.8% cancellations).

For these care processes, we over-excessively schedule capacity by overlapping appointments by some minutes (equal to roughly the percentage of cancellations times the average appointment duration). If all appointments must be treated, it can result in occasionally overtimes. If we over-excessively schedule capacity even more, the overtimes increase. In the 'to-be' situation, we monitored close to no overtimes. We found substantial performance improvements on the average AWT, percentage of appointments satisfied within the acceptable AWT and satisfied One-Stop-Shop appointments. In particular at the MRI (extra 9.2% appointments satisfied within acceptable AWT and 7.2% One-Stop-Shop satisfaction) and CT (9.3% and 11.4%) we find substantial improvements. Nevertheless, we find substantial performance reductions in HWT (extra 5-20 minutes) and the average delay of appointments (extra 2-10 minutes).

Broaden the Employability

We may increase the employability at care processes in a way that they may treat a wider range of less-discipline specific appointments. By reducing the number of days by one day after which appointments may be scheduled on disciplines that are not specially designed for the appointment (e.g. scheduling a Surgery from *CHIR_ORTHO_NEURO* at *CHIR_KNO*), we test the effect of this increased employability. We find positive results on AWT and capacity utilisation at certain care processes. This can be explained by the fact that there is more capacity available on which the appointment can be treated and appointments that may not fit on the care process itself can possibly still fit on other care processes. However, some appointments of certain care processes are negatively affected. We suspect that the capacity at those care processes are scheduled with appointments from other disciplines and that this leaves no room for the appointments of the discipline itself. An efficient planning heuristic may be considered to benefit effectively from the what-if scenario. For example, care processes with low demand that is very variable can fill up gaps in their capacity with other non-discipline specific appointments if they expect insufficient demand.

Various opening times

Opening care processes at various times significantly improves the distribution of workload of the whole hospital. We observe significant fewer queues at the check-in process by opening most outpatient clinical consult 15 minutes apart from each other in the 'to-be' situation. If possible opening the outpatient clinical consult as late as possible in the morning is beneficial for the AWT too, as much of the demand arrives at early morning hours and can immediately be treated on the care process.

Chapter 6 Conclusion & Recommendations

In this paper we analysed and evaluated the flow of patients at an academic animal hospital in order to develop and evaluate alternative solutions to improve it. Through extensive analysis of the 'as-is' situation, four years of historical data and applicable literature, and by consulting many employees, a set of alternative solutions was developed. These alternative solutions were tested on a set of Key Performance Indicators and their performances were evaluated by the use of a developed stochastic dynamic discrete-event simulation model where we performed statistically significant experiments and performed simulation based optimization. With our findings and results, we provided insights that can answer questions like '*Where do my patients originate from? When should we open a care process? How should we deal with cancellations? Should we introduce a walk-in process, what are the benefits and costs, and where should we introduce it?*'.

The research focusses on the fact that the current allocation of resources (the design of the production schedule) causes of over- and under capacity both labour- and physical-wise, an extremely unbalanced workload and mismatches between the supply of and demand for resources. A second focus of the research is based on the fact that patient appointment planning processes are inefficient, are accountable for unrealistic schedules, cancellations and numerous obstructions of the patient flow.

From analysis of the 'as-is' situation, historical data and applicable literature, we conclude that the network of care processes suffers greatly from the bullwhip effect. As a result, the negative impact of variability-related phenomena is first experienced at care processes upstream (mostly outpatient clinical consults) and aggregates the further we arrive at care processes more downstream (mostly the Radiology). Furthermore, we find that the allocation of resources is not demand-driven and contains non-univocal schedules. This mainly results in unnecessary longer waiting times. At last, we conclude that the patient appointment planning processes have no measures in place to deal with or resolve obstructions.

To improve the patient flow through improvements in the allocation of resources, we recommend to:

- Develop a more demand-driven production schedule;
- Develop a production schedule that consist of more univocal schedules;
- Reduce variability upstream through 'variability buffering' of the demand. Prioritise on care processes with high demand, high variability in the demand, many cancellations and strong relations to care processes downstream.
- Reduce variability downstream through 'variability buffering' and clustering of preceding demand at care processes upstream. Prioritise on care processes downstream that aim to provide high availability of capacity to care processes upstream (CT, MRI and Echo).
- Implement the above recommendations simultaneously, as they interact with each other, to substantially save on capacity (up to 45%) while preserving acceptable performances on other KPIs. The presented relationship diagrams and frequency tables can be used to guide the development of a production schedule. The characteristics of care processes strongly influence the effectiveness of developed solutions. Which care processes should be focused on, is explained in the results.

- Distribute the workload by opening care processes at varying times, opening care processes with little to connections to other care processes at desirable times (e.g. *RTC* and certain Operation Rooms), and separating the Radiology as far apart from the outpatient clinical consults by opening as late as possible while maintaining acceptable Hospital Waiting Times.
- Open X-ray whenever Echo is opened. They share many One-Stop-Shop appointments.

To improve the patient flow through improvements to the patient appointment planning processes, we recommend to:

- Introduce measures to facilitate the dealing with and thereby the reduction of the negative impact associated with variability-related phenomena.
- Keep scheduling with 'with reservation' (OVB), if One-Stop-shop satisfaction is valuable. Otherwise, stop scheduling 'with reservation' to reduce average *Hospital Waiting Times* (by roughly 3 minutes) and *Appointment Delays* (by roughly 10 minutes).
- Schedule certain demand <u>separately</u> or <u>before</u> uncertain demand to avoid interaction.
- Introduce walk-in rooms at the MRI, CT, Echo and X-Ray to greatly improve on the performance on *Appointment Waiting Times* (1.1-11.8% appointments within acceptable time) and *One-Stop-Shop satisfaction* (7.8-11% more). Small performance improvements may be expected on *Hospital Waiting Times* (7-15 minutes) shorter and *Percentage of Delayed appointments (*10-20% less). However, take into consideration the possible occurrence of overtime. Depending on the desired performance, different types of walk-in rooms can be used.
- Assign an extra Anaesthetist to the MRI and CT to save on capacity at CT (3.9% in 'as-is'/7.1% in 'to-be') and MRI (5.5% in 'as-is'/12.1% in 'to-be').
- Reduce the number of delays in the arrival of patients and owners at especially care processes upstream (mostly outpatient clinic). In response to fewer delays upstream, we find fewer delays downstream. Also, we find an increased number of (One-Stop-Shop) appointments at the Echo and X-ray that may be treated within the acceptable waiting times.
- Broaden the treatment options at care processes in a way that they may treat more non-discipline specific appointments to reduce appointment waiting times.
- Over-excessively schedule capacity at care processes with many cancellations and high number of appointments during its opening times to greatly reduce the appointment waiting times in days and number of served appointments within acceptable times. However, take into consideration the possible occurrence of overtime. The more over-excessively is scheduled, the more overtime can be expected. Also, substantial increases in average hospital waiting times and delays can be expected.

We would like to point out the following: substantial improvements on all KPIs can be achieved by focussing on the recommendations made on the allocation of resources because the current production schedule is far from ideal. In the research, we undertook the first step to develop a production schedule with these recommendations in mind. The resulting production schedule is more optimal, but still open for improvements. The simulation model can be used as a tool to understand difficult-to-forecast interactions and outcomes as a result of changes to the production schedule. Most recommendations on the patient appointment planning processes (thus what-if scenarios) can be used to steer the performance on specific KPIs at specific care processes. Here, it is more difficult to achieve substantial improvements (with the exception on e.g. *Earlier arrival* and *Overschedule capacity*).

Chapter 7 Discussion

The results from the experimental simulation and the data-analysis of the 'as-is' situation on which the recommendations are based, are open to discussion. Especially, because the historical data had to be extensively processed and prepared before it could be analysed and used. For instance, we had to decide how to identify clinical pathways, appointment cancellations and how to classify the associated discipline for most surgeries. This information could not directly be extracted from the data or was imperfect. While we extensively validated the data and our analysis results with many employees and by manually checking classified data samples, we are certain there is still incorrect data present within the used data set. Furthermore, the data was highly dependent on the historical circumstances when it was recorded. We circumvented most dependencies by using the least dependent data, clustering data and adjusting data (e.g. removing data of specific non-representable periods).

The simulation model that was developed and used to evaluate alternative solutions is a simplification of the reality. Certain processes, such as the planning of patients, are hard to capture as they are partially based on intuition and experience. Nevertheless, we are fairly certain that we grasped the core of the reality by developing a rather comprehensive simulation model. This certainty was especially confirmed because the same observed obstructions in the patient flow (such as peak workloads, and long waiting times and capacity shortages at certain care processes) were observed in the simulation results. The main aspects that we consider to be missing in the simulation model, which could be added in the future, are:

- Making the average delay and number of delays time-dependent. The necessary data and time was missing.
- Introductory stochasticity in the duration of appointments. The necessary data and time was missing.
- Cover side activities, e.g. transportation of patients and the introduction with owners. The necessary data and time was missing.
- Implement Labour capacity. There was not enough time.
- Measure overtime and how well breaks are respected. We may monitor this visually, but cannot measure it. There was not enough time.
- A patient appointment planning process that grasps more than only the core. There was not enough time.
- An optimisation algorithm to optimise the production schedule and what-if scenarios (simultaneously) through iterations and a scoring system. There was not enough time.

Considering the model is grasping the core of the reality, and the data is mostly correct and independent on the situation, we assume that the results from the experiments of non-existent situations are fairly representable if they are applied in the 'as-is' situations and represent the core outcomes that can be expected in the experimented situations. While we lay the basis to improve capacity management at the hospital, we find many yet unexplored areas in primarily the patient appointment planning processes. Here, we find plenty of planning heuristics, rules and flexibility measures that can be explored, some of which are already known to the field and can be found back in literature. For example, the use of block scheduling, more complex planning algorithms (instead of the current simplistic first-come-first-served heuristic) and the application of variance buffering on patient appointment scheduling processes where appointments are clustered based on their variability and other factors.

The research contributes to the field of capacity management in the healthcare industry by providing insights in how capacity can be managed in a complex network that suffers greatly from the bullwhip effect and how capacity can be managed in a general matter. It confirms the benefit of applying experimental simulation to complex networks to explore non-existing situations where one can only guess the outcome and what interactions that may take place. We also ratify the benefit of exploiting variance buffering and implementing measures to reduce the negative impact that comes with the bullwhip effect. Additionally, the research is somewhat nuanced since the healthcare setting is not humane, but veterinarian. The differences in patient groups are addressed and so are the different challenges and obstacles.

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Appendix A. Identification and selection of disciplines

At first, we tried to grasp the network of disciplines and their care processes by taking the department that is shared the most among other departments: DB. If an employee schedules an appointment through Vetware when the employee logged into the discipline it is employed at, we find this discipline to be correctly reported with the appointment. We extracted all appointments from DB and listed all the unique disciplines that scheduled appointments at DB. We then labelled disciplines by abbreviations. See Table_Apx A.1 for those identified disciplines.

We concluded that close to all disciplines were connected to DB through appointments. Therefore, we extracted all the schedules at GD from Vetware and classified the schedules by one of the identified disciplines. In Table_Apx A.2 we present the schedules extracted from Vetware that were classified into disciplines with their treatment types next to it.

At last, after we classified appointments into disciplines (see Appendix N on how we did this), a full list of all disciplines, care processes and appointments was created. This list can be found in Table_Apx A.3.

In addition to the disciplines with their own care process(es), some disciplines have no care process and are therefore treated by other discipline's care processes. These are disciplines *VERPLEEG* (Nursery department), *PROEF* (Department of experimental animals) and PD (previously labelled as Paard, the Horse clinic). Some appointments, e.g. non-specialised surgeries at CHIR, can be treated at many care processes and have no specially designed care process. These are general surgeries labelled by *CHIR_OVERIG(2)*, remaining appointments at ORs (e.g. inspections, cleaning activities and others) labelled by *CHIR_OVERIG(1),* general outpatient clinical consults labelled by *CHIR_OVERIG(2)_Poli* and remaining appointments at the outpatient clinic labelled with *CHIR_OVERIG(1)_Poli.*

Note that *DERM_Poli* is presented under department INT, but belongs to General Medicines.

OOG_Poli is the outpatient clinical consult connected to *CHIR_OOG* surgeries. *OOG_Poli* has its own schedule in Vetware and manages the staffing of care processes themselves. This is similar to *CHIR_THK* with *CHIR_THK_Poli*.

ANGIO (Angiography) is excluded from the data, because it is scheduled on *SA* and could not classify those appointments reliably.

Identified disciplines connected DB	**Code in Vetware**	**Classified discipline**	**Comment**
Anesthesie GD	GD_Klin_AN		Removed from data
Cardiologie-Pulmonologie GD	GD_Klin_CAR	CARDIO	
Algemene Chirurgie GD	GD_Klin_CHI	***CHIR specialization***	
Chirurgische verpleegafd. (CVA) GD	GD_Klin_CVA	VERPLEEG	
Dermatologie GD	GD_Klin_DER	DERM	
Endocrinologie GD	GD_Klin_END	ENDO	
Klinische ethologie GD	GD_Klin_ETH	REST	
Gastro-enterologie/Hepatologie GD	GD_Klin_GAHE	GAHE	
Gastroenterologie GD	GD_Klin_GEN	GAHE	
Hematologie GD	GD_Klin_HEM	HEMA	
Interne Geneeskunde GD	GD_Klin_INT	ALG-INT	
Interne verpleegafd. (IVA) GD	GD_Klin_IVA	VERPLEEG	
Intensieve Zorg afd. GD	GD_Klin_IZA	VERPLEEG	
KNO GD	GD_Klin_KNO	CHIR KNO	
Nefrologie GD	GD_Klin_NEF	URO	
Neurologie GD	GD_Klin_NEU	NEUR	
Oncologie GD	GD_Klin_ONC	ONCO	
Oogheelkunde GD	GD_Klin_OOG	OOG	
Orthopedie / Neurochir. GD	GD_Klin_ORT	CHIR ORTHO/NEURO	
Patientenadministratie UKG	GD_Klin_PADM		Removed from data
Proefdieren GD	GD_Klin_PF	PROEF	
Radiotherapeutisch centrum	GD_Klin_RTC	RAD	
Dagspoed UKG	GD_Klin_Spoed	SPOED	
Tandheelkunde GD	GD_Klin_THK	CHIR THK	
Winkel UKG	GD_Klin_UKG		Removed from data
Urologie/Nefrologie GD	GD_Klin_URNF	URO	
Vogels en bijzondere dieren GD	GD_Klin_VBD	VBD	
Klinische VOEDINGding GD	GD_Klin_VOEDING	REST	
Voortplanting GD	GD_Klin_VPL	VPL	
Zorg Plus afdeling UKG	GD_Klin_ZPa	VERPLEEG	
Diagnostische Beeldvorming	GD_RAD_RAD	RAD	
Spoedkliniek	GD_SPO_SPO	SPOED	
Kliniek Herkauwers	LH_HERK_HERK	REST	
Ambulante kliniek PD	PD_Klin_AK	PD	
Anaesthesiologie PD	PD_Klin_AN	PD	
Inwendige ziekten PD	PD_Klin_IK	PD	
Heelkunde orthopedie PD	PD_Klin_ORT	PD	
Proefdieren PD	PD_Klin_PF	PD	
Voortplanting vrouwelijk PD	PD_Klin_VPV	PD	
Heelkunde weke delen PD	PD_Klin_WD	PD	
Radiologie Paard	PD_RAD_RAD	PD	
Smederij PD	PD_SM_SM	PD	

Table_Apx A.1 Identified disciplines with Vetware names, codes and final discipline abbreviation.

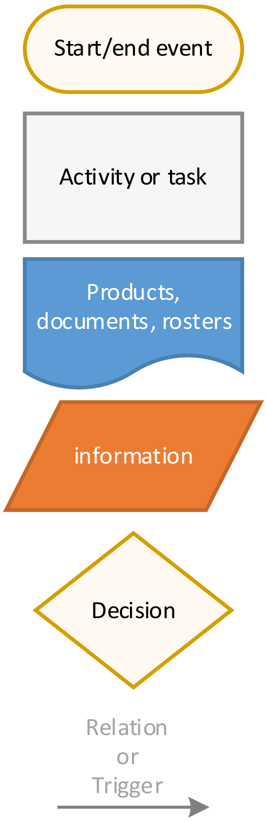
Identified Vetware Agenda's	Classified by discipline	Classified by treatment
CARDIO-1	CARDIO	Poli
CARDIO-2	CARDIO	Poli
CHIR-1	***CHIR discipline***	Poli
CHIR-2	***CHIR discipline***	Poli
CHIR-3	***CHIR discipline***	Poli
CHIR-4	***CHIR discipline***	Poli
DERM-2	DERM	Poli
DERM-6	DERM	Poli
Fysiotherapie	ORTHO	Poli
GEDRAG-12	GEDRAG	Poli
HEMA	HEMA	Poli
INT-1	GAHE/URO/ALG-INT	Poli
INT-2	ENDO/HEMA/ALG-INT	Poli
INT-3	ALG-INT	Poli
NEUR-1	NEUR	Poli
NEUR-2	NEUR	Poli
Nucl Diagn	RAD	Poli
ONCO-4	ONCO	Poli
OOG-1	OOG	Poli
OOG-2	OOG	Poli
Oud SPOED-1	SPOED	Poli
Oud SPOED-2	SPOED	Poli
Overige afspr.	OVERIGEPOLI	Poli
Spoed/SGMN-1	SPOED	Poli
Spoed/SGMN-2	SPOED	Poli
THK-11	CHIR THK	Poli
VBD-1	VBD	Poli
VBD-2	VBD	Poli
VOEDING	VOEDING	Poli
VPL	VPL	Poli
ECHO-GD-1	RAD	ECHO_GD
ECHO-GD2-2	RAD	ECHO_GD
ECHO-PD	RAD	ECHO_PD
Rontgen-GD-1	RAD	X_RAY_GD
Rontgen-GD-2	RAD	X_RAY_GD
Rontgen-PD	RAD	X_RAY_PD
MRI	RAD	MRI
CT	RAD	CT
RTC	RAD	RTC
Nuc	RAD	Nucl_Diagn
Angio	Removed	Removed

Table_Apx A.2 Extracted Vetware schedules with identified discipline and treatment types.

All disciplines	treatment types	Name in text	Appointment	Care process	Comment
CHIR_THK	Poli	CHIR_THK_Poli	Yes	Yes	
CHIR_Overig(1)	Poli	CHIR_Overig(1)_Poli	Yes	No	K.N.G.F consults
CHIR_Overig(2)	Poli	CHIR_Overig(2)_Poli	Yes	No	unclassified consults
CHIR_algemeen	Poli	CHIR_algemeen_Poli	Yes	Yes	
CHIR_KNO	Poli	CHIR_KNO_Poli	Yes	Yes	
CHIR_ONCO	Poli	CHIR_ONCO_Poli	Yes	Yes	
CHIR_ORTHO_NEURO	Poli	CHIR_ORTHO_NEURO_Poli	Yes	Yes	
CHIR_URO_LEVER	Poli	CHIR_URO_LEVER_Poli	Yes	Yes	
CHIR_THK	Surgery	CHIR_THK_Surgery	Yes	Yes	
CHIR_Overig(1)	Surgery	CHIR_Overig(1)_Surgery	Yes	No	Inspections, cleaning activities, etc.
CHIR_Overig(2)	Surgery	CHIR_Overig(2)_Surgery	Yes	No	general surgeries and unclassified surgeries
CHIR_OVERIG	Surgery	CHIR_OVERIG_Surgery	No	Yes	
CHIR_KNO	Surgery	CHIR_KNO_Surgery	Yes	Yes	
CHIR_ONCO	Surgery	CHIR_ONCO_Surgery	Yes	Yes	
CHIR_ORTHO_NEURO	Surgery	HIR_ORTHO_NEURO_Surger	Yes	Yes	
CHIR_URO_LEVER	Surgery	CHIR_URO_LEVER_Surgery	Yes	Yes	
CHIR_OVE	Surgery	CHIR_OVE_Surgery	Yes	Yes	
CHIR_OOG	Surgery	CHIR_OOG_Surgery	Yes	Yes	
GEDRAG	Poli	GEDRAG_Poli	Yes	Yes	
OVERIGEPOLI	Poli	OVERIGEPOLI_Poli	Yes	Yes	
VOEDING	Poli	VOEDING_Poli	Yes	Yes	
CARDIO	Poli	CARDIO_Poli	Yes	Yes	
NEUR	Poli	NEUR_Poli	Yes	Yes	
ONCO	Poli	ONCO_Poli	Yes	Yes	
OOG	Poli	OOG_Poli	Yes	Yes	Poli connected to CHIR_OOG surgeries
ORTHO	Poli	ORTHO_Poli	Yes	Yes	
SPOED	Poli	SPOED_Poli	Yes	Yes	
VPL	Poli	VPL_Poli	Yes	Yes	
ENDO	Poli	ENDO_Poli	Yes	Yes	Internal medicines
DERM	Poli	DERM_Poli	Yes	Yes	Misplaced in tables, part of General Medicines
GAHE	Poli	GAHE_Poli	Yes	Yes	Internal medicines
HEMA	Poli	HEMA_Poli	Yes	Yes	Internal medicines
URO	Poli	URO_Poli	Yes	Yes	Internal medicines
ALG_INT	Poli	ALG_INT_Poli	Yes	Yes	Internal medicines
VBD	Poli	VBD_Poli	Yes	Yes	
	SA	SA	Yes	Yes	Known as Service Anaesthesie
RAD	Poli	RAD_Poli	Yes	Yes	
	Nucl_Diagn	Nucl_Diagn	Yes	Yes	
	MRI	MRI	Yes	Yes	
	RTC	RTC	Yes	Yes	
	CT	CT	Yes	Yes	
	ECHO_PD	ECHO_PD	Yes	Yes	
	ECHO_GD	ECHO_GD	Yes	Yes	
	X_RAY_PD	X_RAY_PD	Yes	Yes	
	X_RAY_GD	X_RAY_GD	Yes	Yes	
	FLUOR	FLUOR	Yes	Yes	
VERPLEEG		VERPLEEG_	No	No	Has appointments at DB
PROEF		PROEF_	No	No	Has appointments at CHIR_THK
PD		PD_	No	No	Has only appointments at DB

Table_Apx A.3 Final list of disciplines with care processes and appointments.

Appendix B. Legend for flowcharts



Start and end event that triggers a set in motion activities, tasks, decisions or other elements.

Activity or task executed.

Information management entities used.

Information generated or used.

Decision, described by a question, answered with relationship or trigger arrows.

Relationship and trigger arrows describing the flow through the flowcharts from elements to other elements.