MASTER

Understanding the dynamics and complexities of personnel scheduling in practice

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Award date:
2023

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Master thesis Innovation Management

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EINDHOVEN, April 16, 2023

Abstract

The personnel scheduling problem is notoriously hard to solve, and the importance of having the right schedule has been noted. Therefore, many researchers have studied this problem. However, solutions are mostly theoretical, and less is known about the dynamics in practice. This research investigates which primary interactions cause scheduling complexities and dynamics in practice by conducting an inductive case study. The effects of the complexities of the planning in practice can be recognized by an unbalanced workload between shifts and an overall time shortage or surplus. These effects are caused by the relationship between the static form of the planning, the dynamic environment of the organization, and the subjective judgment of this environment. The dynamic environment makes it hard to predict the required hours for certain shifts. Multiple interactions give reasons for this; At first, employee satisfaction factors such as simplicity, continuity, and planning clarity keep the current scheduling manual method in place. Secondly, resistance to change plays a role in not wanting another way of planning. However, this method requires more planning reallocation to ensure service levels are met and work levels are balanced. Overall, the research suggests that a more comprehensive approach to workforce planning is needed to understand the dynamic interactions of scheduling in practice.

Keywords: *personnel scheduling problem, workload balance, causal loop diagram, dynamic environment, static shift planning, inductive case study*

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1 Introduction

Personnel scheduling is defined as "the process of constructing work timetables for its staff so that an organization can satisfy the demand for its goods or services" (Ernst, Jiang, Krishnamoorthy, and Sier 2004a). In the service industry, it is one of the most challenging tasks managers face (De Bruecker et al. 2015). The goal is to create a model that ensures efficient use of the resources, ensures a balanced workload, and includes the concerned individuals' needs as much as possible (Özder et al. 2020). Extra difficulties arise when demand fluctuates. This can be experienced by organizations such as hospitals, airlines, and call centers (Purnomo and Bard 2007). Complexity increases even more by employee preferences, equality of shifts and tasks, and satisfying all workplace and legal constraints (Ernst et al. 2004a, Uhde et al. 2020). As a result, decisions become very dynamic, and planners face an extremely heterogeneous group of employees (De Bruecker et al. 2015). In addition, the shortage of skilled workers is a growing problem (Uhde et al. 2020). Proper personnel scheduling is vital for the functioning of the organization: The results of having poor employee scheduling affects, for example, the productivity and quality of the service (Ağralı et al. 2017), job satisfaction (Purnomo and Bard 2007), and costs (Türker and Demiriz 2018).

Due to the importance of scheduling, personnel scheduling problems and solutions have been studied widely. According to several literature reviews, the main categories can be divided into: days off scheduling, shift scheduling, or a combination of both, called tour scheduling (Ernst et al. 2004a, Van den Bergh et al. 2013). Besides those three classifications, Özder et al. (2020) introduces static versus dynamic scheduling categories. Static scheduling includes a structure that stays the same over time, and a dynamic schedule is based on a variable schedule structure (Özder et al. 2020). Within all the classifications, mathematical programming approaches are the most popular studied approaches to model the problem, and thereafter comes the use of heuristics (Van den Bergh et al. 2013).

Commonly, studies focus on finding the optimal schedule for employees under different contexts using several methods, such as mathematical programming and heuristics. However, in the real world, scheduling is mostly done manually (Wolbeck 2019). This creates a problem as manual schedules are often static, while environments in the service industry are mostly dynamic. Furthermore, creating such a plan focuses mostly on designing the schedule, especially finding the optimal one in a certain context. The results of using a certain planning method are less intensively tested.

Thus, scheduling in practice remains highly challenging, despite the existence of all these models. Therefore, this study serves to investigate why the schedules are not using the approaches from literature in practice despite the many studies on scheduling problems. This results in the following research question:

> *What are the primary interactions causing scheduling complexities and dynamics encountered in practice?*

The results of this research will provide the dynamic interactions that cause the complexities and dynamics in the context of the personnel scheduling problem in a practical setting. This could create a better understanding of the personnel scheduling problem in the real world and therefore narrows the gap between theory and practice.

2 Theoretical Background

Personnel scheduling is essential for the manufacturing and service sector (Özder et al. 2020). For many organizations, the labor cost is the main direct cost component (Van den Bergh et al. 2013), indicating the importance of effective use (Türker and Demiriz 2018). Therefore, personnel scheduling problems have been studied widely (Van den Bergh et al. 2013; Özder et al. 2020). Furthermore, scheduling is time-consuming and the inclusion of many different employee preferences makes the problem more difficult (Özder et al. 2020), especially when generating the schedules by hand (Kletzander and Musliu 2020). The importance of satisfying those employees' preferences has grown (Van den Bergh et al. 2013). As a result, decisions in personnel scheduling are very dynamic, and planners have to work with a heterogeneous group of people (De Bruecker et al. 2015). Having a heterogeneous group of employees means that they have different skill levels, contracts, and preferences. Thus, it is extremely hard to find optimal schedules that minimize the cost of planning too many employees, while meeting service levels, employee preferences, and other organizational restrictions. Overall, the scheduling problem is described as NP-hard to solve (Özder et al. 2020).

The next sections provide more details about personnel scheduling in general, the different categories of the problem, the methods used in literature, and the problem in practice.

2.1 Personnel scheduling problem

As described by Ernst et al. (2004a), personnel scheduling is defined as "the process of constructing optimized work timetables for staff". In other words, the process of assigning employees to shifts in the planning to have the right amount of personnel at the right time (Wolbeck 2019). The main goals are; to ensure the efficient use of qualified resources, realize balanced workload distribution, and incorporate individual preferences as much as possible (Özder et al. 2020).

Three main literature reviews are commonly named in literature, covering the personnel scheduling problem including; Van den Bergh et al. (2013), Ernst et al. (2004a) and De Bruecker et al. (2015). More recent literature from Özder et al. (2020) is also important for the personnel scheduling problem to substantiate those earlier reviews.

The personnel scheduling problem has been given multiple names in literature; personnel scheduling problem, rostering problem (Ernst et al. 2004a), employee scheduling problem, staff scheduling problem, and workforce scheduling problem (Özder et al. 2020). All of the terms cover the personnel scheduling problem. However, the workforce scheduling problem also includes the staffing part and the reallocation of the problem, which involves the strategic decision on how many employees to hire and to fire (De Bruecker et al. 2015).

Regarding the study areas, personnel scheduling has been studied in many different sectors. Popular areas are healthcare, call centers, transportation, airline industries, and production. The first three sectors are often studied because those sectors are often unstable, and employee requirements fluctuate over time (Özder et al. 2020). In practice, however, scheduling is mostly done manually (Wolbeck 2019), including the planner picking a schedule that he or she considers fair for everyone (Uhde et al. 2020). Resulting in subjectivity in the planning (Uhde et al. 2020).

As scheduling problems vary depending on the context (Ernst et al. 2004a), different underlying constraints have been included following the corresponding shape of the problem. Popular constraints included are: Contractual constraints (e.g. full-time versus part-time) (Kletzander and Musliu 2020; Özder et al. 2020; Uhde et al. 2020; Van den Bergh et al. 2013), Different skill sets and skill levels (De Bruecker et al. 2015), Fixed or flexible shifts (Özder et al. 2020; Kletzander and Musliu 2020), Balancing workload or fairness of work (Özder et al. 2020; Kletzander and Musliu 2020; Van den Bergh et al. 2013), Overlapping versus non-overlapping shifts (Van den Bergh et al. 2013), Duration length (Van den Bergh et al. 2013), Preference constraint (e.g. days they would like to have off, or shifts they want) (Özder et al. 2020; Van den Bergh et al. 2013), Coverage rate, meaning how much of the demand has to be covered by the staff (Van den Bergh et al. 2013), Static or dynamic scheduling, reflecting whether the structures change over time or not (Özder et al. 2020), and Legal constraints (e.g. days off, union rules). The specific values and variations of those shapes are dependent on the context.

2.2 Schedule categories

Three main classifications for personnel scheduling are distinguished, including days off scheduling, shift scheduling, and tour scheduling. Days off scheduling is scheduling based on the required resting days, which is mostly used when demand is variable (Ernst et al. 2004a), typically the length of the employee's working week does not match the length of the operating week (De Bruecker et al. 2015). Shift scheduling is determining the number of employees to be assigned to which shifts (Aykin 1996) and assigning shift sequences to employees (Kletzander and Musliu 2020). Which classification fits best depends on the context since the scheduling problem comes in many shapes (Ernst et al. 2004a). Lastly, tour scheduling involves a combination of the earlier two; it is useful when the operations involve seven days a week with more than one shift a day (De Bruecker et al. 2015).

The mentioned constraints from the previous section are mostly related to the classifications. However, due to the many studies, different interpretations of the classifications exist. As a result, there is a lot of overlap between those three classifications based on context or constraints. Therefore, an important higher-level distinction is introduced by Özder et al. (2020); static scheduling and dynamic scheduling, whereas a static schedule focuses on a plan that does not change over time, whereas dynamic scheduling has a variable underlying structure.

2.3 Solutions to scheduling problems

Many different methods can be applied to solve personnel scheduling problems. Most commonly used methods focus on mathematical programming, particularly (mixed) integer programming or heuristics, including improvement- or constraint-heuristics (De Bruecker et al. 2015; Özder et al. 2020; Van den Bergh et al. 2013). Other methods can also be found, such as discrete-event simulation, simulation optimization, constraint programming, and queuing (De Bruecker et al. 2015). In literature, researchers try to find gaps in combinations of constraints that have not been tested yet. This results in more and more variations on the existing methods to solve the scheduling problem. In addition, Kletzander and Musliu (2020), tried to make a general framework for implementing different heuristic solvers. However, Kletzander and Musliu (2020) claims that providing one algorithm to deal with all problems is impossible. While many approaches have been proposed to solve the personnel scheduling problem, many practical implementations and their results are missing. Not many of those created algorithms make it to implementation (Van den Bergh et al. 2013). It can be very challenging to integrate the aforementioned algorithm into an organization (Van den Bergh et al. 2013), as real-life implications are neglected, and the model fails to represent the real-life problems (Özder et al. 2020). Since practical implications are lacking, scheduling is still mostly done manually (Wolbeck 2019). Literature focuses on finding optimal solutions based on different constraints and often does not investigate the consequences of using a particular method. This makes investigating the practical consequences of a certain way of scheduling interesting. As a result, possible interactions explain why theoretical methods are often not effective in real-world settings or help to make those methods work within a real-world context.

2.4 Scheduling in practice

The previous section (section 2.3) explained that literature methods are often not implemented or tested in practice. Scheduling is mostly done manually, increasing subjectivity. Moreover, there is a gap between the methods used in literature and those mentioned on information websites. One of the information websites gave a very clear overview of the four often named scheduling methods classification in practice; 1) individual unique schedule, with the possibility to apply self-scheduling, 2) individual repeating schedule, 3) collective unique schedule, and 4) cyclic schedule. The first one is about making a new schedule for every planning horizon, including the individual preferences for that period as much as possible, as found in literature in preference scheduling or a version of shift schedule. The second one is a basic schedule based on the workers' preferences, and changes are only made for vacations or absentees. Collective unique scheduling means making a unique schedule per group every planning period again. Those methods can all be categorized in the shift scheduling problem since shift scheduling deals with assigning employees to a shift over a planning horizon (Côté et al. 2011) as well. The last one, cyclic scheduling, is also often directly investigated in the literature. Cyclic scheduling is mostly used in situations with an operation week of 24 hours, 7 days a week. Therefore, the tour scheduling classification is the best one linking to this practical method since that method is often used in such a context too. In cyclic schedules, all employees have the same schedule lagged in time (Becker et al. 2019), which is most suitable for situations where demand is continuous and workforces are homogeneous (Becker et al. 2019). Thus, cyclic scheduling is an important theme in tour scheduling.

The four methods used in practice can be seen as static schedules and mostly subjective since the planning is often handmade and does not change after it has been made. However, the methods used in the literature (within shift scheduling and dynamic scheduling) do not need to be static. The problem with static schedules is that it assumes that all information regarding the process is available and that this information does not change over time (Lee and Pinedo 2017). However, the service environment is often tangled with uncertain demand and unanticipated employee absences (Campbell 2012), making the problem dynamic and creating a possible mismatch between the static schedule and the dynamic environment.

This research aims to analyze the gap between the practical side and the literature by answering the research question:

> *What are the primary interactions causing scheduling complexities and dynamics encountered in practice?*

Answering this question will help to give a better understanding of the personnel scheduling problem. It will highlight which interactions found in practice are important to take into account for literature.

3 Methodology

In order to find the dynamic interactions of the personnel scheduling problem in practice, this research conducts an inductive case study. An inductive approach is valuable as it builds new theories/models out of grounded data (Gioia et al. 2013). This means that theory emerges as data is analyzed. This research draws on Eisenhardt (1989), to structure this theory. The process of Eisenhardt (1989) consists of different steps. The first step is getting started with a research question and finding a case based on theoretical sampling. Thereafter, multiple data collections are used, both quantitative and qualitative, and based on some first analyses, adjustments in data collections are made. From this data collection, data are analyzed and hypotheses are formed and compared with the literature.

The physio department at the Elisabeth-TweeSteden Hospital has been chosen as the case for this research. The physio department meets the goals of theoretical sampling (Eisenhardt 1989; Eisenhardt and Graebner 2007), which means that the case is chosen based on theoretical reasons. A first argument for this is the fact that the hospital setting is one of the largest and most important industries in the Netherlands, and the cost of personnel accounts for 50-70% of the total costs (Berden et al. 2016). In addition, healthcare is by far the most studied component in personnel scheduling problems, with nurse scheduling as the most popular area (24,6%) (Özder et al. 2020), caused by the importance of health care and the difficulty of work (Ernst, Jiang, Krishnamoorthy, Owens, et al. 2004b). Therefore, planning the right number of employees is important in the healthcare sector. On top of that, the service level also needs to be very high, as patients have to be treated. Furthermore, this industry has to deal with both unplanned and planned demand, while a lot of other service industries only work with fixed appointments. The physio department specifically is an interesting scope for this research due to a few reasons. At first, physiotherapy has an integral part in the healthcare team (Ramanandi et al. 2019), and plays a crucial role in ensuring that patients receive the appropriate level of care. Besides, demand fluctuates (Ernst et al. 2004a), and it has a heterogeneous set of employees, marked by different preferences and skill levels. Because of this, the planner experiences difficulties in planning the employees. Interestingly, while a lot of literature within the healthcare area focuses on nurse scheduling problems (Özder et al. 2020) or physician scheduling problems (Erhard et al. 2018), physiotherapy has been left behind. This is despite their participation in many treatment programs or care paths of other departments (Griffiths et al. 2012). Furthermore, the physio department has a relatively small team, and planning is made manually based on a historically determined basic roster. This makes it easier to investigate. As in practice, scheduling is still done mostly manually and consists of a static schedule in a dynamic environment.

3.1 Case description

The physio department consists of 27 full-time equivalents (FTE) and 37 therapists and is located in two locations in Tilburg, the Elisabeth Hospital (EZ) and the TweeSteden (TZ) hospital. Most of the therapists work in one of the locations; however, some work in both locations. As Fransen (2004) states: "The goal of physiotherapy is to restore (or maintain) optimal physical functioning", both for inpatients and some types of outpatients. In addition, therapists participate in different external activities, such as projects or presentations. Since the planning of both locations is historically determined while different factors have been changed over the years, the department struggles to determine whether current work activities still match the current planning. Resulting in a perception of an unequal work division and fluctuating work pressure.

The first subunit of analysis is the EZ location. The focus in the EZ is on the internal patient treatments requested by the nurses. In many cases, the focus of these patients is on mobilizing them. Most therapists work only in clinical treatment. Whereas therapists at the EZ mainly focus on internal patients, therapists at the TZ treat outpatients as well, in both individual as well as in groups. Both locations have a combined static planning, that is fixed for the coming 8 weeks. However, both locations have different structures and different needs, so the locations are investigated as subunits. As it includes a single case (the physio department), consisting of two subunits, this research is based on the theory of an embedded single case study as described by Yin (2009). This means that within the single case, there exist two units of analysis that are used for the research to provide one final model.

3.1.1 Case interpretation

To interpret the results from this case, it is important to know how the planning is made and which classifications from the literature can describe this scheduling problem. The planning of the physiotherapists consists of several shifts, with all having a specific length and a line of tasks relating to it. Those shifts were determined way before the current planner worked here. Minimal changes were made based on hospital changes and therapist feedback. Most shifts are part of a shift sequence; if possible, a therapist is assigned to a shift sequence. For example, someone who works on the sequence of shifts belonging to cardiology. During a cardiology shift, the therapist must perform all the tasks belonging to this shift, which consists of treating patients who stay in this department. A shift, therefore, always has a fixed set of tasks to perform. The planner assigns the therapist to a specific shift and is based on the therapist's preferences as much as possible. However, the longer someone works at the department, the more priority someone has due to the stable basic schedule. This arises from the fact that the planning for the coming eight weeks is based on a two weeks basic planning where employees are already assigned to a specific shift. This results in most therapists having the same shift sequences every time. A few employees do not have a fixed shift or shift sequence every time. They are assigned to shifts that experience deviations due, for example, to planned absentees. The decision on which shift those flexible employees have to work is also made eight weeks ahead; this is fixed and included in the static plan as well. During those eight weeks, shifts are only changed by unplanned absentees, and tasks (patients) may be reallocated due to unplanned fluctuations in demand. The EZ part incorporates reallocation into multiple daily heads-up meetings with all therapists. Whereas at the TZ, only informal communication is used to reallocate tasks. Important to note is that inpatients are not scheduled according to a specific time, while outpatients are scheduled according to a timeslot. Therefore, only inpatients can be reallocated on the day itself.

As mentioned in the literature review, the scheduling problem comes in many overlapping classifications and is modeled with many different methods, mostly mathematical or heuristic algorithms. Those classifications and methods can be divided further into the main themes of having a static or dynamic schedule. The schedule of this case can be seen as a static schedule. The planning for the therapists is set as fixed for eight weeks in advance and does not change, in line with static scheduling. The personnel scheduling problem, in this case, can be classified as the shift scheduling problem, as it involves determining the number of employees to be assigned to which shift and assigning shift sequences to employees. Besides, the specific method used to make the schedule is manual and thus does not involve the often used methods from literature, such as linear programming. Therefore, the schedule of the physio department is part of a static shift scheduling problem that is handmade and focused on optimizing individual preferences and skill matching.

From the practical methods mentioned, the physio departments has a individual repeating schedule. The department has a repeating planning that is only changed based on deviations and the schedule is based on the preference of the employees.

Furthermore, scheduling constraints from chapter 2, that are important for the department, include:

- Contractual constraints: There are both part-time and full-time therapists.
- Different skill sets and skill levels: Therapists have different skill levels, especially in experience on certain departments. For the outpatient appointments, therapist even miss certain skills to do tasks from other therapists.
- Preference constraint: The shifts people want, the days they would like to work, etc. This is partly a soft constraints since not all therapists can be placed on the shifts they want.
- Fixed shifts & shift length: The shifts can only be performed between 8am and 6 pm.
- Coverage rate: All patients need to be treated according to their treatment plan.
- Balancing workload: It is important to balance the workload as much as possible in order to have a fair workload division between the therapists.

Therefore, questions related to whether those constraints are achieved at the ETZ are included in the interviews.

3.2 Data collection

As proposed by Eisenhardt (1989), multiple data collection methods have been used, including qualitative and quantitative approaches. For both subunits, data has been collected by the means of semi-structured interviews and archival data. The archival data consists of historical data, minutes from (regular) meetings, and interactions with the planner and business analyst, next to the handmade spreadsheet planning. Together with casual conversations and observations, the archival data served as a valuable way to triangulate and complement the interview findings (Yin 2018). Triangulating a research with different sources is important to determine the consistency of the results (Yin 2009). A detailed overview of the data sources and what they include can be found in Table 3.1. The interviews were collected in the period from November 2022 to March 2023, and participants were mostly chosen with the goal of having a diverse as possible group (stratified purposive sampling). As seen in Table 3.1, all therapists have other regular specialisms they work in. This creates a varied view of the schedule in practice. To know what planning method is used in similar cases, the physio departments of two other hospitals have been interviewed. The addition to primary data only consists of data that has only been used to validate data from the interviews and historical data.

Source	Information
Semi-structured interviews with 9 therapists (recorded)	
Interview Therapist EZ Neuro cluster	View on Current schedule
Interview Therapist EZ IC cluster	View on Current schedule
Interview Therapist EZ Intern cluster	View on Current schedule
Interview Therapist EZ Surgery cluster	View on Current schedule
Interview Therapist EZ Neuro cluster	View on Current schedule
Interview Therapist TZ Cardio, cardiac	View on Current schedule
Interview Therapist TZ Orthopedic	View on Current schedule
Interview Therapist TZ & EZ clinical	View on Current schedule
Interview Therapist TZ Orthopedic, TENS	View on Current schedule
Addition to primary data	
Validation session with three physiotherapists EZ	Validation on output EZ
Participatory observations	Frequent meetings and interactions, walk along with department, informal talks with therapists
Interview with two external Dutch hospitals	Initial insights into the planning methods (not recorded)
Historical data generated by the Electronic Patient Dossier	
Outpatient data cube	Storing all data that arise from treating outpatients
Care activities data cube	Storing all information that relates to conducting care activities for inpatient treatments
Historical data generated by hand	
Handwritten spreadsheet planning	Consisting of the personnel scheduling for the coming planning horizon and the historical personnel planning from August 2021 onwards made by the planner.

Table 3.1: Data sources

For the historical data sources on the inpatient and outpatient treatments, only years 2021 and 2022 were used as input since those are the most re-presentable years in the data.

Furthermore, only data from 2 Augustus 2021 until December 2022 have been used for the handwritten sheet source due to its availability. In section 6.1, more information is presented about the historical data, how it looks, and how the handwritten sheet has been transformed into a data set for this research is presented.

3.3 Data analysis

The data collected has been used to investigate the dynamics of the schedule in practice. Firstly, informal talks, shadow days, and initial data analysis have created an understanding of the context. Thereafter, an iterative approach has been used by alternating analysis of interviews with the archival data (e.g. historical data, meeting minutes), as related to the phase of entering the field from the process of Eisenhardt (1989). Thereafter the data was analyzed in more detail, followed by building theories from those data and reflecting this again with the literature.

In the data analysis, the mentioned quantitative historical data and the semi-structured interviews are analyzed. An inductive coding method is used since the interviews focus on data from the field rather than from literature (Leedy and Ormrod 2005). The guidelines for the semi-structured interviews can be found in section 6.2. To analyze the interview data, interviews are transcribed and coded according to the approach described by Gioia et al. (2013). This methodology has the advantage of capturing and modeling the participants' understandings (Gioia et al. 2013). At first, 1st concepts are created to break down the interview. Where-after those concepts are linked to 2nd order themes that connect multiple 1st order concepts. The 2nd order themes are used as a basis to describe the underlying aggregate dimensions of the planning consequences. All those concepts and themes are structured into a visual map or data structure to illustrate the progression from raw data to themes. The system thinking approach of Sterman (2010) has been used to present the dynamic relations of the data structure in a Causal Loop Diagram (CLD). CLD is an essential tool to check certain dynamics' causes and communicate the important feedback mechanisms relating to this problem. The CLD resulting from this study dynamically describes the consequences and interactions of the manually created static shift planning in practice. The historical data is mostly used to find patterns and relationships that may explain underlying mechanisms as well as to find whether those are in line with the interviews, thus triangulating the interviews. Other informal interactions are used to verify and triangulate the relations found as well. Thus, during the process of making and describing the CLD, the concepts are iteratively compared and validated by those multiple sources in order to get as much value as possible from those data. In the end, the model and results are modified after a verification meeting with the planner.

Lastly, as followed by the process of Eisenhardt (1989) the developed theory will be compared to the literature again to close the loop and to answer the research question. As an extension to the theoretical contribution, steps for improving the current planning have been generated for the department. To give a practical contribution to the department, different planning scenarios have been tested for the EZ on the available data to increase the objective reasoning for improving the personnel planning. A detailed elaboration on the scenarios and how it has been conducted can be found in section 6.6. Unfortunately, insufficient data was available for creating a valuable scenario analysis for the TZ. Only general insights were presented to the planner.

4 Results

In this chapter, the results of the research are presented and described. At first, the data structure formed from the interviews is depicted. Thereafter, the resulting CLD is presented with a detailed description, including all the arguments explaining the dynamic mechanisms of the model. It is important to note that the quotes used to support the description are translated from Dutch into English.

4.1 Data Structure

The results of using the iterative method by Gioia et al. (2013) for analyzing interviews are shown in Figure 4.1. The data structure includes the 1st order themes, 2nd order themes, and the aggregate dimensions. The structure shows a static visualization of the studied cases, while dynamic relations exist. Therefore, the next part will represent the research findings in a CLD (Sterman 2010) to find the underlying mechanisms caused by having the static schedule. It also shows a detailed description of those different relations found. The corresponding quotes of the data structure related to the themes can be found in section 6.3.

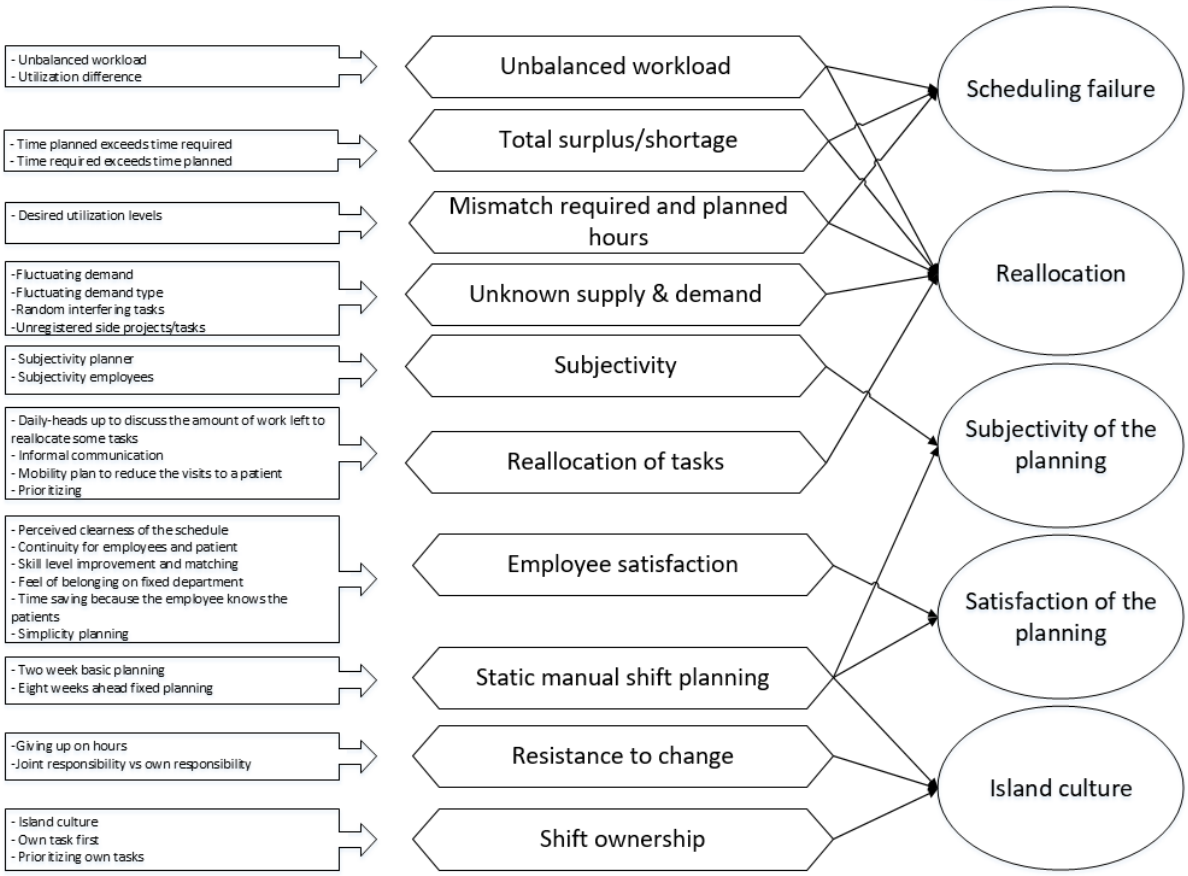


Figure 4.1: Data Structure

4.2 Causal Loop Diagram (CLD)

Combining the Data Structure with the archival data results in the following CLD depicted in Figure 4.2. The next sections of this chapter will explain this diagram step by step. Starting with the mismatch between required and planned hours itself, followed by the consequences of this mismatch and finally the dynamics that maintain the current situation.

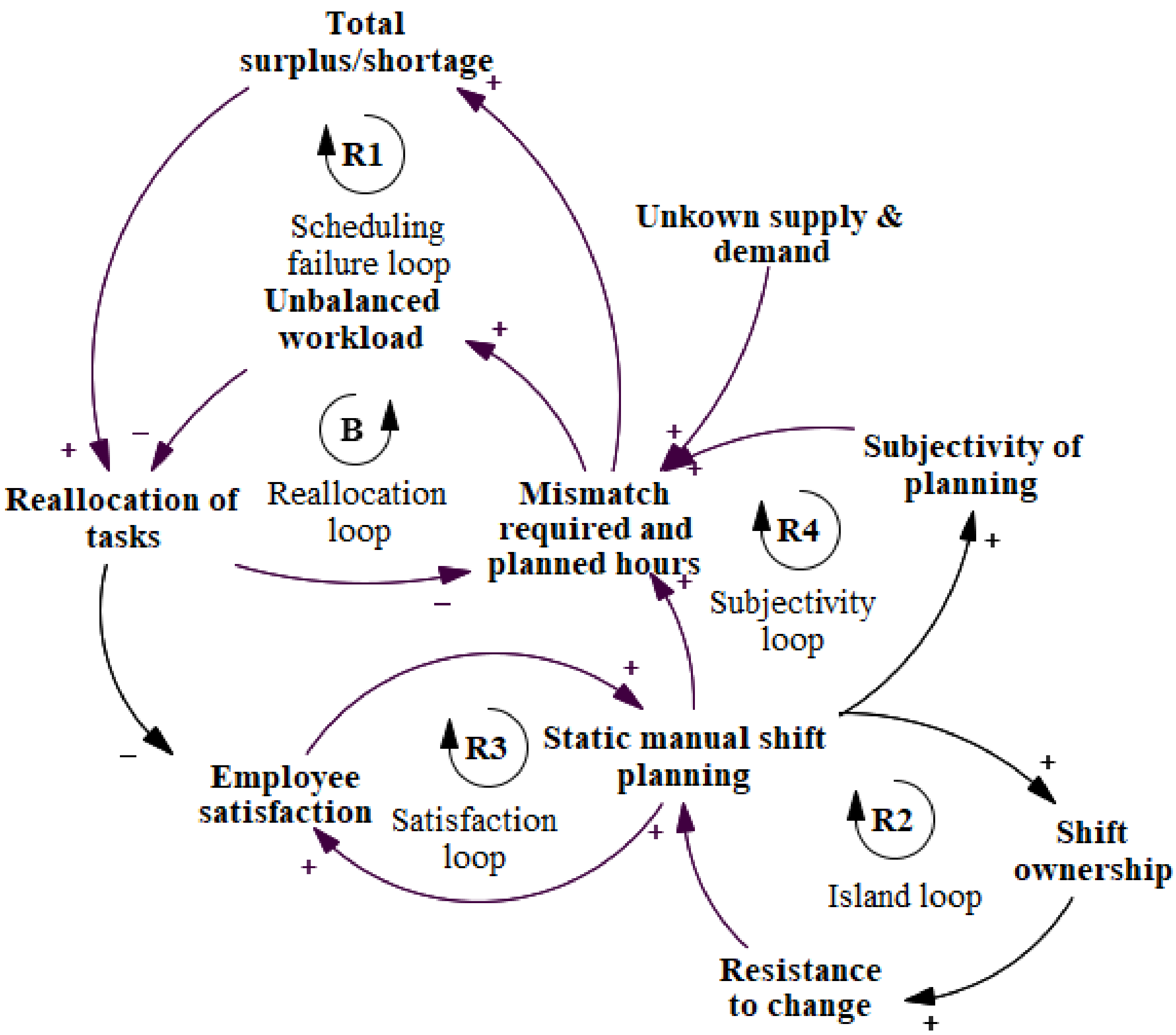


Figure 4.2: Causal Loop Diagram

4.2.1 Mismatch required and planned hours

According to informal sessions with the planner and insights into the department's planning, the planning can be seen as static manual shift planning, as explained in subsection 3.1.1. In this real-world case, multiple dynamic interactions cause a mismatch between the required hours and the hours planned for a specific shift or group of shifts. This can be encountered by an unbalanced workload between the different shifts and a total time surplus or shortage, as explained later on. As shown in the part of the model presented in Figure 4.3, the mismatch is caused by multiple related mechanisms, including the static, manual shift schedule itself in relation to the unpredictable demand/supply and the subjective input.

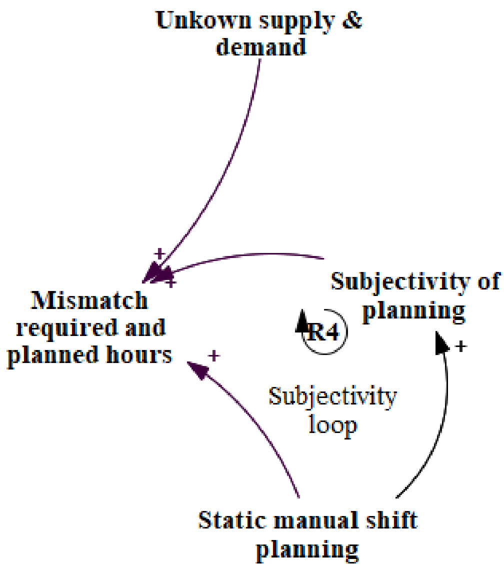


Figure 4.3: Mismatch dynamics

The unpredictability of demand and supply can be explained by multiple aspects. It is recognized as an external variable. At first, the demand, and thus the number of tasks related to a shift, fluctuates as described by multiple interviews, for example, the quote: *"The amount of patient fluctuates of course. You can't respond very well to that, so the pressure will be higher one day than the other day"* (Interviewee 4). A detailed overview of all the quotes related to fluctuating demand can be found in section 6.3. This effect is also visible in the historical data on mean time spent per day (over the week) on the treatments (the time spent on the patient tasks), in Figure 4.4. The mean time spent per day is calculated instead of the total time to cope with holiday effects. For the EZ, the total time spent on inpatient care is shown, and for TZ, the time spent on individual outpatients and the total time spent on inpatients per week is presented. Group sessions are included since those sessions are fixed over time and experience no significant demand fluctuation. For clinical care, fluctuations in both locations can be found, confirming the demand fluctuations mentioned in the interviews. Besides, outpatient treatment on the TZ also includes fluctuation in patient treatment time. To confirm this even more, the average time spent per day on clinical care per cluster (total clinical care per group of departments), is shown in Figure 6.3 in section 6.4.

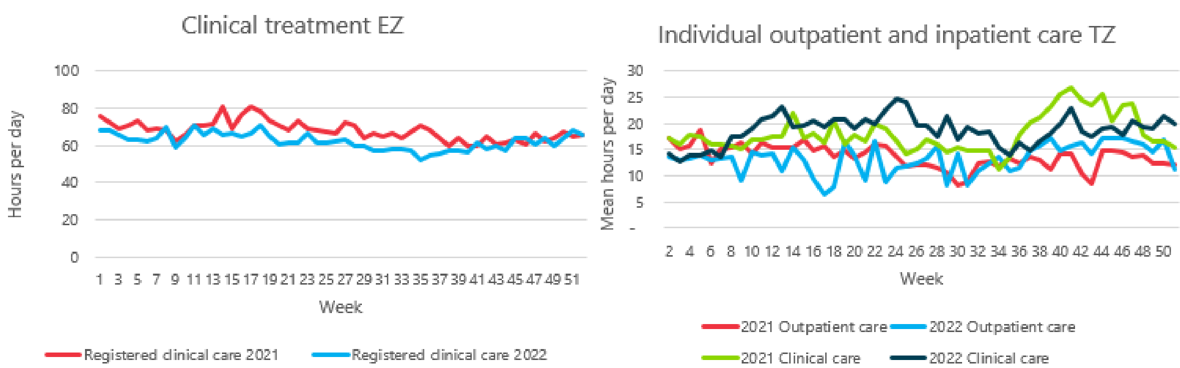
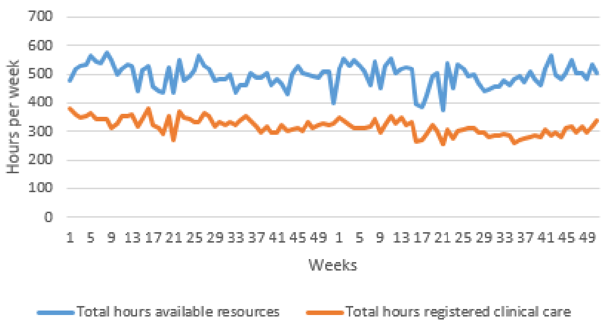


Figure 4.4: Registered hours Care TZ & EZ without group sessions

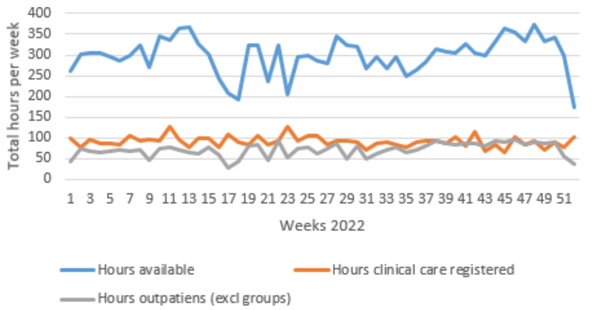
The length of the tasks can fluctuate as well. This is mentioned by the interviews, for example: *"very variable indeed. Sometimes we have patients here who have had a cerebral infarction and others who only have something wrong with their little finger. there is no level to measure"* (Interviewee 8). The observations during the shadow day confirmed those statements too. All patients are different and need distinct treatments resulting in a variable duration of the tasks in a shift.

On top of that, random interrupting factors can interfere with the tasks that belong to a certain shift, including a lack of resources or side tasks with higher priority. For example, a shortage of walkers, help requests from nurses, or missing out on patients. Quotes illustrating this: *"you cannot always visit, you have so many factors to take into account"* (Interviewee 5) , *"we have a lack of walkers lately, I sometimes spend up to 20 minutes looking for a walker when I need it"* (Interviewee 7) and *"then you have those days when everyone hasn't been washed and ironed by 10 o'clock in the morning and then you can not treat anyone"* (Interviewee 7). This was visible during the observations on the shadow days where nurses often called for support not related to the scheduled tasks or that it was not possible to treat a patient at a certain moment.

The employee side can have interfering factors that affect the match between the required and planned resources too. Absentees, planned and unplanned, cause fluctuations in the availability of resources for a certain moment. This could be drawn from quotes such as; *"If someone is ill, then we try to cut back a bit in the clinic"* (Interviewee 3). The fluctuations between the available time of the therapists and the total time spent on clinical care can be seen in Figure 4.5a and Figure 4.5b, where the planned number of resources fluctuates as well.



(a) Registered care vs resources EZ (2021-2022)



(b) Total hours available system vs hours registered TZ (2022)

Figure 4.5: Registered hours versus hours of resources planned per week

All those uncertainties together result in difficulties in predicting the supply and the demand side of the schedule. This makes it hard to determine the right shifts and shift lengths. A static, manual shift schedule assumes a stable demand over time. However, demand is not stable, which increases the chance of having a mismatch between the required hours and the planned hours available.

A second factor that increases a mismatch is the subjectivity of the planning, as seen in the subjectivity loop. The schedule has been made and interpreted by humans; therapists, and the planner. In the interviews, this surfaced in quotes like: *"make your own assessment whether or not you will make it"* (Interviewee 5). The planner makes decisions based on the opinions he hears from his employees and his perception of those opinions and estimations.

Thus, the interactions between the static form of planning, the subjectivity resulting from the manual aspect of the planning, and the dynamic uncertain supply and demand patterns create a mismatch between required hours and planned hours. This resulting mismatch can also be seen in figure Figure 4.6. The picture shows the planned hours per group of shifts (clusters) versus the registered time on patient tasks at the EZ. An example of such a cluster is the Surgery cluster, which consists of all the shifts that belong to the departments related to surgery. As can be seen for the Internal(Intern) cluster, the necessary hours sometimes exceed the planned hours, and for the IC cluster, the gap between those two is bigger than for the other clusters. Furthermore, the fluctuations in both patterns can be seen again, and the mismatch can be further recognized as not having the same demand and supply patterns. The following section will go further into the results of those mismatches.

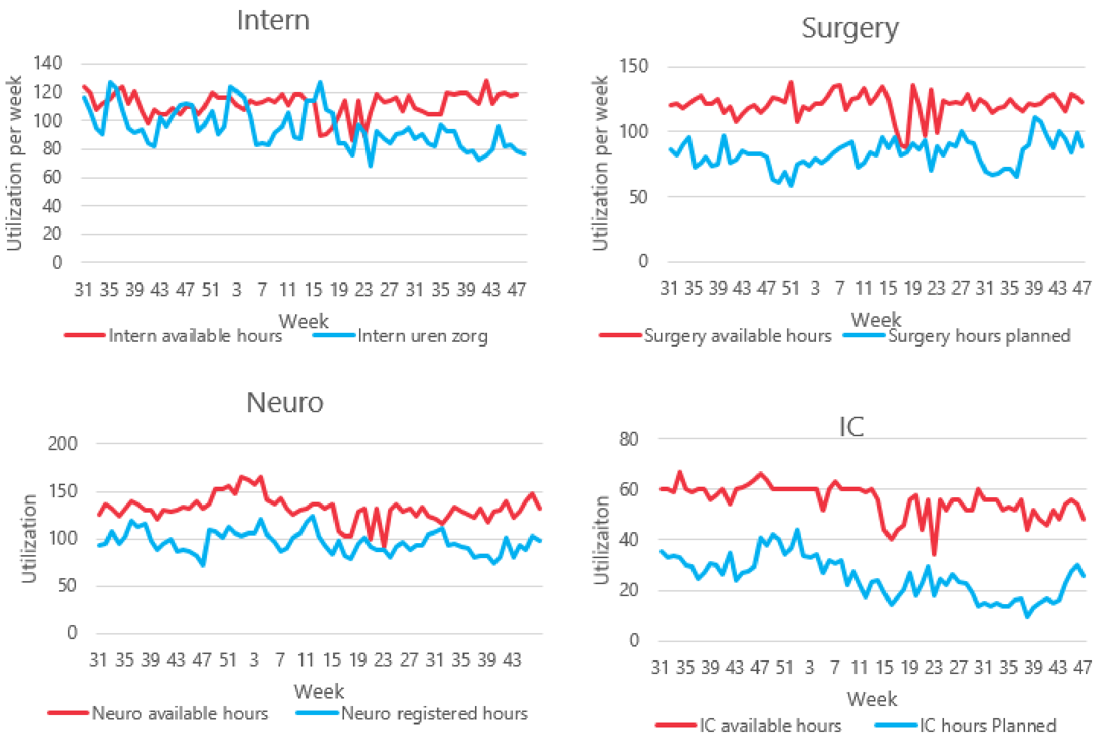


Figure 4.6: Registered patient time versus resource hours planned

4.2.2 Consequences of mismatch

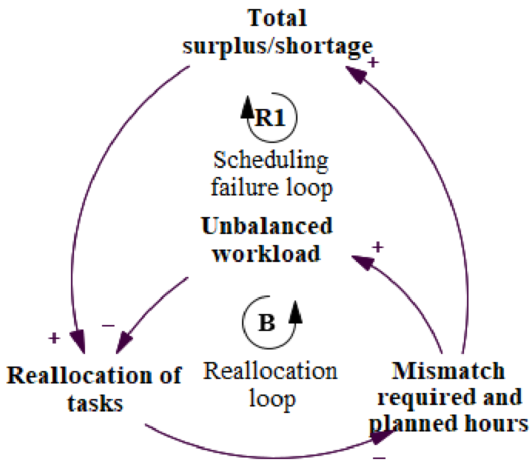


Figure 4.7: Consequence and intervention dynamics

Figure 4.7 shows the consequence and intervention mechanisms that occur as a result of the mismatches. According to the findings, the mismatch results in two unwanted effects. First of all, an unbalanced workload between different clusters/groups of shifts, which can be shown by comparing the utilization between these clusters. Secondly, it is possible that when evaluating the capacity of the whole department, a total surplus or shortage in hours can be observed. These loops are further discussed below.

Unbalanced workload

The unbalanced workload is noticed by almost all employees with quotes such as: *"No it is not always fairly distributed"* (Interviewee 1). The unbalanced workload can be best visualized by calculating the utilization rates for the different clusters. Utilization is the time spent on patient tasks divided by the time available for that cluster:

$$Utilization = \frac{Time_{registered}}{Time_{available}}$$

The utilization of each day is computed, then the average over all days in the data set is taken to compare the clusters. This results in Table 4.1. The mean utilization deviates between the different clusters on the EZ. The biggest difference exists between the Intern and IC cluster, indicating a structurally higher time necessary for patient tasks for shifts in the Intern cluster compared to the IC cluster.

Cluster	Neuro	Internal	Surgery	IC	Mean all cluster	Total Elisabeth
Mean utilization	73,3%	83,7%	69%	45,4%	70,7%	63,6%

Table 4.1: Mean utilization of clusters (August 2021 - December 2022)

A detailed overview of the utilization of the EZ over the weeks is presented in section 6.5. The Intern clusters most often exceed the 100% rate. Besides this, no other clusters have utilizations above 100%. The mean utilization per cluster per weekday and per month can also be found in section 6.5. The results show a lower utilization on Friday for the neuro cluster en a higher utilization on Thursday and Friday for the Intern cluster. Furthermore, IC has a lower utilization on Monday and a higher utilization on

Tuesday, which may be caused by the weekend effect of discharging patients. Lastly, Thursdays seem to have lower utilization for surgery. In total, Fridays have the lowest utilization. All differentiation in utilization's are caused by fluctuations in the hours spent on the demand side rather than the demand side (derived from Table 9.2 and Table 9.3 in section 6.5). This also strengthens the earlier-mentioned fluctuation in demand. On a monthly level, differences in utilization can be found as well. The difference for the neuro cluster is 15% difference between January and March, 26% difference between September and December for IC, 19% difference between December and May for surgery, and 18% difference between Intern between April and August. Overall, April contains the highest utilization, and September the lowest. On a monthly level, fluctuations were mostly caused by fluctuations in demand, except for January. In January, the Neuro cluster had structurally more hours planned, with no big difference in registered care. Those augmentations are concluded from the mean numbers registered per month and mean numbers available found in section 6.5 (Table 6.5 & Table 6.6). The TZ has differences between workload when calculating the utilization from the assumed basic planning too, as depicted in Table 4.2. However, this is based the assumption that the estimated current planning (2022) is followed the whole year, making it weaker than the results of the EZ as no details are available on the actual historical utilization. Nevertheless, all of those together strengthened the perception of the unbalanced workload according to the interviews.

Department	Cardio& urology	Lung	Geriatric	Orthopedics
Mean utilization	48%	62,5%	42,8%	48,5%

Table 4.2: Mean utilization TZ (2022)

Total surplus/shortage

A total shortage or surplus of the department can exist due to the gap between the hours planned and the required hours. This is mostly explained by quotes related to the interventions such as *"than we have to prioritize together"* (Interviewee 8) and *"In case of a shortage, we check who needs it the most and help them properly"* (Interviewee 5) , and *"Last summer, it was okay. Then we really had some time left where we could work on projects and stuff"* (Interviewee 5).

To cope with the mismatch, different ways of reallocating tasks (mostly patients), are conducted, as related to the reallocation and scheduling failure loop. In case of a shortage, patients are prioritized on importance. In case of a surplus, therapists start working on relevant side projects. Thus a shortage or surplus is handled by prioritizing or doing other tasks outside the line of tasks of the assigned shift.

To correct for the unbalanced workload, a reallocation of specific tasks is done. At the EZ formal communication in the form of daily heads up are conducted to reallocate task from employees with a higher total amount of tasks (patients) to employees with a lower total amount of tasks. At the TweeSteden hospital, only informal communication is done to reallocate patients. Some related quotes from the interviews are; *"We always have a day start, so I think we take a good look at how each cluster is doing and who needs help"* (Interviewee 5) ; *"I think that the day start and restart is really something we have an advantage off"* (Interviewee 1) ; *"then I ask the colleagues who I think might have some time and space if they could help me"* (Interviewee 6).

Both ways of reallocation are a way to reduce the mismatch between the required and planned hours. Therefore the reallocation variable is an important aspect of those balancing loops.

4.2.3 Maintaining dynamics

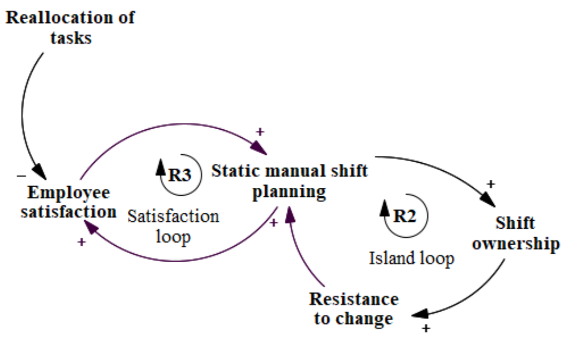


Figure 4.8: Maintaining dynamics

There are multiple reasons why the static manual shift planning has been kept in place. The mechanisms referring to this can be found in the part of the model that is depicted in Figure 4.8. The first can be explained by the satisfaction loop. In the interviews, multiple positive things are mentioned, including the clarity of the planning, simplicity, continuity, the time saving for reading-in, feeling of belonging to the department they are working on, and it creates improved knowledge and skills for that particular shift. Specific quotes are: *"Personally, I think it is very clear this way"* (Interviewee 2), *"Suppose you do orthopedics today and you are on cardiology tomorrow, it will take me a lot of time to read in all those patients again"* (Interviewee 6), *"I think it is good this way. that is why you do have your specialism and that is why you have a nice affinity with neurology"* (Interviewee 8), *"I feel completely at home there. it also feels a bit like home. Connected to the department. That connection that I feel with the nurse there and with the doctors."* (Interviewee 4), *"I already do this for years, but I still like it"* (Interviewee 9), and many more in section 6.3.

In addition, due to this unchanged and historical way of planning, people tend to get attached to their own shift. As a result, an island culture arises where people give their own line of tasks higher responsibility, causing people not wanting to give hours of their shift away. In other words, the resistance to change increases, making it harder to change the planning. Example quotes on this are *"More thinking beyond own boxes"* (Interviewee 6) and *"There are many colleagues with goodwill to help each other, also outside their cluster, however, it is not yet naturally"* (Interviewee 5). All be explained by the reinforcing island loop.

Lastly, a slightly weaker link between reallocation and employee satisfaction is created due to the fact that employees are irritated when they have to reallocate a lot, increasing resistance to change. This link is explained primarily by informal meetings and observations. Quotes that indirectly show this irritations are: *"Feeling the responsibility for those 5 patients that are put into the acquisition list"* (Interviewee 2) and *"It is difficult that in the end, everyone is responsible for the whole list of patients"* (Interviewee 1).

5 Discussion

As mentioned in both chapter 1 and chapter 2, scheduling personnel is a difficult problem, especially in dynamic environments where demand is uncertain, and the set of employees is heterogeneous. Planning the right number of employees is important to avoid unnecessary costs and satisfy service levels. Literature has focused on making a model to find the optimal way of planning, including many different constraints (Özder et al. 2020). However, making a generic model seems impossible due to all the context variations. Besides, few of the algorithms and models in literature do make it to implementation since it is hard to integrate such an algorithm. Many real-life implications are neglected in these models. For example, models assume that all information regarding the availability of patients and staff is known before making the schedule. Therefore, scheduling is still done manually in practice. This results in a gap between what is proposed in the literature and what the effects of scheduling in the real world are. This research has investigated the effects of having a static shift schedule in the real-world setting more by focusing on the following question:

What are the primary interactions causing scheduling complexities and dynamics encountered in practice?

In order to answer the research question, an inductive case study has been performed in the physio department of the ETZ hospital. Based on interviews, a data structure has been constructed according to the approach from Gioia et al. (2013). This is followed by transforming those results into CLD to describe the real-world mechanisms in a dynamic way. Together with historical data, the CLD is explained and verified. As described in chapter 4, suboptimality can be recognized in a mismatch between the required and the planned hours. This is observed in both the total hours planned and for specific shifts, resulting in an unbalanced workload. This is caused by the relationship between the static form of the planning, the dynamic environment of the organization, and the subjective judgment of this environment. The dynamic environment makes it hard to predict the required hours for certain shifts. Still, the current, static way of planning is kept in place. Multiple interactions explain this. At first, there are satisfaction factors such as simplicity, continuity, and clarity of the planning. Second, shift ownership results in a resistance to change the way of planning.

5.1 Theoretical implication

Literature often fails to represent a realistic scenario due to the needed simplifications to efficiently solve the personnel scheduling problem (De Bruecker et al. 2015). As a consequence of these simplifications, elements such as preferences and stochasticity are often left out of the model (De Bruecker et al. 2015). This study shows those factors, especially the impact of the employees on the schedule in practice and the impact of stochastic task demands on the mismatch between required and planned hours. Despite the importance of stochasticity in the real world, as shown in this research, most reports only refer to stochasticity in their future research section (De Bruecker et al. 2015).

For the mentioned impact on the employees, this study emphasizes the importance of considering subjective opinions and employees' perceived positiveness when scheduling staff. While previous literature has mostly focused on objective optimization criteria, by using, for example, the mathematical models, this research shows that employee satisfaction, resistance to change, and simplicity of the planning process can significantly influence the success of a personnel schedule in practice. Hence, future research could investigate how to incorporate subjective aspects into the personnel scheduling process to increase overall efficacy instead of ignoring those impacts.

On top of that, authors hardly ever provide details of the implementation process or the observed results (Van den Bergh et al. 2013). It seems that implementing a solution algorithm is hard, despite that most authors used real-life data in their research(Özder et al. 2020). The involvement of different stakeholders in the implementation process increases complexity (Van den Bergh et al. 2013), which can be found in this research as the impact of the employees on the scheduling method. Another reason why optimizations in literature do not make it to implementation is that they consider a restrictive problem setting rather than testing the solution with a more practical method such as simulation (Van den Bergh et al. 2013). Van den Bergh et al. (2013) also mentioned that sometimes a proposed algorithm is hard to incorporate into the company's software systems. This could be caused by having a different software in place or software that does not allow for changes (Özder et al. 2020). The presented model of this study could help those studies to better understand which dynamics are important to take into account when implementing in practice.

To find solutions to the real-world problem, different methods have been used in literature. Metaheuristic, for example, is a method that can easily deal with complex objectives and is relatively easy to implement (Ernst, Jiang, Krishnamoorthy, and Sier 2004a). However, metaheuristics are not good at providing optimal global solutions. The question arises whether including this method would give a better solution than just keeping the planning as it is since the current schedule is generally perceived as sufficient. Another example of a method used in literature is integer programming. This method is relatively difficult, time-consuming, and only useful when rostering rules are static over time (Ernst, Jiang, Krishnamoorthy, and Sier 2004a). This research explains that rostering in the service industry is not always static over time, indicating that such a method is unrealistic. Simulation is mentioned as one of the best methods to overcome the limitations of the other methods, but solutions may be very computationally expensive (Ernst, Jiang, Krishnamoorthy, and Sier 2004a). Simulation is often combined with queuing models to strengthen the solution for practice. Thus, it seems that literature fails to find a practical method that is both simple and captures all of the important dynamics of the real world in the same time.

As said, important realistic dynamics are often ignored by simplifying assumptions and assuming static rules. The implementation of the solution is often missing in the literature since most studies are theoretical or difficult to solve in practice. This research shows that some variables (stochastic, impact stakeholders) that are often ignored in the methods in the literature are very important to consider over time. More specifically, the findings suggest that the static nature of personnel schedules can lead to suboptimality when faced with unexpected changes in demand or task requirements. As a result, new research could focus on developing dynamic scheduling approaches that can adapt to changing circumstances in real-time. This improves overall efficiency and effectiveness, and should not ignore those aspects. Overall, methods used in literature are only justified when the extra benefits of the solutions exceed the efforts and complexity of implementing and using such a method.

Furthermore, due to the mentioned stochastic environment, the importance of considering the reallocation aspect of the problem has been noted, and the findings demonstrate the essence of investigating the scheduling and reallocation aspects together rather than separating them. As described in chapter 2, the personnel scheduling problem only includes scheduling, whereas the workforce planning problem also includes staffing and reallocation. This research highlights the importance of understanding the interaction between different aspects of workforce planning, including scheduling and reallocation. Warner (1976) mentioned that the division between staffing, scheduling, and reallocation should be kept together to achieve a total solution. However, literature on the personnel scheduling problem has been separating those three aspects. This implies that the interaction between those aspects is missing and that the results of earlier research may give a distorted picture of reality. For example, ignoring the staffing part means making the assumption of always having the right staff. In practice, there may be a shortage of employees, which could affect the optimizations used in previous literature. New research should consider all aspects of the workforce planning problem to achieve a comprehensive solution.

In general, this research suggests that a more comprehensive approach to workforce planning is needed to understand the dynamic interactions of the static schedule in practice. Additionally, understanding the reasons behind using a static shift schedule with a manual method in practice can lead to improvements in the planning process by addressing employee satisfaction, simplicity, and resistance to change. On top of that, this study emphasized the effect of the employees themselves on the way of planning. This is in line with what is explained by studies on preference scheduling (Wolbeck 2019). Wolbeck (2019) even claims that preference scheduling has one of the biggest potentials to create a fair schedule. In preference scheduling, the general preferences of the employees are taken into account by penalizing a violation of those preferences. The satisfaction and subjective judgment of the employees greatly impact the schedule, and should therefore be considered when designing it.

5.2 Practical implication

Besides implications for the literature, more specific practical implications can be given for organizations that work with a static schedule that has been manually made in a dynamic environment. For those organizations, it is important to try to decide the shifts on objective reasoning and to focus on satisfying the employees. Objectivity can be increased by using a forecast or using a dashboard on the historical demand patterns. With more objectivity, the planner and the employees gain more insights into each other and the total workload, making it possibly easier to lower the resistance to change.

The findings of this thesis show that the therapists are overall positive about the way of planning because the planner tries to incorporate most shift preferences and employee constraints. The static shape creates a belong of feeling to the departments they are working on. Moreover, it creates clarity, and ensures that they are more skilled for the work they do, which results in efficiency together with the time savings of seeing the same patients. In addition, the team is relatively small. Thus, a dynamic schedule would create a lot of complexity, while current interventions seem to work fine for the setting, as substantiated by the employee's satisfaction with the planning. However, from the results of both the quantitative data and the qualitative gut feelings, a difference in workload exist based on the utilization level per cluster. section 6.5 shows a structural difference in workload between different clusters in the EZ. This is caused by the subjectivity of the employees, the resistance to change the basic planning, and the unpredictability of demand. A planning suggestion has been made for the EZ to give objective reasoning to change current subjective-based basic planning. Due to the uncertain and dynamic behavior and the fact that the suggestion is only based on data from 2022, iterative changes have to be made in the future based on new data. When enough data exists, it is also wise to forecast and investigate the holidays and weekends in more detail.

To keep it simple and keep the same planning as much as possible (high satisfaction with current planning), improvement suggestions on the basic planning has been made. This creates a valuable example of how to create changes to the planning that are more objective possible. The results indicate the number and the length of the proposed shifts based on four scenarios. The goal of the scenario analysis is to create a more balanced workload and limit the amount of under-staffing. As mentioned, the planning is divided into five clusters, including multiple work shifts. According to the planning, a basic schedule exists on how many hours, and, therefore how many shifts to plan. Shifts are always in the duration of 4, 6, or 8 hours. In comparison with the current basic planning, it is suggested to change one shift sequence to a sequence of working four days of nine hours instead of four days of eight and one day of four hours in the Neuro cluster. Secondly, for the IC cluster, it is proposed to move a 4-hour shift every day from the IC cluster to the Intern cluster. For the surgery cluster, it is advised to move a 4-hour shift from Thursday to Monday. Lastly, due to the lack of data and skilled personnel, no suggestion is made for the Child cluster. A detailed description of the scenarios can be found in section 6.6. This all results in the following few recommendations for the EZ location:

- It is recommended to keep the overall structure of the schedule the same. However, the allocation of the hours to the clusters could be changed in order to equalize the workload between the clusters. For example, the 4-hour shift change from IC and Intern is suggested in the basic planning.
- The analysis excludes all treatments that could not take place, therefore it is recommended to report the patients that could not be treated due to peaks in demand. From here, a better objective decision can be made for the required hours in the planning.
- When more years of data are available, it is advised to do forecasts on the expected demand to make a more reliable suggestion on the necessary hours in the planning. For this also take into account the planned reductions for the coming year.
- To know what time is needed for relevant projects, it is proposed to make it possible to apply for planned time spent on certain projects. The planner can evaluate whether the project is important enough for the hospital to give certain fixed planned hours to work on this project.

Unfortunately, for the TZ hospital, no similar scenario analysis can be performed for a few reasons. First, no specific hours are assigned to specific shifts. For example, it is only noted that employees A and B have to work in the cardiology department on Monday and not how many hours they have. On top of that, at the TZ, employees also have other types of tasks. Some employees also have outpatient appointments. They try to use only certain time slots. However no specific administration on whether they use those blocks, whether they have changed over time, and whether those blocks are completely filled. Lastly, it is difficult to find the time spent in outpatient group treatment. If 8 patients are treated in a one-hour block, the time registered is 8 hours in total, while the employee spends only 1 or 2 hours. Also, due to the involvement of multiple kinds of tasks, there is more unregistered switching time. Thus, to get more objective conclusions, more detailed data is necessary. Right now, the number of assumptions would have too much impact on objective suggestions. Nevertheless, some general recommendations can be given for the TZ:

- The orthopedics department is highly related to the number of operations as seen in the data (section 6.8). Since the operations planning is already known at least a week in advance, it is suggested to have a bit of flexibility in the planning until this schedule is known. When more data is available, a prediction for the demand during normal weeks and reduction weeks would create a good estimation for the required hours
- To increase the willingness to help each other, it may help to try another way of formal communication. The daily heads-up was practically not possible; however, a weekly heads-up may increase the willingness to help and will give a better insight in the workload of colleagues.
- Knowing how many patients could not be treated is valuable, since the dependency of the availability of employees is high in the TZ, due to the small size of the team.

It is important to find objective ways to change the schedule in order to decrease the mismatch between supply and demand and to have objective arguments to overcome the resistance to change.

5.3 Limitations and Future Research

Several limitations can be found in this research. The most important ones are mentioned in this section, followed by suggestions for future research. One of the limitations is the focus on the employee side of the problem. This thesis focuses primarily on the effects that arise on the employee and planner side of the scheduling problem. However, since customers (patients) also experience the effects of the chosen schedule method, it is important to incorporate more of the effects of a certain schedule for the customers. In this research, this could be, for example, when a patient cannot be treated due to a shortage of therapists or the satisfaction that may arise when seeing as much as possible the same therapist every day, which is a suggested effect explained from the therapist view.

As mentioned, the personnel scheduling problem comes in many shapes with many different contexts, not just within healthcare. Therefore, another limitation is that observing this specific context is not sufficient to generalize the effects of a static planning for completely different environments. Future research on the effects in other contexts is necessary to draw conclusions in these settings.

In addition, some limitations can be found regarding both quantitative and qualitative data. Regards the interviews, the participants were mostly scheduled in the same department every day. Less attention has been paid to employees that are so-called flex workers, who frequently work in different departments (line of tasks). Besides, some departments were less represented in the interviews and the child department has even been left out due to the small size and the limited number of employees that can work on those tasks (not many different schedule options possible). On the other hand, the limitations on the quantitative side are mainly in the subjectivity of the input. At first, due to the manual registration of the planning sheet regarding the specific cluster hours, the data may conclude some errors. Furthermore, the hours spent on the clinical data is based on the manual time registration. The time registration has been filled in by the therapists in time slots of ten minutes. The time registration is always an estimation and rounded to 10 minutes, therefore precision in the data misses. Also, some therapists include the read-in time structurally whereas others sometimes forget to take this time into account. Furthermore, the amount of data has been very limited, mainly due to Covid and the age of the current system (implemented in 2018), so testing the scenarios on multiple years was not possible. Furthermore, no data is available on patients that could not be treated due to a lack of resources caused by absentees or peak demand. Resulting in no information on how many times there was a real shortage of employees. On top of that, no data is available on the lost time due to interruptions and projects, therefore no data validation can be done to show how big this effect is on the predictability of the required tasks.

This research assumed that the department has the right amount of staff; however, a mismatch in the necessary number of employees also has an effect on the mismatch of the required hours of employees. Therefore, it is recommended to investigate optimal utilization levels for different contexts to also include the required hours based on how many hours employees can work on certain tasks based on the total hours planned. For now, the focus of the scenarios was to optimize based on equalizing the workload instead of maximizing efficiency. For future research, it is also recommended to include the staffing problem as well since it is related to the scheduling problem. As mentioned before, the reallocation problem is important to take into account as well.

The current literature mostly focuses on the problem setting and optimizing the schedule based on available real-world data, and not on the results of the optimized schedule in practice. This study does the opposite; it focuses on the effects of the schedule in practice, but not in detail on optimizing this schedule. For future research, it is recommended to include both aspects, optimizing the schedule and implementing the schedule to analyze the dynamic effects of certain optimized planning. As a result, the best method can be selected on the basis of the results in practice.

As described in section 2.2, three classifications were listed; shift scheduling, day-off scheduling, and tour scheduling. In this research, only shift scheduling is mentioned since therapists mostly work day shifts during the workweek. However, weekends are neglected as only a few hours are planned in the weekends, resulting in fewer available data. To expand this research, including weekends would result in a small cyclic rostering, as therapists have to work on a weekend day once a month, which is assigned on a cyclic basis. Therefore, the tour scheduling problem would also have to be included. Thus, the choice to leave out the weekends might limit the interpretations of the results.

For future research, it would also be valuable to investigate the task scheduling problem. At the ETZ, employees are planned for a specific shift which corresponds with a line of tasks that fluctuates. However, at Jeroen Bosch Hospital, specific task planning has been made every morning based on the length of the shifts of the employees. A comparison of the effects of such an extension on the personnel scheduling problem in practice may generate new insights into how to effectively plan the employees. Lastly, it is suggested to investigate a context where they use a more dynamic way of planning. Afterward, the results can be compared with this research to know which way of scheduling is best.

5.4 Conclusion

To conclude, the personnel scheduling problem is a diverse and complex problem. The gap between literature and practice is hard to overcome as generalizing one way of planning for all situations is impossible. This research highlights the limitations of previous literature on personnel scheduling problem and the need for a more comprehensive approach to workforce planning. The study results have shown the mechanisms that cause the suboptimality of the planning and the mechanisms that interact with the way of planning in a hospital setting. It shows that the dynamic nature of personnel schedules and the simplifying assumptions used in the literature can lead to suboptimal solutions in practice. There are several practical options to mitigate the suboptimality of the schedule. First of all, it is important to have reallocation strategies in place. Moreover, it is useful to find objective arguments for constructing the planning. Lastly, it is important to reduce the resistance to change as much as possible. This study has created a basis for how to conduct an inductive case study on the dynamics of a specific way of scheduling. This way, it presents an additional way of exploring the personnel scheduling problem.

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6 Appendix

6.1 Structure of historical data and transformation handmade planning

In the ETZ, many different pivot tables are constructed based on data generated by Epic, the Electronic Patient Dossier (EPD). This research mainly used two pivot tables, one for the inpatient treatments of the physio-department and one for the outpatient treatments. The "zorgactiviteiten kubus" Excel document is essential for the inpatient treatments related to all conducted care activities. For the outpatient treatments, the necessary Excel document is called "polikliniek kubus", storing all data that arises in the outpatient part of the department. The so-called "Pivot table" within Excel allows the display of the data in many variants. The most important aspects used from the data sets are the time registration for the clinicial care activities and the time of the outpatient appointments. For those datasets, only years 2021 and 2022 were used as input since those are the most re-presentable years in the data. The oldest data is from 2018. However, many mistakes were made in the system as the employees were not used to the new system. In 2019, the departments in both locations were different; some departments were, for example, moved to the other location. Lastly, 2020 was a different year due to corona, some departments were closed, and treatments time were longer due to changing into protected clothes, for instance. However, 2021 still had an impact of Covid, therefore sometimes 2021 and 2022 are investigated separately.

The second source of historical data consists of a handwritten Excel sheet, generated by the team leader. This Excel document presents the therapist's planning for the coming weeks and the completed planning of the finished weeks. The inpatient therapist planning consists of data on the hours/day-part planned for a therapist for specific departments and clusters, who were absent during a specific day, and who was planned for which group session. Figure 6.1 shows a general overview of how the data appears in the Document. Only data from 2 august 2021 till December 2022 has been used since older data is not available. Besides, this data is compared to the total hours registered in Epic.

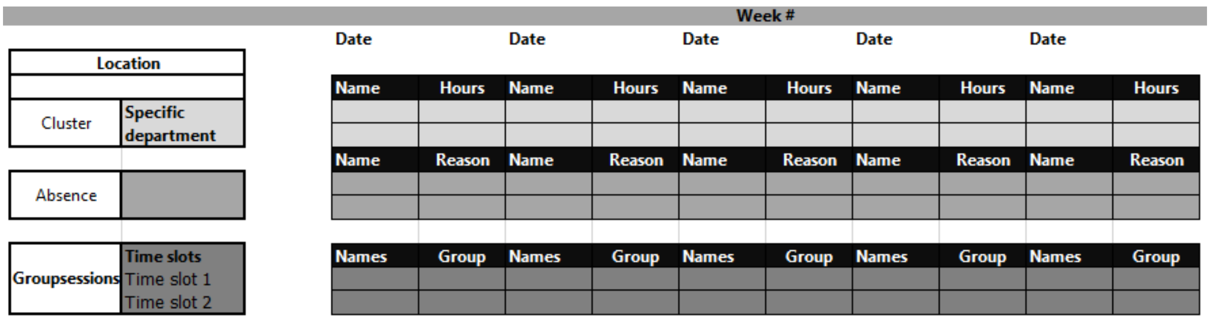

Figure 6.1: Planning therapists

This handwritten planning sheet has been transformed into a data set showing all hours planned over the weeks and days for the different clusters of the EZ. An example, can be found in Figure 6.2. The new data sheet displays how many hours were planned for a specific week (also in day format). For the TZ hospital no specific number of hours per therapist per department/cluster were noted, therefore no specific data over time for the hours planned could be analysed. This data set could be further used to calculate the utilization rate per day or per week, indicating the percentage time spent on patient treatment in comparison to the planned hours for that day/week for a specific cluster.

Year	Week	date	Neuro	IC	Surgery	Intern	Total
20XX	X	DD/MM/YEAR	Hours planned	Hours planned	Hours planned	Hours planned	Hours planned
20XX	X	DD/MM/YEAR	Hours planned	Hours planned	Hours planned	Hours planned	Hours planned
20XX	X	DD/MM/YEAR	Hours planned	Hours planned	Hours planned	Hours planned	Hours planned

Figure 6.2: Hours Planned

As said, for the TZ, no hours on the planned hours per department can be found, and the utilization over the last year can not be calculated. However, assumptions can be made to check the utilization of the current basic planning. To check how many hours are planned for the clinical care, a few steps have been taken. At first, since no specific hours are given per person per department, 8 or 4 hours are given, depending on whether the employee works the whole day or half a day. From this, the standard outpatient blocks and group session blocks (as given by the planner), are subtracted from those hours. A few assumptions were made here; 1) an outpatient block is fully filled, 2) a morning shift takes 3 hours, and an afternoon shift 4,5 hours (half hour break in between), 3) no one plans outside there outpatient block. This all resulted in the followed assumed planned hours per department per week as shown in Table 6.1, verified by the planner.

	Monday	Tuesday	Wednesday	Thursday	Friday	Total
Cardiology + Urology	13	7,5	5,5	11,5	13	50,5
Lung	5	5	5	5	3	23
Geriatric	10	8	9	7,5	9	43,5
Orthopedics (even weeks)	14,5	15	14,5	18,5	11,5	74
Orthopedics (uneven weeks)	10,5	15	14,5	15	11,5	66,5
Total outpatient	39,75	13,5	11,5	27,5	17,75	110
Total group hours	8	10	4	10	8	40

Table 6.1: Assumed planned hours 2022

6.2 Interview set up

Introduction on the project

1. How long are you working on the ETZ, and why did you choose to work here?
2. What are your responsibilities and tasks?
3. On which departments do you most often work?
4. Which departments do you never work in? and why?
5. Do some departments require extra training?
6. Are there departments you can not work in?
7. What do you think of the current work division and shift division?
8. Is the workload balanced between you and your colleagues?
9. What do you want to prove in the planning and what in the work division?
10. How do you see the planning in the most optimal situation?
11. Do you think that you sometimes have time left?
12. Which tasks do you have outside your patient care?
13. How much time do those tasks costs?
14. How many patients do you see during the day?
15. How many new patients do you see each day?
16. How often do you need to rush your treatments?
17. How often do you have interruptions in your work and what are the reasons?
18. What is important for you about the work division?
19. What would you like to see different?
20. Do you work on the other locations as well? if yes, can you name some differences and things to learn from each other etc.

Note that those questions are translated into English and are only used as inspiration and as a guideline during the interviews

6.3 Complementary Quotes Data structure

2nd order themes	1st order theme	Quotes
Employee satisfaction	Perceived clearness of the schedule	"het is ook wel fijn om vaste gezichten te zien op de afdeling" (Interviewee 1)
		"persoonlijk vind ik het wel overzichtelijk"(Interviewee 2)
		"ik vind toch dat het werken in clusters fijn is maar ik vind het wel fijner als er een paar all round zijn die zegmaar in kunnen springen waar nodig"(Interviewee 4)
		"fijn je weet wel een beetje wat je kan verwachten"(interviewee 3)
	Time saving because the employee knows the patient	"het feit dat ik elke dag de hele dag op de longafdeling sta maakt het dat ik kan kiezen dat ik 1/3 van de patienten niet zie op maandag, deel niet op dinsdag en deel niet op woensdag. Zo kan je door rouleren"(Interviewee 2)
		"dan mag je beide keren 20 nieuwe patienten inlezen die je niet kent. Dat kost denk wel meer werk dan als je gewoon beide dagen op dezelfde afdeling staat"(Interviewee 7)
		"stel dat je vandaag orhtopedie doet en je staat morgen op cardiologie dan kost het mij heel veel tijd om al die patiénten weer in te lezen"(Interviewee 6)
	Skill level focus and matching	"ik kan overal staan maar bijvoorbeeld op neurologie als het echt ingewikkeld is of nieuwe patienten, daar heb ik geen verstand van" (Interviewee 1)
		"er komen ook vaak veel nevenactiviteiten bij die je moet doen, dan is het wel fijn als je weet waar je het over hebt bijvoorbeeld een presentatie moeten geven of een klinische les" (Interviewee 1)
		"werken met clusters, ik denk dat het wel goed is. Daardoor heb je wel je specialisme en daardoor heb je lekker affiniteit met neurologie"(Interviewee 8)
		"ik heb voor neurologie nog wat verdiepende cursusses gedaan en verbredende ook. Neurologie is voor sommige best lastig. Iedere patient is anders en kwa kennis van het brein (Interviewee 8)
		"Bijvoorbeeld bij de IC, dat is wel handig als je dat een keer hebt gezien en weet wat alle apparaten doen" (Interviewee 8)
		"master afgerond neuro-revalidatie"(Interviewee 5)
		"neuro achtergrond is wel wenselijk, maar in principe krijg je neurochirurgie niet in je opleiding" (Interviewee 5)
		"ik heb een cursus astma en COPD gedaan"(Interviewee 2)
		"ïk vind opzich een indeling in clusters en collega's die er staan met de meeste expertise daarin wel een goede verdeling" (Interviewee 4)

	Feel of belonging on the department	"ik merk wel dat ik daar helemaal thuis ben. Dat voelt ook wel een beetje als thuis. Verbonden met de afdeling. De verbinding die ik voel met daar de verpleegkundige en met de artsen" (Interviewee 4) (Interviewee 5)
	Continuity	"verder proberen om toch continuïteit te krijgen" (Interviewee 1)
		"het is ook handig als ik daar op maandag heb gewerkt dat ik naar de MDO kan gaan dus dan sta ik die dag ook op ortho en MDO" (Interviewee 1)
		"ik ben wel iemand die het belangrijk vind dat een patiënt zoveel mogelijk dezelfde gezichten ziet" (Interviewee 1)
		"maar ik ben wel iemand die het belangrijk vind dat een patient zoveel mogelijk dezelfde gezichten ziet" (Interviewee 6)
	Right preferences	"ik doe dit al jaren maar ik vind het nog steeds leuk." (Interviewee 9)
		"dat vind ik wel het leukste om te doen" (Interviewee 1)
		"neurologie is toch wel mijn ding. Werkment met clusters, ik denk dat het wel goed is. Daardoor heb je wel je specialisme en daardoor heb je lekker affiniteit met neurologie" (Interviewee 8)
		"ik zou het prima vinden om daar eens te werken alleen neuro hebben ze daar niet en daar ligt wel mijn grote interesse" (Interviewee 5)
		"en ja er zijn ook niet veel mesnen die long leuk vinden en ik werk full time dus is het ook vrij efficient" (Interviewee 1)
Reallocation	Daily heads-up	"we beginnen in de ochtend met die dagstart om 9 uur en dan kijken we hoe het ervoor staat. In principe is het wel dat je op je eigen afdeling begint. Dat werk moet ook gedaan worden en vanuit daar ga je kijken of je mee kan helpen" (Interviewee 1)
		"als je kijkt hoe het ging toen ik hier begon, dat is echt een wereld van verschil met die dagstart en doorstart om 1 uur en doorstart om 3 uur dat is wel heel fijn. Toen zat iedereen op z'n eigen eilandje. Dan hielp je elkaar ook niet zegmaar" (Interviewee 1)
		"opzich denk ik dat we dat in de dagstart proberen te doen"(Interviewee 5)
		"we zijn 1 team dus als het op neurochirurgie rustig is kan ik wel ergens anders helpen" (Interviewee 5)
		"We hebben altijd een dagstart dan vink ik dat we best wel goed kijken van hoe staat elk cluster ervoor en wie heeft er hulp nodig" "we proberen dan ook wel zo evenredig mogelijk te verdelen" (Interviewee 5)
		"ik denk dat de dagstart en doorstart echt iets is waar we veel aan hebben" (Interviewee 1)

	Mobilisation plan	"Het zal echt wel efficienter kunnen en daar zijn we al mee bezig we hebben een mobilisatie schema gemaakt en dan uitgeschreven, iemand die mobiel is en zelfstandig is hoe vaak zie je die" (Interviewee 1)
	prioritizing	"Dus dan moet je met z'n alle een beetje prioriteren" (Interviewee 8)
		"ik maak sowieso een shifting. Ik kijk naar deze persoon moet ik iedere dag zien, deze persoon moet ik 3 keer in de week zien en deze hoef ik maar 1x per week te zien" (interviewee 8)
		"dan kijk ik wel wie het meeste nodig heeft en dan help ik die goed" (Interviewee 5)
		"dan blijf ik vaak langer of ik sla ze over en dan zie ik ze de volgende dag goed" (interviewee 2)
		"klinisch worden patienten vaker overgeslagen" (Interviewee 2)
		"als ier iiemand ziek is dan proberen we in de kliniek vooral een beetje te schrappen. " (interviewee 3)
		"als er dan ziekte is dan wordt daar wel eens mee geschroven. Dan kan het zijn dat ik op de long afdeling of toch orhtopedie, of een andere afdeling waar ik kan bijspringen" (Interviewee 6)
	Informal communication	"dus dan zeg je eerder van joh het is wat rustiger moch ik straks nog tijd over hebben zal ik jou dan even bellen om te kijken of ik jou nog kan helpen" (interviewee 6)
		"dan vraag ik aan de collega's waarvan ik denk dat ze misschien wat tijd en ruimte kunnen hebben of ze zouden kunnen helpen" "of als je 's middags zit te rapporteren en dat je dan vraagt hoe staat iedereen ervoor want ik heb eigenlijk, ik noem maar wat, ik moet nog iets voor ons EPD doen" (Interviewee 6)
Static planning	Fixed planning structuur	Er wordt gewerkt vanuit een basisplanning en de planning staat vast voor de komende 8 weken. Er wordt nu al gekeken naar de vakanties ver vooruit (Planner)
Workload inequality	Unbalanced workload	"nee het is niet altijd eerlijk verdeel" (Interviewee 1)
		"je merkt wel dat daar verschillen zitten in drukte" (interviewee 5)
		"of het aantal uren per cluster klopt dat weet ik niet" (Interviewee 1)
		"ik denk wel dat de ene meer patienten ziet dan de andere. Als degene het dan ook druk met 10 heeft, wie ben ik dan om te zeggen he doe even meer, maar misschien kan degene wel niet meer" (interviewee 8)
		"als iemand 20 patiënten kan zien en ik 15, dat is helemaal geen punt. Misschien moeten we dan ook gaan kijken waarom die er niet zoveel zien" (interviewee 8)

		"daar proberen we wel goed te verdelen. Als het op de neurologie drukker is dan komt er wel hulp naar neurologie" (interviewee 5)
		"nee dat vind ik niet" "op de longgeneeskunde ben je soms klaar in 15 minuten en dan heb je gewoon goede therapie kunnen geven en op neurologie heb je voor zo'n patient een half uur tot 3 kwartier nodig. Maar het moeten inlezen van 25 mensen en het rapporteren kost ook wel even tijd. Ik vind die verdeling niet helemaal netjes" (interviewee 2)
		"aan de ene kant wel, aan de andere kant niet" "op een afdeling vind ik dat je sneller meer pätienten kan zien dan bijvoorbeeld op de IC" "alleen in aantallen verschilt dat dan" (interviewee 4)
		ïn taken sowieso niet""ik denk wel dat er best een verschil is tussen dat sommige maar 1 onderdeel hebben en er andere zijn die veel meer neventaken hebben" (interviewee 6)
		"ik denk wel dat daar nog wat winst te behalen valt. Ik bedoel, ik kan natuurlijk alleen met mezelf vergelijken. Als ik naar mezelf kijk dan staat mijn agenda best wel vol met al die neven taken zegmaar en verantwoordelijkheden. Dat vind ik niet erg, dat past ook wel bij mij, dat ervaar ik niet als te veel. Maar als ik het soms vergelijk met andere dan denk ik ja die zitten dan vanuf nu gewoon, ik wel niet zeggen te chillen want dat klinkt negatief, maar die zitten dan vanaf nu, die hebben alle tijd om administratie bij te werken"(Interviewee 3)
Time shortage or surplus	Time required exceeds time planned	"dus dan moet je met z'n alle prioriteren" (Interviewee 8)
		"Dan kijk ik wel wie het het meeste nodig heeft en dan help ik die goed" (Interviewee 5)
	Time planned exceeds time required	"afgelopen zomer viel het wel mee voor mijn gevoel. Toen hadden we wel echt wat tijd over waarbij we dan weer aan projecten enzo konden werken" (Interviewee 5)
Mismatch required and planned hours	unbalanced workload & Time shortage/surplus	See above
Predictability of supply and demand	Flucutating Demand	"in de winter op long is het bijvoorbeeld als het koud is dat er een piek is" (Interviewee 1)
		"minder druk in de vakantieperiodie omdat ze dan wat bedden sluiten. Dat is wel een zekerheidje" (Interviewee 6)
		"op maandag kan het wel rustiger zijn" (Interviewee 5)
		"afgelopen zomer hebben we wel momenten gehad dat het rustiger was maar je hebt dan ook wel echt minder personeel" (Interviewee 5)

		"dat wisselt heel erg per periode, op dit moment is het griepvirus aan de orde, dan is het eerder dat mensen mij moeten helpen omdat het heel erg druk is op de long" (Interviewee 1)
		"Vaak zien we net voor kerst een grote piek van influenza en op dit moment het RS virus en een beetje voor mijn gevoel voor de zomer" (Interviewee 1)
		"het aantal patiënten fluctureert natuurlijk. Daar kan je niet zo goed op inspelen waardoor de druk de ene dag hoger zal zijn dan de andere dag" (Interviewee 4)
		"ik gok 10 ofzo. Het wisselt heel erg" (Interviewee 6)
		"vorige week lag het opeens wel erg vol. En deze week ook wel redelijk maar ja de week ervoor, lag het maar half vol" (Interviewee 4)
	Fluctuatin Demand type	"op een afdeling vind ik dat je sneller meer patiënten kan zien dan bijvoorbeeld op de IC" "alleen in aantallen verschild het dan" (Interviewee 4)
		"heel erg wisselend wel. Soms dan hebben we hier patiënten liggen die hebben een herseninfarct gehad en andere die hebben alleen iets aan hun pinkie" "daar is geen peil op te trekken" (Interviewee 8)
		"de ene 15 duurt langer dan de ander" (Interviewee 1)
	Interferring random tasks	"denk 1 op de 4 patienten" "onderzoek of inderdaad verzorging of ontlasting" (Interviewee 5)
		"je kunt niet altijd terecht, je hebt met zoveel factoren rekening te houden" (Interviewee 5)
		"soms heb je van die dagen dat iedereen om 10 uur 's ochtends nog niet gewassen en gestreken is dan kan je nog nergens terecht" (Interviewee 7)
		"daar zijn ze wel opeens naar de scan, daar gebeuren onverwachte dingen." (Interviewee 4)
		"ze hebben natuurlijk meer dan alleen fysiotherapie, dus iedere dag kom ik wel bij patiënten waar ik later terug moet komen" (Interviewee 9)
		"andere onderzoeken, verzorging die nog niet gedaan is, patient die niet wil op dat moment omdat die net van alles heeft gedaan" (Interviewee 9)
		"soms in de ochtendzorg als we vroeg op de afdeling zijn dan kan het voorkomen dat je net achteraan loopt dat iedereen nog in de badkamger is" (Interviewee 6)
		"zeker in de ochtend gebeurd het heel vaak dat mensen net aangekleed worden. Dat is soms lastig met laag belastbare patiénten omdat die dan net gewassen zijn" (Interviewee 4)
		"dan ben je net aan het inlezen en dan worden die patiënten weer verplaatst naar long. Zo denk je soms ach allemaal tijd voor niks" (Interviewee 3)
		"we hebben de laatste tijd een gebrek aan rollators, ik ben soms wel 20 minuten lang opzoek naar een rollator als ik die nodig heb" (Interviewee 7)

	Unknown list of required time exta tasks/projects	"traumanetwerk" (Interviewee 4)
		"GTU aan het opzetten dat mensen meer bewegen" (Interviewee 1)
		"dwarsleasie werkgroepje" (Interviewee 1)
		"het is niet dat je daarvoor wordt gepland" (Interviewee 1)
		"daar gaat best wel wat werk inzitten" (Interviewee 1)
		"ik heb zelf een project opgezet. Dat loopt een beetje door" (Interviewee 8)
		"Project rehabilitatie"(Interviewee 8)
		"ik zit nog in het beweegziekenhuis" (Interviewee 5)
		"ik doe nog een stukje onderzoek" (Interviewee 5)
		"CIP, contact persoon Impact preventie" (Interviewee 2)
		"kwaliteit en veiligheid" (Interviewee 2)
		"werkgroep van niet aangeboren hersenletsel" (Interviewee 4)
		"verbeteren van protocollen op de afdeling" (Interviewee 2)
		"werkgroep van ealy mobilisation" (Interviewee 4)
		"ik zit in de werkgroep van de visie op de fysio" (Interviewee 9)
		"Ons EPD"(Interviewee 6)
subjectivity planning	subjective input	"maak je zelf de inschatting of je het wel of niet gaat halen" (Interviewee 5)
		"het is ook wel dat mensen nou ja ik kom wel een eind en dat je dan in de loop van de middag te horen krijgt van ik heb nog een aantal patienten kan iemand nog helpen. Dat vind ik niet handig" (Interviewee 9)
		"weetje als je 's middags om 4 uur te horen krijgt dat iemand nog patiënten heeft, dan heeft deze persoon eerder op de dag kansen misgelopen om dit aan te geven. Dat moet je gewoon voorkomen" (Interviewee 9)
		"er blijven wel eens patiënten over, zoals nu voor de middag, dan denk ik ja het is bijna structureel en dan gaat er dus in hun planning iets niet goed. Ze trekken dan pas rond half 4/4 uur aan de bel. Dat vind ik te laat" (Interviewee 3)
		"Peter kijkt dan waar er in de planning geschroven kan worden"(Interviewee 6)
Resistance to change	Joint responsibility versus own responsibility	"lastig dat je met z'n alle verantwoordelijk bent voor die lijst patiënten, dat werkt niet want de ene 15 duurt langer dan de ander"(Interviewee 1)
		"er zijn heel veel collega's met goodwill die elkaar helpen en die elkaar ondersteunen en ook buiten de

		clusters, dat is alleen nog niet voor iedereen vanzelfsprekend" (Interviewee 5)
		"dat iets minder oppervlakkig kunnen communiceren. Verantwoordelijkheid voelen voor die 5 patienten die in de overnamelijst gegooid worden" (Interviewee 2)
		"het minst fijne aan dit werk is dat je met z'n alle verantwoordlеijk bent voor het werk dat er ligt" (Interviewee 1)
Shift ownership	Own box first	"omdat je verantwoordelijk wordt gemaakt voor een bepaalde afdeling dat mensen dat ook zien als hun verantwoordelijkheid, dat ze denken eerst moet dit hokje af en als dit af is dan ga ik over de hokjes heen kijken" "eigen toko eerst" (Interviewee 6)
		"ik denk dat het soms iets iet meer hokjes, dat er iets meer hokjes overstijgend gekeken mag worden" "dat je onderling bereid bent om elkaar te helpen" (Interviewee (Interviewee 6)
		"meer voorbij die hokjes denken"(Interviewee 6)

6.4 Fluctuations demand

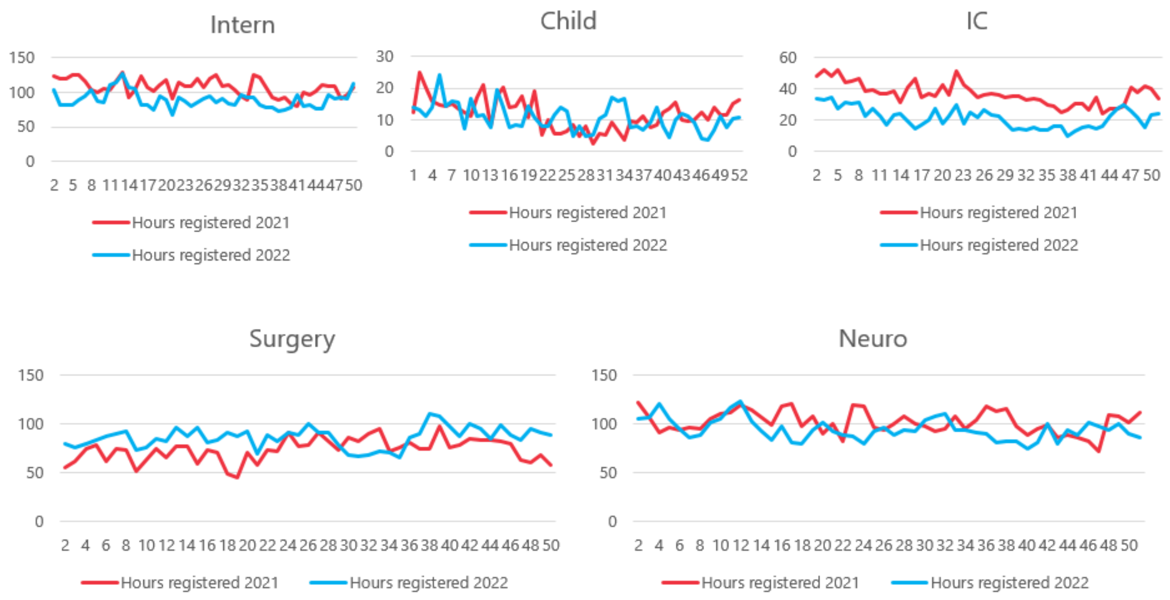

Figure 6.3: Registered hours treatment per week per cluster

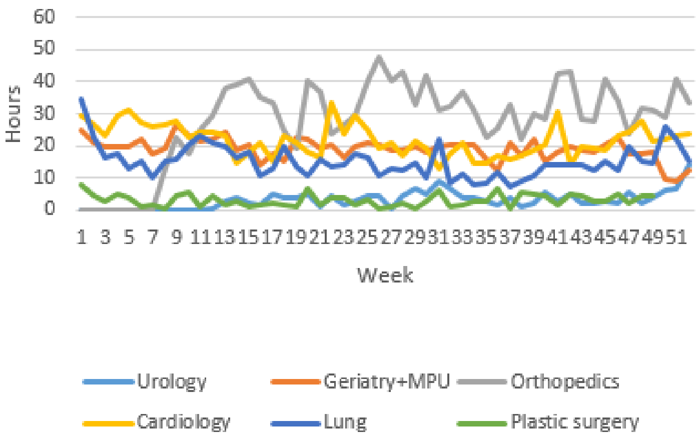

Figure 6.4: Registered hours treatment per week per department TZ

6.5 Utilization Elisabeth per week

Year	Week	Neuro Utilization	IC utilization	Surgery utilizaiton	Internutilization	Total utilization
2021	31	76,40%	59,17%	68,06%	84,14%	73,89%
2021	32	79,08%	54,72%	73,36%	78,19%	73,92%
2021	33	72,90%	56,78%	80,79%	82,56%	75,36%
2021	34	83,47%	49,50%	58,88%	111,01%	78,31%
2021	35	89,65%	49,72%	60,80%	105,22%	79,90%
2021	36	81,18%	49,44%	63,39%	88,71%	73,95%
2021	37	85,42%	41,11%	60,66%	75,00%	69,65%
2021	38	75,51%	44,72%	61,71%	79,85%	68,36%
2021	39	68,33%	54,46%	77,87%	76,31%	71,53%
2021	40	79,31%	52,30%	66,52%	78,66%	71,55%
2021	41	76,15%	44,17%	65,97%	82,14%	69,90%
2021	42	67,71%	64,51%	78,55%	92,75%	77,01%
2021	43	68,08%	40,28%	73,89%	92,15%	71,74%
2021	44	65,04%	44,81%	70,62%	96,83%	71,66%
2021	45	61,87%	44,62%	69,03%	100,76%	71,39%
2021	46	51,79%	45,57%	69,57%	104,49%	68,64%
2021	47	83,72%	62,12%	52,52%	98,33%	75,43%
2021	48	79,53%	58,85%	48,02%	82,27%	68,08%
2021	49	66,56%	70,00%	54,67%	93,27%	69,95%
2021	50	73,46%	67,22%	47,56%	96,97%	71,27%
2021	51	68,06%	56,94%	54,11%	75,28%	64,42%
2021	52	72,00%	60,83%	73,99%	82,90%	74,53%
2022	1	63,45%	70,83%	61,62%	90,80%	70,82%
2022	2	65,74%	56,39%	68,23%	88,65%	70,99%
2022	3	76,58%	55,00%	61,89%	74,17%	69,14%
2022	4	63,64%	57,50%	65,56%	75,15%	66,08%
2022	5	67,37%	52,24%	66,27%	72,08%	66,48%
2022	6	63,24%	53,06%	65,67%	80,21%	66,89%
2022	7	62,35%	48,68%	66,05%	83,33%	66,78%
2022	8	77,15%	52,78%	78,63%	90,58%	77,75%
2022	9	84,53%	37,22%	58,27%	76,99%	68,05%
2022	10	90,00%	45,83%	59,79%	72,18%	70,28%
2022	11	93,56%	37,22%	63,53%	99,40%	78,13%
2022	12	75,06%	29,38%	67,49%	97,18%	72,76%
2022	13	68,14%	38,61%	75,59%	107,34%	76,76%
2022	14	63,76%	42,86%	65,55%	94,44%	69,65%
2022	15	71,45%	43,94%	76,80%	92,11%	75,78%
2022	16	71,91%	32,08%	74,13%	91,20%	72,95%
2022	17	76,63%	37,50%	88,15%	89,74%	78,19%
2022	18	90,36%	42,75%	100,00%	76,67%	82,38%
2022	19	78,42%	48,51%	63,97%	91,42%	73,00%
2022	20	69,70%	30,75%	77,64%	78,65%	69,03%
2022	21	86,70%	46,97%	66,15%	77,71%	72,85%
2022	22	67,18%	52,98%	66,92%	80,70%	68,82%
2022	23	79,89%	50,98%	77,44%	91,67%	80,74%
2022	24	70,77%	44,35%	73,66%	74,06%	69,35%
2022	25	70,96%	42,63%	73,09%	75,28%	68,73%
2022	26	69,01%	47,02%	81,30%	79,50%	72,78%
2022	27	70,83%	42,26%	75,27%	80,56%	71,54%
2022	28	74,60%	43,91%	71,35%	74,86%	69,56%
2022	29	78,45%	36,54%	67,24%	84,42%	71,52%
2022	30	87,10%	23,06%	54,67%	69,37%	64,08%
2022	31	92,22%	26,49%	55,23%	76,45%	67,53%

2022	32	80,89%	25,00%	59,65%	95,48%	69,13%
2022	33	76,08%	27,08%	60,73%	89,10%	68,16%
2022	34	68,03%	26,28%	59,94%	83,33%	65,65%
2022	35	70,05%	26,10%	52,00%	76,76%	61,22%
2022	36	64,29%	30,77%	72,27%	66,39%	62,47%
2022	37	67,35%	29,76%	77,87%	64,27%	64,97%
2022	38	62,34%	21,59%	91,46%	60,69%	65,91%
2022	39	63,14%	25,32%	90,00%	63,61%	66,06%
2022	40	63,28%	31,60%	79,78%	71,88%	65,70%
2022	41	77,44%	35,87%	69,58%	83,63%	72,62%
2022	42	56,79%	28,85%	78,39%	62,11%	61,20%
2022	43	76,91%	34,03%	76,83%	69,79%	70,95%
2022	44	69,01%	42,59%	72,84%	67,94%	65,63%
2022	45	73,38%	49,70%	77,34%	64,44%	68,81%
2022	46	66,78%	55,86%	70,50%	80,34%	70,42%
2022	47	70,83%	53,82%	67,89%	76,69%	69,68%

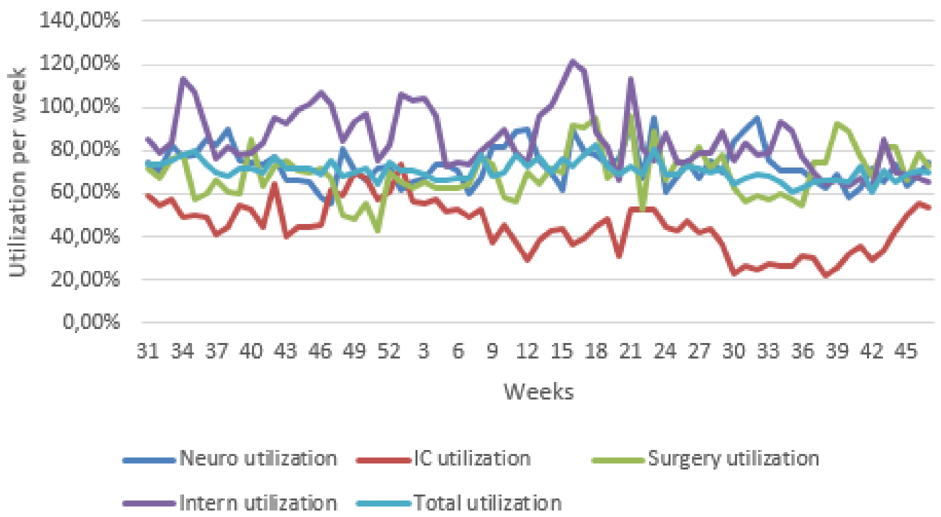

Figure 6.5: Utilization clusters per week

Day of the week	Mean utilization Neuro	Mean utilization IC	Mean utilization Surgery	Mean utilization Intern	Mean Utilization Total
Monday	75,0%	41,2%	70,4%	82,1%	70,7%
Tuesday	74,0%	49,4%	68,2%	83,0%	71,2%
Wednesday	74,2%	45,9%	71,1%	82,4%	71,4%
Thursday	75,5%	43,1%	66,5%	86,0%	71,3%
Friday	68,3%	45,6%	68,7%	85,8%	68,9%

Table 6.2: Mean utilization per weekday

Day of the week	Mean available hours Neuro	Mean available hours IC	Mean available hours Surgery	Mean available hours Intern	Mean available hours Total hours
Monday	26,51	11,92	24,85	23,29	86,57
Tuesday	27,75	10,43	24,69	22,60	85,46
Wednesday	26,73	11,41	24,30	22,95	85,39
Thursday	26,40	11,25	24,23	22,15	84,03
Friday	26,11	11,77	24,23	21,98	84,09

Table 6.3: Mean hours planned weekdays

Day of the week	Mean registered hours Neuro	Mean registered hourss IC	Mean registered hours Surgery	Mean registered hours Intern	Mean registered hours Total hours
Monday	19,80	4,90	17,34	19,02	61,16
Tuesday	20,39	5,15	16,75	18,59	60,77
Wednesday	19,69	5,23	17,16	18,79	60,79
Thursday	19,81	4,89	16,02	18,73	59,86
Friday	17,68	5,33	16,54	18,40	57,89

Table 6.4: Mean hours registered weekdays

Day of the week	Utilization Neuro	Utilization IC	Utilization Surgery	Utilization Intern	Utilization Total hours
January	68,51%	58,47%	64,50%	82,06%	69,16%
February	67,34%	53,11%	70,12%	83,31%	69,85%
March	**83,60%**	38,20%	64,52%	90,91%	73,41%
April	70,54%	41,19%	76,51%	**92,74%**	74,95%
May	79,28%	44,40%	**75,75%**	82,35%	72,61%
June	71,78%	48,12%	74,89%	80,12%	71,91%
July	77,01%	37,76%	67,81%	77,38%	67,55%
August	78,31%	41,51%	63,89%	88,25%	70,79%
September	73,35%	**36,21%**	72,45%	**74,77%**	68,83%
October	70,81%	42,05%	73,88%	80,54%	70,14%
November	68,58%	51,50%	68,24%	88,26%	71,57%
December	70,82%	63,16%	56,01%	87,11%	69,11%

Table 6.5: Mean utilization per month

Month	**Mean available hours Neuro**	**Mean available hours IC**	**Mean available hours Surgery**	**Mean available hours Intern**	**Mean available hours Total hours**
January	32,24	12,00	24,00	22,62	90,86
February	27,20	11,95	25,50	22,85	87,50
March	26,48	11,96	25,39	23,09	86,91
April	26,16	10,53	24,89	22,74	84,32
May	25,85	11,20	24,70	22,20	83,95
June	25,52	10,57	24,67	22,43	83,19
July	25,24	11,05	24,48	22,52	83,29
August	25,32	11,39	24,10	21,61	82,42
September	25,91	10,93	24,30	23,85	84,99
October	25,57	10,81	23,86	22,10	82,33
November	27,07	11,73	24,15	22,41	85,37
December	29,96	12,00	24,78	22,52	89,26

Table 6.6: Mean hours planned per day months

Month	**Mean registered hours Neuro**	**Mean registered hourss IC**	**Mean registered hours Surgery**	**Mean registered hours Intern**	**Mean registered hours Total hours**
January	21,90	7,02	15,40	18,52	62,83
February	18,43	6,13	17,71	18,75	61,02
March	22,04	4,45	16,30	20,94	63,73
April	18,63	4,11	19,00	20,83	63,38
May	20,47	4,83	18,38	18,13	60,86
June	18,41	4,97	18,63	17,82	60,06
July	19,61	4,00	16,63	17,56	56,67
August	19,75	4,85	15,32	19,39	59,01
September	18,91	4,03	17,55	17,59	58,32
October	18,09	4,51	17,49	17,29	57,68
November	18,46	5,97	16,46	19,43	60,96
December	21,09	7,58	13,65	19,16	61,49

Table 6.7: Mean hours registered per day months

6.6 Scenario analysis Elisabeth Hospital

As mentioned, with the current static planning, the utilization differs between clusters over time at the EZ, meaning an unequal workload in the basic planning before the intervention. In order to improve the current static planning, different scenarios are tested on the data of 2021 and 2022; how many hours should have been planned to equalize the utilization between the clusters over different time frames? The four scenarios that have been tested for the EZ can be found in Table 6.8.

Scenario	Explanation
1. Moving hours IC to Intern	This scenario shows what happens when a fixed number of hours would have been moved from the IC cluster to Intern
2. Current basic planning	This scenario shows how the current basic planning would have been performed when it was followed over the historical data and how it could be better.
3. Equalizing utilization over Months	This scenario shows how many hours per day (differing per month) are needed to have all clusters have the same utilization over all the months.
4. Equalizing utilization over Weekdays	Does the same as scenario 3 on weekday level instead of monthly level, thus months are set fixed and hours per cluster can change between weekdays.

Table 6.8: Scenarios Elisabeth

6.6.1 Moving hours between IC and Intern

For the first scenario, all days will be increased or decreased with the same number of hours per day for 2022. Data is available from august 2021, however since 2022 is a more representable year, the last months of 2021 are neglected. Only the IC and intern clusters are considered in this scenario since those have a deviated utilization rate. Table 6.9 shows what happens when the same number of hours are changed daily. Planning until three hours per day extra for intern and one less for IC would have proven the utilization of both clusters without worsening the total times exceeding 100%. The mean utilization rate is almost equal when four hours of resources are moved from IC to intern each day. However, in this scenario, the times exceeding the 100% have increased which also indicates a more often wrong allocation of resources.

Hours switched from IC to Intern	Utilization IC	# times exceeding 100%	Utilization Intern	# times exceeding 100%
0	45,4%	0	83,7%	49
1	50%	0	80,1%	35
2	55,6%	3	76,7%	24
3	62,8%	16	73,7%	17
4	72,4%	46	70,9%	12

Table 6.9: Fixed hours from IC to intern (Aug 2021-Dec 2022)

To further evaluate the fixed moving hours per day, Table 6.11 and Table 6.10 show what happens with the mean monthly utilization and mean weekday utilization when changing hours from IC to Intern. When checking the months, the four hours strategy creates some high peaks in utilization rates, indicating a sub-optimal solution. However, when checking the mean utilization per month for the different strategies, some months have very equalized utilization rates without having very high peaking utilization rates. Since it is important to reduce the times exceeding 100% utilization, a mean utilization below 80% is used as a criterion in evaluating the best strategy per month. For this scenario, the overall utilization targets levels are unimportant since the scenario assumed to keep the overall planned hours, and thus the overall utilization, the same. To optimize the 4 hours strategy, combining the strategy with the 3 hours strategy is more appropriate based on the mentioned goals of equalizing utilization and trying to keep utilization below 80% results in the combination; using the 3-hour strategy for January, February, June, and November, and December. Resulting in the mean utilization rates per month mentioned in Table 6.12. Evaluating this monthly changing fixed hours per day on the weekday level, the same criteria of staying below the 80% and trying to have a more equalized utilization level between the clusters is met, as shown in Table 6.13.

Month	IC 0 hours	Intern 0 hours	IC 1 hour	Intern 1 hour	IC 2 hours	Intern 2 hours	IC 3 hours	Intern 3 hours	IC 4 hours	Intern 4 hours
January	58,5%	82,1%	63,8%	78,5%	70,2%	75,3%	78,0%	72,4%	87,7%	69,6%
February	53,1%	83,3%	58,3%	79,7%	64,6%	76,5%	72,5%	73,4%	82,9%	70,7%
March	38,2%	90,9%	41,9%	87,1%	46,4%	83,6%	52,1%	80,4%	59,5%	77,4%
April	41,2%	92,7%	46,0%	88,8%	52,2%	85,1%	60,4%	81,7%	72,1%	78,6%
May	44,4%	82,4%	49,1%	78,7%	54,9%	75,4%	62,3%	72,4%	72,4%	69,6%
June	48,1%	80,1%	53,5%	76,6%	60,4%	73,4%	69,5%	70,5%	82,1%	67,8%
July	37,8%	77,4%	41,9%	74,1%	47,1%	71,1%	53,9%	68,3%	63,3%	65,7%
August	27,0%	84,5%	29,9%	80,6%	33,5%	77,1%	38,2%	73,9%	44,7%	71,0%
September	26,9%	65,8%	30,0%	63,1%	33,9%	60,6%	39,1%	58,3%	46,3%	56,2%
October	33,5%	72,4%	37,7%	69,4%	43,0%	66,5%	50,3%	63,9%	60,8%	61,5%
November	51,9%	74,5%	57,7%	71,5%	65,1%	68,7%	74,8%	66,0%	88,4%	63,6%
December	39,6%	86,7%	43,9%	83,2%	49,3%	80,0%	56,3%	77,0%	65,8%	74,3%

Table 6.10: Mean utilization per month moving hours IC to intern

Day of week	IC 0 hours	Intern 0 hours	IC 1 hour	Intern 1 hour	IC 2 hours	Intern 2 hours	IC 3 hours	Intern 3 hours	IC 4 hours	Intern 4 hours
Monday	35,9%	80,3%	39,1%	77,0%	43,1%	74,0%	48,0%	71,1%	61,4%	68,5%
Tuesday	45,8%	80,8%	51,4%	77,4%	58,6%	74,2%	68,3%	71,3%	71,2%	68,6%
Wednesday	43,6%	78,9%	48,3%	75,6%	54,1%	72,6%	61,7%	69,8%	72,2%	67,2%
Thursday	39,4%	84,6%	43,7%	80,9%	49,1%	77,4%	56,2%	74,3%	68,6%	71,4%
Friday	42,3%	80,3%	46,5%	76,9%	51,8%	73,7%	58,4%	70,8%	70,6%	68,2%

Table 6.11: Mean utilization per weekday moving hours IC to intern

	Jan +/- 3	Feb +/- 3	Mar +/- 4	Apr +/- 4	May +/- 4	Jun +/- 3	Jul +/- 4	Aug +/- 4	Sept+/- 4	Oct+/- 4	Nov +/- 3	Dec +/- 3
Utilization IC	78,0%	72,5%	59,5%	72,1%	72,4%	69,5%	63,3%	44,7%	46,3%	60,8%	74,8%	49,3%
Utilization Intern	72,4%	73,4%	77,4%	78,6%	69,6%	70,5%	65,7%	71%	56,2%	61,5%	66%	77%
Current IC	58,5%	53,5%	38,2%	41,2%	44,4%	48,1 %	37,8%	27,0%	26,9%	33,5%	51,9%	39,6%
Current Intern 82,1%	83,3%	90,9%	92,7%	82,4%	80,1%	77,4%	84,5%	65,8%	72,4%	4,5%	86,7%	

Table 6.12: Combining strategies month level

	Mean utilization IC	Mean utilization Intern
Monday	59,1%	71,1%
Tuesday	79,7%	71,5%
Wednesday	67,3%	71,4%
Thursday	63,9%	74,1%
Friday	66,1%	73,2%
Total mean	67,4%	72,3%

Table 6.13: Evaluation in mean utilization for the monthly changing strategy

Thus, for the period August 2021 till November 2022, combining a daily fixed 3 and 4 hours movement from IC to intern, would have improved the equalization of the utilization. Also, it reduced the times exceeding 100% which means fewer daily switches between those clusters.

The fixed-hours strategies can also be evaluated and improved on a weekday level instead of a monthly level. The resulting utilization per day when moving a fixed amount of hours from IC to Intern per weekday is given in Table 6.14. When using the same criteria as for the monthly level mean utilization, On the weekday level (equalizing the utilization between the clusters and staying below the 80% utilization), moving four hours, thus a half day part, from IC to Intern, would work well on all days, except for Tuesday. For Tuesday a change of three hours would fit better since the utilization rates are more equalized and the utilization of IC remains below 80%. Table 6.14 shows the mean utilization rates per weekday when three hours are moved from IC to intern each Tuesday and four hours on all other days. Comparing the utilization's equalization on the weekday level between Table 6.14 and Table 6.13, the planning seems to be improved. However, as illustrated in Table 6.15, the times exceeding 100% have increased, therefore more often therapists had to help between clusters than in the current situation. Thus, making a distinction only on the weekday level is not preferred.

Day of week	utilization IC	Utilization Intern
Monday +/- 4	62,5%	70,0%
Tuesday +/- 3	71,2%	73,1%
Wednesday +/- 4	72,2%	70,0%
Thursday +/- 4	68,6%	72,5%
Friday +/- 4	70,6%	71,9%

Table 6.14: Combining strategies weekday level

Month	Utilization IC	Utilization Intern
January	85,8%	70,1%
February	81,3%	71,2%
March	56,7%	78,1%
April	67,7%	79,3%
May	67,6%	70,4%
June	77,3%	68,3%
July	59,2%	66,3%
August	41,9%	71,6%
September	44,5%	56,5%
October	58,6%	62,0%
November	86,8%	64,1%
December	64,0%	74,8%

Table 6.15: Evaluation in mean utilization for the weekday changing strategy

To not integrate too much complexity and the lack of data, including different weekday strategies in different months is not further investigated.

6.6.2 Current basic planning

In this section, this division in hours of the current basic planning is tested over the registered hours in 2021 and 2022. What if this planning would have been perfectly followed? In Table 6.16 the concerned hours per day per cluster are presented.

Cluster	Monday	Tuesday	Wednesday	Thursday	Friday
Neuro	28	28	28	28	28
IC	12	12	12	12	12
Surgery	24	28	26	28	28
Intern	24	24	24	24	24

Table 6.16: Hours per day basic planning

The mean utilization of this basic planning can be found in Table 6.17. For 2022, the current basic planning is better equalized for Neuro, surgery and Intern and worse for IC, than in 2021. This can be explained by the higher demand for IC during Covid. Therefore, 2022 is a more representable year for evaluating the basic planning. The current basic planning seems to be in general giving a very low utilization rate for the IC cluster, indicating that too many hours are planned for the IC. On the other side, Intern still has higher utilization than the other clusters, however, the difference is smaller than in the current realized planning.

Mean utilization	Neuro	IC	Surgery	Intern	total	# >100%
2021-2022	71,3%	50,2%	62,6%	83,9%	69,5%	88
2021	74,0%	63,2%	57,4%	91,2%	72,5%	72
2022	68,6%	37,2%	67,8%	76,5%	66,6%	16

Table 6.17: Utilization evaluation current basic planning

Day of the week	Utilization Neuro	Utilization IC	Utilization Surgery	Utilization Intern
Monday	70,9%	35,8%	75,9%	79,4%
Tuesday	72,1%	36,7%	62,2%	77,3%
Wednesday	68,1%	39,2%	69,5%	74,9%
Thursday	69,7%	34,7%	58,7%	77,8%
Friday	62,1%	39,7%	73,0%	73,5%
Month				
January	78,2%	58,5%	60,0%	77,1%
February	65,8%	51,1%	68,4%	78,1%
March	78,7%	37,1%	62,4%	87,3%
April	66,5%	34,3%	73,6%	86,8%
May	73,1%	40,3%	71,5%	75,5%
June	65,8%	41,4%	71,8%	75,0%
July	70,0%	33,3%	64,7%	73,9%
August	69,2%	24,1%	53,7%	74,1%
September	57,4%	22,9%	73,8%	64,4%
October	63,8%	26,4%	73,0%	69,4%
November	68,2%	44,5%	70,8%	72,1%
December	65,4%	35,3%	72,5%	85,4%

Table 6.18: Utilization weekday & month current basic planning

In Table 6.18 the utilization rates of the current basic planning on month and weekday level are given as well. In general, IC has a very low utilization for all months and weekdays, whereas, intern shows some obvious peaks in comparison to the other clusters. Since the IC cluster always has very low utilization, a scenario in which hours from IC are moved somewhere else. Since it is practical to work in either 4, 6, or 8 hours shifts, the most obvious tryout is to move a 4-hour day part from IC to the Intern. The results of this 4 hours a day change can be found in Table 6.19. The utilizations are closer to each other, both over the weekdays as well as between months. Only for January changing a whole 4-hour block seem to be too much as the mean utilization increases to 87,7%. Furthermore, for the months of August, September, and October the utilization rates would still have been very low. However, for those months all utilization's are low, indicating that too many hours were planned in general. For January, a better equalization could be generated from planning 2 hours less for IC and surgery, and planning 4 hours extra for intern per day (in comparison to the basic planning shown in Table 6.16). resulting in utilization rates: 78,2%, 70,2%, 62,8% and 66,1% for Neuro, IC, Surgery, and Intern in January respectively. To further equalize the utilization the next section will provide a calculation to determine the required planned hours with different target utilization levels.

	Utilization Neuro	Utilization IC	Utilization Surgery	Utilization Intern
Monday	70,9%	53,7%	75,9%	68,0%
Tuesday	72,1%	55,0%	62,2%	66,3%
Wednesday	68,1%	58,7%	69,5%	64,2%
Thursday	69,7%	52,0%	58,7%	66,6%
Friday	62,1%	59,6%	73,0%	63,0%
January	78,2%	87,7%	60,0%	66,1%
February	65,8%	76,7%	68,4%	67,0%
March	78,7%	55,6%	62,4%	74,8%
April	66,5%	51,4%	73,6%	74,4%
May	73,1%	60,4%	71,5%	64,7%
June	65,8%	62,1%	71,8%	64,3%
July	70,0%	50,0%	64,7%	63,4%
August	69,2%	36,1%	53,7%	63,5%
September	57,4%	34,3%	73,8%	55,2%
October	63,8%	39,6%	73,0%	59,5%
November	68,2%	66,8%	70,8%	61,8%
December	65,4%	52,9%	72,5%	73,2%

Table 6.19: Utilization weekday & month current basic planning

6.6.3 Fixed planned hours per weekday

As found in section 6.5, weekdays have different mean hours of registered care, therefore hours planned should differ as well. In order to equalize all weekdays, the mean total utilization of 70,7% (for August 2021-December 2022) has been taken as a guideline. As a result of taking this guideline, the total number of employees' hours would almost be the same. To calculate the necessary hours the following formula is used (rounding to whole hours):

$$Plannedhours = \frac{Hoursregistered}{targetutilization(70,7\%)}$$

This results in the planned number of hours per weekday per cluster shown in Table 6.20. Overall, the current basic planning involves more planned hours per weekday than the hours necessary to get the equalized utilization of 70,7% on the weekday level.

Day of the week	Hours Neuro	Hours IC	Hours Surgery	Hours Intern	Difference with current basic planning
Monday	28	6	26	27	-1
Tuesday	29	6	25	26	-6
Wednesday	27	7	26	25	-5
Thursday	28	6	23	26	-9
Friday	25	7	25	25	-10

Table 6.20: Optimal mean planned hours per weekday 70,7% utilization

Earlier in the research, a suggestion for a desired utilization of 75% or 80% is mentioned since all the above utilizations already exclude some of not directly patient-related activities. The 75% sounds more realistic in comparison with the current mean utilization of 70,3% for Augustus 2021 till 2022 and the 73,1% for 2022. Also to cope with uncertainties of absentees 75% is safer. The results of how many hours are necessary on a weekday basis to equalize the utilization between clusters on a weekday level are given in Table 6.21.

Day of the week	Hours Neuro	Hours IC	Hours Surgery	Hours Intern	Difference with current basic planning
Monday	26	6	24	25	-7
Tuesday	27	6	23	25	-11
Wednesday	26	6	24	24	-10
Thursday	26	6	22	25	-13
Friday	23	6	23	24	-16

Table 6.21: Optimal mean planned hours per weekday 75% utilization

To evaluate both the target utilization rate, the utilization rate over the months and weekdays are presented in Table 6.22 and Table 6.23. In general, the target utilization of 75% shows an increase in the total times exceeding 100% utilization (55 compared to 49 times), which is not preferred. Considering the fact that the scenario is optimized on a weekday basis, those values are all around the target utilization level. Furthermore, in both scenarios some big peaks in utilization rates can be found. For IC, January, February, and November show a clearly higher utilization than desired, and August, September, and October have a lower value. Therefore both suggested hours per weekday do not work well for those months. However, since both scenarios have hours left to plan, those months can have extra hours allocated for IC.

	Neuro	IC	Surgery	Intern
January	79,9%	110,0%	61,6%	71,6%
February	67,0%	95,9%	70,9%	72,6%
March	80,2%	69,9%	65,5%	81,2%
April	68,3%	64,1%	76,3%	81,0%
May	74,5%	75,5%	72,8%	70,1%
June	67,0%	77,4%	74,8%	70,0%
July	71,9%	62,9%	66,5%	68,9%
August	70,7%	45,1%	55,2%	68,8%
September	58,8%	42,7%	76,4%	60,1%
October	65,3%	49,7%	75,0%	64,4%
November	69,6%	83,9%	73,3%	67,2%
December	67,3%	65,9%	75,4%	79,6%
Monday	70,9%	71,7%	70,1%	70,5%
Tuesday	69,6%	73,4%	69,6%	71,4%
Wednesday	70,7%	67,1%	69,5%	71,9%
Thursday	69,7%	69,3%	71,4%	71,8%
Friday	69,6%	68,1%	70,1%	70,5%
Total times >100%	3	29	0	4

Table 6.22: Utilization level weekday strategy with target utilization of 70,7%

	Neuro	IC	Surgery	Intern
January	85,6%	116,9%	66,3%	75,2%
February	71,8%	102,2%	76,4%	76,2%
March	85,7%	74,2%	70,4%	85,1%
April	73,3%	68,6%	82,2%	84,8%
May	79,8%	80,6%	78,7%	73,7%
June	71,5%	82,8%	80,4%	73,3%
July	77,1%	66,7%	71,7%	72,2%
August	75,6%	48,2%	59,5%	72,2%
September	63,0%	45,7%	82,3%	62,9%
October	69,9%	52,8%	80,9%	67,7%
November	74,4%	89,0%	78,9%	70,4%
December	72,1%	70,5%	81,2%	83,3%
Monday	76,3%	71,7%	75,9%	76,2%
Tuesday	74,8%	73,4%	75,7%	74,2%
Wednesday	73,4%	78,3%	75,3%	74,9%
Thursday	75,1%	69,3%	74,7%	74,6%
Friday	75,6%	79,4%	76,2%	73,5%
Total times >100%	9	42	4	8

Table 6.23: Utilization level weekday strategy with target utilization of 75%

6.6.4 Changing all months the same

As reported in the previous section, optimizing on weekdays gives non-preferred outcomes for the utilization for some of the months. For this reason, the calculation for the mean optimal hours is also made on a monthly level. This means that for this scenario, all weekdays are treated the same and hours per day per cluster differ between months. In this scenario, the same formula has been used to calculate the necessary hours per day per cluster over the months of the year (2022). Both the 70,7% and 75% utilization have been used as well. Table 6.26 and Table 6.27 show the resulting hours per day per cluster for the two different utilization rates. Again, for both scenarios fewer hours per day are needed to achieve the target utilizations than the current basic planning. To evaluate those clusters, again the utilization per weekday and over the months are analyzed, as found in Table 6.24 and Table 6.25.

	Neuro	IC	Surgery	Intern
January	70,6%	70,3%	69,6%	71,1%
February	70,9%	69,5%	71,1%	69,0%
March	71,1%	74,2%	70,3%	69,9%
April	71,7%	68,6%	70,4%	71,8%
May	71,3%	69,0%	70,7%	70,0%
June	70,8%	71,6%	71,9%	72,0%
July	70,0%	66,7%	69,3%	71,0%
August	71,7%	72,3%	69,3%	71,1%
September	69,9%	68,6%	70,6%	70,2%
October	71,5%	79,2%	69,7%	69,4%
November	70,7%	66,8%	70,5%	72,1%
December	70,5%	70,5%	72,2%	70,7%
Monday	73,1%	68,7%	73,6%	73,5%
Tuesday	74,5%	68,9%	70,0%	71,3%
Wednesday	70,2%	74,3%	72,7%	69,3%
Thursday	72,4%	65,6%	65,8%	71,6%
Friday	64,5%	75,4%	70,1%	68,0%
Total times >100%	1	10	0	0

Table 6.24: Utilization level weekday strategy with target utilizaiton of 70,7%

	Neuro	IC	Surgery	Intern
January	75,5%	78,2%	72,9%	74,1%
February	73,7%	77,7%	74,1%	74,5%
March	76,0%	74,2%	73,6%	74,8%
April	74,5%	68,6%	76,0%	74,4%
May	76,4%	79,2%	73,5%	75,5%
June	73,7%	72,5%	75,0%	75,0%
July	75,4%	80,0%	75,6%	73,9%
August	74,5%	72,3%	72,9%	74,1%
September	76,6%	68,6%	76,2%	73,6%
October	74,4%	79,2%	75,2%	75,8%
November	73,4%	76,3%	76,4%	75,3%
December	76,3%	70,5%	75,1%	75,9%
Monday	77,3%	72,9%	78,0%	77,8%
Tuesday	78,8%	73,0%	74,2%	75,4%
Wednesday	74,2%	78,4%	77,1%	73,3%
Thursday	76,7%	69,3%	69,9%	75,6%
Friday	68,3%	79,9%	74,4%	71,8%
Total times >100%	3	21	0	2

Table 6.25: Utilization level weekday strategy with target utilizaiton of 75%

Now, the utilization rates of the months are around the target utilization due to optimizing on a monthly level. However, the utilization on weekday levels is way more equalized per cluster than the monthly levels were when optimizing on the weekday level. Also, the total times exceeding the 100% utilization rate, indicating a misallocation of planned hours, is lower for the monthly changing strategy. It seems therefore more appropriate to change hours on a monthly level than on a weekday level. However, this can also be explained by the fact that on the monthly level the hours per day are changed 12 times, and for the weekday level only 5 times, for only one-year data. This can cause overfitting. For this reason, the outcomes of the monthly-based scenario have to be considered carefully.

Month	Neuro planned	IC planned	Surgery planned	Intern planned	Total planned	Difference old planned
January	31	10	22	26	-1	
February	26	9	25	27	-3	
March	31	6	23	30	0	
April	26	6	27	29	-2	
May	29	7	26	26	-2	
June	26	7	26	25	-6	
July	28	6	24	25	-7	
August	27	4	20	25	-14	
September	23	4	27	22	-14	
October	25	4	27	24	-10	
November	27	8	26	24	-5	
December	26	6	26	29	-3	

Table 6.26: Optimal mean planned hours per day per month with target utilization of 70,7%

Month	Neuro planned	IC planned	Surgery planned	Intern planned	Total planned	Difference old planned
January	29	9	21	25	-6	
February	25	8	24	25	-8	
March	29	6	22	28	-5	
April	25	6	25	28	-6	
May	27	6	25	24	-8	
June	25	7	25	24	19	
July	26	5	22	24	13	
August	26	4	19	24	17	
September	21	4	25	21	19	
October	24	4	25	22	15	
November	26	7	24	23	10	
December	24	6	25	27	8	

Table 6.27: Optimal mean planned hours per day per month with target utilization of 75%

6.7 Suggested planning

Finding the best scenario not only depends on the scenario with the best-equalized utilization rates and the lowest value for exceeding the 100%, but also on whether the hours per day can be practically implemented. Therefore, the scenarios are partly combined in this section to formalize one overall strategy.

According to the analysis section, therapists are satisfied with the clusters and keep the planning as similar as possible for clarification and continuity. For this reason, the current planning is used as a basis, and as minor changes as possible will be made to achieve improvements in the allocation of the work and, therefore, the work division. At first, it is important to consider the current lengths of the shifts, whereafter decisions for changes based on the scenarios are suggested. For the Neuro cluster the current shifts are 3,5 full day shifts (3 * 8 hours and 1 * 4 hours). As shown in the evaluation of the current basic planning, overall, this planning works well. However, on average, Friday can have fewer hours allocated. A possible suggestion to reduce the hours on Friday within the Neuro clusters is to have one person work a 4x9 schedule (instead of 4x8 and 1x4 hours). To achieve this within the Neuro cluster a suggestion is made to have one person work a 4x9 schedule. The results of the utilization can be found in Table 6.28. Over 2022, the utilization only 3 times exceeded the 100% utilization.

The current schedule for IC consists of one employee working an 8-hour shift and one employee working a 4-hour shift. The main conclusion from the scenarios is that the IC cluster does not need this many hours per day. Furthermore, an indication of a declining demand pattern is shown in the registered hours care over 2021 and 2022 (Figure 6.3) as well as the utilization rates in all scenarios. However, those higher peaks in January and February could be caused by Covid effects. The suggestion for IC is the plan one 8-hour shift per day. The first scenario shows a better equalization when changing four hours from IC to intern, and for the monthly and weekday calculation, almost all values required are below the eight hours. The last reason indicates that for some moments, a value below eight hours is more appropriate, however planning a therapist for a full daily shift is preferred. Besides, always including an 8-hour shift makes the planning simplistic. When using the suggestion, for 2022, the times exceeding 100% have been only 7 times. The results can be found in Table 6.28.

Thirdly the planning of the surgery has been investigated in more detail. The basic planning consists of two full 8-hour shifts for all days. Then, for Mondays also, two half-day shifts (4 hours) are planned. For Wednesday and Friday also, one 4-hour and one 6-hour shift are planned. For Tuesday, two 6-hour shifts extra, and for Thursday, three 4-hour shifts. Resulting in the total hours of 24, 28, 26, 28, and 28 per day as mentioned in Table 6.16. From the evaluation of the current performance, the overall mean utilization of the Surgery cluster is 69%. Furthermore, Thursdays show in general, a lower utilization, indicating that fewer therapists are necessary on those days, whereas Mondays show the highest utilization. To equalize the utilization over the weeks, a suggestion of moving a 4-hour shift from Thursday to Monday is suggested, resulting in the utilization rates shown in Table 6.28. The total times exceeding 100% is 0 times, indicating that this schedule would have resulted in never having too few therapists.

Lastly, the Intern cluster has a generally higher utilization rate compared to the other clusters. Since the 4-hour shift of the IC cluster is still left over, this shift can be added to the intern cluster every day. Resulting in having three 8-hour shifts and one 4-hour shift per day. With this strategy, the times of exceeding the 100% utilization in 2022 would have been once. Table 6.28 shows the results of the utilization rates over the months and weekdays.

	Neuro	IC	Surgery	Intern	Total
Mean utilization 2022	68,75%	55,86%	65,52%	65,59%	65,97%
January	78,2%	87,7%	57,4%	66,1%	69,9%
February	65,7%	76,7%	66,3%	67,0%	67,5%
March	78,4%	55,6%	61,4%	74,8%	70,3%
April	67,4%	51,4%	70,9%	74,4%	69,8%
May	73,3%	60,4%	67,7%	64,7%	67,8%
June	65,3%	62,1%	70,3%	64,3%	66,5%
July	70,8%	50,0%	62,0%	63,4%	64,3%
August	69,3%	36,1%	51,6%	63,5%	59,3%
September	57,7%	34,3%	71,5%	55,2%	59,4%
October	64,0%	39,6%	70,1%	59,5%	62,4%
November	68,1%	66,8%	68,6%	61,8%	66,9%
December	66,3%	52,9%	70,4%	73,2%	68,6%
Monday	68,4%	53,7%	65,1%	68,0%	66,4%
Tuesday	69,6%	55,0%	62,2%	66,3%	65,9%
Wednesday	65,8%	58,7%	69,5%	64,2%	65,9%
Thursday	67,3%	52,0%	68,4%	66,6%	66,4%
Friday	72,5%	59,6%	62,6%	63,0%	65,3%
Total times >100%	3	7	0	1	11

Table 6.28: Utilization suggested basic planning

To validate the suggested division in planned hours, the division of the hours of the basic planning and the suggested planning is shown in Figure 6.6. When comparing this with the division of registered hours in 2022 as illustrated in Figure 6.6. The division of total hours of care is more comparable with the division of the suggested planned hours per cluster than with the current basic planning. For the IC cluster, the difference between the registered and planned was 5% for the current basic planning, and is only 1% for the suggested planning. Also, the difference for Intern was 4 % and is in the suggested planning 1%, indicating a better overall allocation of planned hours.

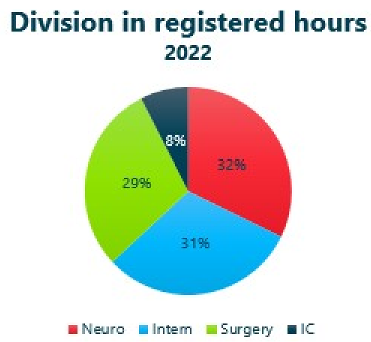

Figure 6.6: Cluster distribution Elisabeth based on registered time

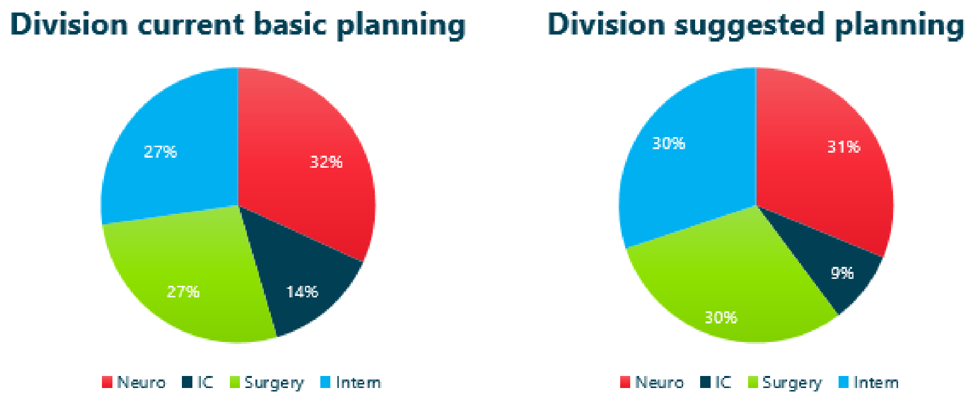

Figure 6.7: Division hours planned basic & suggested (EZ)

In general, the above strategy per cluster is a basis for the weekdays, however when going into more detail in the months, for some months fewer hours are required and more therapists can go on a holiday break or work extra on Projects. To cope with planned absences, the department has flexible workers. Therefore it is easier to meet the suggested hours. Furthermore, when applying extra time for projects, the utilization rates can also help to choose which days fit best. For example, for surgery Tuesdays and Friday the utilization rate is lower, making it easier to plan other things as well.

6.8 Relation operations and registered care Orthopedic department TZ

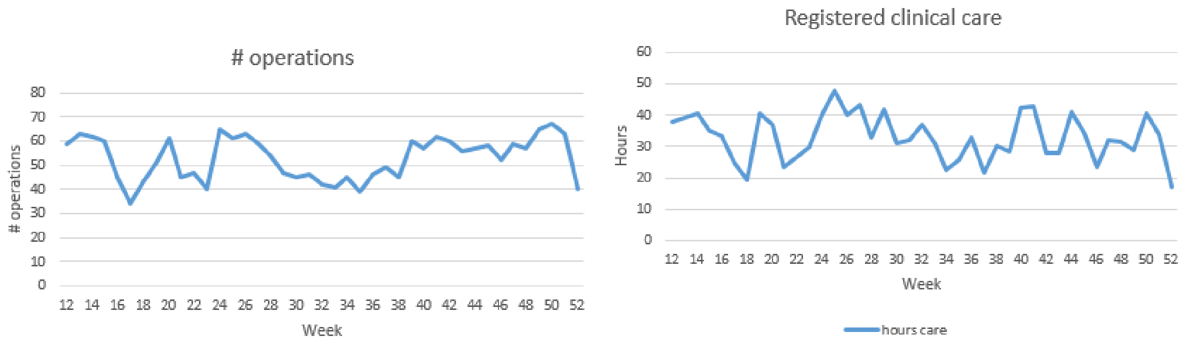

Figure 6.8: Operations versus registered care orthopedics department in normal weeks