

Balancing Satisfaction and Efficiency

Designing a New Physician Scheduling Approach for a Pediatric Cardiology Department at a Dutch Children's Hospital

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Balancing Satisfaction and Efficiency

Designing a New Physician Scheduling
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Department at a Dutch Children's Hospital

by

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Cover: Close up of medic pointing at tablet screen by Freepik

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*Ilja van der Heide
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Executive summary

Physician scheduling is a challenge faced by hospitals worldwide. The pediatric cardiology department in a children's hospital in the Netherlands also faces physician dissatisfaction due to the work schedule. Therefore, the aim of this study is to develop a new scheduling approach to address the scheduling problem in this department. Existing literature on physician scheduling revealed that this is a common problem and that mathematical optimization models are the most commonly used approach to address it. However, the biggest limitation of this approach is its practical implementation. These models often fail to capture the complexity of real hospital environments, making it difficult to apply them in practice. To address this limitation, a socio-technical approach was adopted to incorporate these social factors into a practical scheduling solution. The literature review revealed that limited research has been conducted on the use of a design science approach in physician scheduling. Therefore, this study answered the following main research question: *How can a design science approach contribute to balancing physician satisfaction and institutional efficiency in cardiologist scheduling?*

First of all, factors contributing to a satisfying schedule were identified from the literature. These factors were used as design criteria in the development of the prototypes. The design criteria are as follows: fairness, job rotation, predictability, consistency, flexibility, transparency, rest and recovery, professional development, and hospital regulations and policies. During this process, a key finding emerged: a big challenge organizations face is balancing organizational efficiency with employee satisfaction.

Subsequently, the study examined how physician scheduling is managed in practice. Exploratory conversations with the cardiologists and observations resulted in an extensive list of the different tasks performed by the cardiologists. This revealed that clinical tasks are perceived as more demanding than non-clinical tasks. This observation resulted in an initial identification of the problem: tasks are not distributed fairly among the cardiologists. Individuals with a higher number of clinical tasks perceive the schedule as unfair. However, after conducting a process and context analysis, the problem within the department appeared to be broader than initially assumed. These analyses showed that the problem can be described as a process inefficiency problem, an **organizational culture problem**, and a **scheduling related problem**. As process inefficiencies do not directly impact physician satisfaction, it was decided to only focus on organizational culture and scheduling related issues. Scheduling related problems are a broad concept. In this study they mainly consist of overly tight schedules, inaccurate estimations of the time required for tasks, and a huge administrative burden. The aim of the final design is to address both of these identified problems.

The final design was developed based on insights gathered during the emphasize and define phases and through user feedback on the prototypes. The first part of the final design is the 8-hour outpatient clinic blocks and the second part is the point system:

1. **8-hour outpatient clinic blocks:** Specialized outpatient clinics will be done in blocks of eight hours, including administration time.
2. **Point system:** Clinical tasks will be assigned points. Each cardiologist is required to reach a specified number of points every three months. This number is based on their profile. Additionally, extra points can be received by working extra shifts. Extra points can, in turn, be traded for a day off or a Niet-patiëntgebonden tijd (NPGT) day.

The first part of the final design, 8-hour outpatient clinic blocks, is presented in Figure 1 and the second part of the final design, the point system, is presented in Figure 2.

This design satisfies almost all design criteria and problem aspects. However, there are two limitations to the final design. The first limitation is the reduction of clinical production with the 8-hour outpatient clinic blocks. This is compensated by only applying this approach to the specialized outpatient clinics. In addition, calculations indicate that implementing the final design while maintaining the same level of clinical production would require an additional 0.43 FTE. Hiring one additional cardiologist is therefore

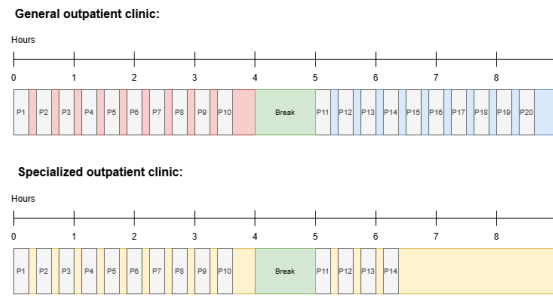


Figure 1: 8-hour blocks

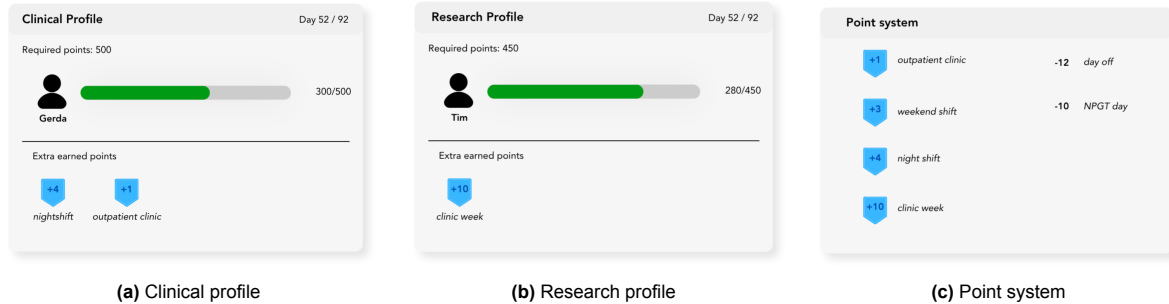


Figure 2: Point system

recommended. The second limitation is the implementation of the point system, which is complex and time-consuming. This is a complex process which requires clear arrangements with the team first.

The socio-technical approach used in this study moved the focus from operational efficiency to physician satisfaction. However, some of the studies that used mathematical optimization tried to incorporate social factors. The difference with this approach is that usable prototypes were developed that address the department's unique problems. Extensive stakeholder interaction contributed to balancing organizational efficiency with physician satisfaction. Furthermore, the iterative process of the design science process resulted in a final design that was constantly refined based on user input. Despite the fact that the socio-technical approach contributed to balancing institutional efficiency and physician satisfaction, this remained a challenge in the study.

However, this study did provide some key-takeaways about physician scheduling:

- Physician scheduling problems are often seen as fairness or distribution issues, but in reality they may be related to broader factors. Therefore, changing the schedule alone may not be sufficient to address physician satisfaction, the underlying problems need to be addressed as well.
- A good schedule can distribute work more fairly, but it cannot solve a structural lack of capacity. If there is more work than available time, even the best designed schedule will involve a trade-off between physician satisfaction and institutional efficiency, rather than improving both.

The key limitations of this study were related to the semi-structured interviews. Not all cardiologists were interviewed and there exists a risk of researcher bias while analyzing the data collected from the interviews. Furthermore, the prototypes and final design developed in this study were not tested in practice. The test phase consisted of user feedback. The fact that the feedback was provided by cardiologists only is another limitation.

Recommendations for future research are implementing and evaluating the final design within the department, using this research approach in other hospitals or other high pressure environments, and further developing the point system into a fully operational system.

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Acronyms

- AIOS** Arts in Opleiding tot Specialist. 20, 23
- BPMN** Business Process Model and Notation. 6, 10, 29, 30, 36
- CoSEM** Complex Systems Engineering and Management. 1, 5, 6
- FTE** Full-Time Equivalent. 12, 49, 51, 53, 95
- HC** Heart Catheterization. 20, 25, 28, 34, 81
- HIS** Hospital Information System. 29
- HREC** Human Research Ethic Committee. 12
- HTx** Heart Transplantation. 20
- ICM** Integrated Capacity Management. 17, 18, 51, 56, 57
- NPGT** Niet-patiëntgebonden tijd. ii, 24, 42–45, 48, 49, 53, 60
- POS** Post-Operative Screening. 20
- SSM** Soft Systems Methodology. 6, 10, 11, 55, 58, 73

Introduction

This chapter first discusses the physician scheduling problem, followed by the scientific knowledge gap. Based on these, the research objectives and the main research question are presented. Furthermore, the relevance to Complex Systems Engineering and Management (CoSEM) is clarified. This chapter concludes with an overview of the structure of this thesis.

1.1. The physician scheduling problem

Hospitals play a vital role in society, as they are responsible for maintaining and improving public health. To fulfill this responsibility, they are required to provide continuous care to their patients, which means that physicians must be available at all times (Gross, 2018). To ensure this, hospitals must consistently develop duty rosters for their staff. The quality of these schedules is crucial for maintaining the quality of care (Bruni & Detti, 2014; Cheang et al., 2003). However, the development of duty rosters for physicians is a complex process (Abdalkareem et al., 2021). This complexity is caused by several factors. First of all, physicians are highly specialized resources (Erhard et al., 2018; Santos & Eriksson, 2014). Due to their high level of specialization, some tasks can only be carried out by specific physicians. Furthermore, physicians perform a wide range of tasks (Moy et al., 2020; Santos & Eriksson, 2014). In addition to clinical tasks, physicians also have to perform non-clinical tasks such as education, research, professional development and administration (Moy et al., 2020; Nohara et al., 2014). There is insufficient time in a workweek to complete all of these tasks. Another factor that makes physician scheduling complex is that physicians often have different types of employment contracts (Abdullah et al., 2024; Erhard et al., 2018; Santos & Eriksson, 2014). The workforce typically includes both residents and specialists, with some working full-time and others part-time (Erhard et al., 2018; Kraul et al., 2024). The diversity of working hours and medical specialties complicate the process of creating a physician schedule. The variation in demand for care is also an important factor (Erhard et al., 2018), as demand is often highly unpredictable. Beside these factors, scheduling is also influenced by various constraints, such as labor regulations (Kraul et al., 2024), and by physician preferences, such as days off (Abdalkareem et al., 2021).

Scheduling problems also occur in many other commercial sectors. However, what makes this issue particularly complex in the medical sector is the need for around-the-clock service, the highly specialized work, and the frequent last-minute schedule changes caused by unexpected emergencies (Erhard et al., 2018). Furthermore, physicians experience unique and compounding pressures that distinguish their work from other professions (Schaepe et al., 2025), such as office-based jobs. In addition to working longer hours on average, physicians must make life-or-death decisions and carry a heavy emotional burden (Schaepe et al., 2025). In the literature, this problem is also known as the physician scheduling problem or the physician rostering problem.

As mentioned above, the quality of physician schedules is crucial for maintaining the quality of care (Erhard et al., 2018). According to Erhard et al. (2018), high-quality schedules meet many of the physician's preferences, such as workload, shift timing, shift order, and the distribution of different tasks among colleagues. Creating high-quality schedules affects physicians in several ways:

- **Increased productivity:** Accounting for a higher number of physician preferences in scheduling leads to an increased satisfaction Erhard et al. (2018). Therefore, good physician scheduling improves job satisfaction, leading to higher motivation levels and increased productivity.

- **Reduced burnout rates:** Inefficient distribution of physician workload can increase work pressure, which can lead to burnout symptoms (Patel et al., 2019). This negatively affects physician well-being and may contribute to depression, poor self-care, and addictive behaviors (West et al., 2018). Therefore, satisfying work schedules lead to a reduced burnout rate among physicians.
- **Better work-life balance:** Inefficient physician schedules can result in a disrupted work-life balance. This means that physicians are unable to adequately balance their family and work responsibilities. As a consequence, they may experience work-family conflict, increased job dissatisfaction, lower job performance and higher stress levels. (Korucu et al., 2023). These consequences can negatively impact physicians' job performance.
- **Less medical errors:** Inefficient work schedules can result in sleep deprivation. According to Booker et al. (2024), staff who experience fatigue and sleep deprivation are much more likely to make medical errors. This study also indicates that efficient scheduling improves safety on the work floor. Moreover, 13% of all workplace accidents can be attributed to sleep problems among employees (Booker et al., 2024).

These examples suggest that poor schedules are associated with reduced physician satisfaction. Because physicians are the most costly and scarce hospital staff, they require careful management. In order to maintain the stability of staffing, it is highly important to ensure physician job satisfaction (Korucu et al., 2023). Furthermore, studies show that reduced physician satisfaction leads to a lower quality of care (Gendreau et al., 2007).

1.2. Problem statement

The Department of Pediatric Cardiology at a children's hospital in the Netherlands is no exception and also faces physician scheduling problems. Currently, there are 11 cardiologists working in this department, each with their own specialization, such as cardiac catheterization, heart failure, rhythm disorders, and cardiac MRI. In addition to these specializations, physicians also perform core clinical tasks and other responsibilities, such as conducting research, administrative tasks, and management tasks. Preliminary observations suggest that scheduling within the department presents challenges for cardiologists, which may contribute to dissatisfaction. One potential explanation for the complexity of the scheduling process is the large variety of tasks and responsibilities within the department. Consequently, cardiologists are dissatisfied with the existing scheduling approach and indicate a preference for an alternative approach.

Cardiologists aim for a scheduling approach that contributes to greater work satisfaction and improved well-being. However, cardiologists are not the only stakeholders contributing to this problem. A schedule that is considered satisfying by cardiologists may not align with the priorities of the hospital board. Hospital policy requires that clinical objectives must be met. These objectives can be achieved through the efficient allocation of resources, including cardiologists. Therefore, clinical objectives must also be taken into account, requiring efficient scheduling. However, a balance between these two factors needs to be found. Furthermore, cardiologists may also have different opinions on what they consider a satisfying schedule. Each individual has their own way of working most effectively. There are multiple stakeholders involved who have different perspectives on the problem, which may even conflict with one another. Thus, while it is clear that dissatisfaction with the scheduling system exists, the actual problem and the underlying causes remain unclear and require further research. That is why this research will contribute to identifying the causes of dissatisfaction within the department and, based on this, develop a new scheduling approach.

1.3. Scientific knowledge gap

As outlined in section 1.2, physicians within the pediatric cardiology department at a children's hospital in the Netherlands have expressed dissatisfaction regarding the current scheduling approach. Extensive research has already been conducted on physician scheduling. This section outlines how other studies have addressed the physician scheduling problem and compares existing studies to identify the remaining scientific knowledge gap. The goal of this literature review is to find an appropriate method to address this problem. Therefore, a focused literature search was conducted on the physician scheduling problem. An overview of the literature review process can be found in Appendix A.

The dominance of mathematical programming in medical scheduling

During the review of the literature, it became apparent that there is a substantial overlap in the methods used to address the scheduling problem. Almost every article included in this section of the review applies mathematical optimization and heuristics (Bagheri et al., 2016; Böðvarsdóttir et al., 2021; Drake, 2013; Glass & Knight, 2009; Goh et al., 2022; Knust & Xie, 2017; Maenhout & Vanhoucke, 2012; Zanda et al., 2018). Ernst et al. (2003) and Ngoo et al. (2022) conducted a literature review on the field of staff scheduling and the commonly used solution methodologies. Their research also revealed that mathematical optimization and heuristics are the most commonly used methodologies. Therefore, it is common to solve this problem through mathematical programming techniques. While this approach is very useful for addressing this complex problem, it also comes with some limitations. Due to the involvement of large and complex datasets, mathematical programming techniques are often time-consuming and computationally demanding (Bagheri et al., 2016; Maenhout & Vanhoucke, 2012; Zanda et al., 2018). Additionally, when employing the mathematical programming approach, it is necessary to incorporate constraints, such as personal preferences and skill levels. Because real-world cases are frequently over-constrained, applying this method in actual hospitals is highly challenging (Drake, 2013). It is therefore often tested on simplified datasets, called benchmark testing. Benchmark testing is a commonly used approach for optimizing schedules. Ernst et al. (2003), Glass and Knight (2009), Goh et al. (2022), Knust and Xie (2017), and Ngoo et al. (2022), also used benchmark datasets in their study and claim that the complexity and scalability of the problem make it difficult to apply to real-world data. Real world rostering problems may differ significantly from benchmark instances. There is a gap between benchmark-based research and real applications according to research by Ngoo et al. (2022). Furthermore, even if it is possible to apply it successfully in a real hospital, adopting it across multiple hospitals is challenging. According to Böðvarsdóttir et al. (2021), developing a one-size-fits-all model is very difficult.

Consequently, a significant part of the literature focuses on the mathematical programming approaches for schedule optimizing. However, research by Drake (2013) indicates that rostering is not purely a technical optimization problem, but also a social and political process. They state that there is a need for better designed roster policies at the organizational level. According to Drake (2013), too much focus is placed on computational techniques rather than the development of practical roster requirements. Furthermore, informal agreements or cultural norms can affect scheduling requirements. Political factors may also play a role; for instance, experienced physicians often receive more favorable schedules or are allowed more personal preferences (Drake, 2013). According to the research of Drake (2013), non-formalized constraints emerge, which are challenging to implement in a mathematical model. Findings from this study suggest that there is a gap between theoretical optimization and practical applicability. Therefore, this section concludes that mathematical programming techniques are not sufficient on their own for hospital scheduling, as the problem extends beyond purely mathematical considerations and includes social factors.

Social factors and qualitative research methods

This section explores existing qualitative research on the social factors involved in physician scheduling. It examines which research approaches have already been used and which have not yet been explored (or not enough). First of all, a lot of studies use mixed methods, combining qualitative and quantitative research. An example of this is the combination of a survey study with mathematical approaches (Barnes-Farrell et al., 2008; Emmanuel et al., 2023; Sullivan et al., 2022; Wynendaele et al., 2021). In order to examine the scheduling problem within the specific context of the pediatric cardiology department at the children's hospital examined in this study, a suitable method is required. A method that is suitable for this and has often been employed in previous studies is the use of interviews. Some of the studies that conducted interviews employed mixed methods, combining them with quantitative research (Drake, 2013; Ostberg et al., 2021; Rerkjirattikal et al., 2020; Thomas & P, 2025). The aim of this study is to find a way to create efficient and satisfying schedules for the cardiologists at the children's hospital. The research conducted by Rerkjirattikal et al. (2020) has a goal comparable to that of this research. The goal of their study is to develop a model for scheduling that considers individual preferences and workload fairness. In this study, interviews are combined with mathematical programming. However, the model struggles to account for the unpredictability encountered in hospitals Rerkjirattikal et al. (2020). This research aims to develop a new scheduling approach that can be practically implemented in the hospital. Therefore, a method is required that can adequately capture

the complex reality of a hospital in the solution.

Additionally, some studies focus exclusively on qualitative research in the form of interviews, sometimes combined with focus groups (Barker et al., 2025; Gerlach et al., 2025; Renggli et al., 2025). The studies that employed only interviews and/or focus groups are all very recent, dating from 2025. All of these studies focus on the social factors that contribute to higher job satisfaction among physicians. The research conducted by Gerlach et al. (2025) and Renggli et al. (2025) examined fairness, transparency, and efficiency in scheduling. Interviews and focus groups allow for the measurement of these social factors. According to the interviews conducted by Barker et al. (2025), consistent, predictable and flexible scheduling contributes to better physician well-being. Therefore, interviews and focus groups are an effective way to identify the social preferences of the physicians. However, in this study we want to take it a step further by also finding a method to create the schedule. The literature shows that interviews and focus groups provide a solid foundation. However, an additional qualitative method needs to be integrated into this approach. The studies mentioned above identify factors that contribute to a good schedule, but do not contribute to the development of a scheduling approach.

During the literature search, two studies were identified that use a design science approach (Uhde et al., 2021; Walter et al., 2024). The research by Walter et al. (2024) designed and tested an AI-supported scheduling tool that prioritizes user needs. The research of Uhde et al. (2021) also employs a design science approach, and complements it with interviews and focus groups. The researchers use the interviews and focus group to design solutions that address user needs. The design science approach that Uhde et al. (2021) used is called "design for well-being". The design approach in this study is closely connected to the daily realities of a hospital. There is limited research on physician scheduling that combines interviews and focus groups with a design approach. The study by Uhde et al. (2021) focuses specifically on self-scheduling, but it demonstrates that this is an excellent method for incorporating physician preferences into scheduling design, which can lead to a higher job satisfaction.

Additionally, research shows that the actual workload of physicians is currently often misinterpreted (Ostberg et al., 2021; Sinsky et al., 2016; Yasmine et al., 2024). An example of this misinterpretation of workload distribution is presented in a study by Sinsky et al. (2016). The study investigates tasks allocation in ambulatory care. The research shows that the actual distribution of a physicians workload in ambulatory care differs from what is expected. According to their research, physicians spend approximately half of their working time on desk-based tasks (updating electronic health records, administrative tasks etc.) and less than one third of their time in face-to-face interactions with patients (Sinsky et al., 2016). These desk-related tasks are also often completed outside of working hours. Consequently, a significant part of physicians work is considered as "invisible work". Another study that addresses the misinterpretation of workload is the work by Ostberg et al. (2021). Findings from their research indicate that clinical intensity in specialized departments can be variable and difficult to predict. According to Ostberg et al. (2021), a gap arises between what the system perceives as necessary and what is actually required in practice. This can result in an increased workload. What the studies by Sinsky et al. (2016) and Ostberg et al. (2021) have in common is that they both conclude that physician workload is often misinterpreted, which can lead to an increased work pressure. As a result, the workload demanded of physicians frequently exceeds the time they have available. This increased work pressure can result in job dissatisfaction and an increased proportion of burnout symptoms (Sinsky et al., 2016), (Ostberg et al., 2021), (Narlı & Derse, 2025). According to Sinsky et al. (2016), physician dissatisfaction is rapidly increasing due to the way their time and skills are utilized. In order to develop efficient schedules, it is essential that the physicians workload is accurately captured. Sinsky et al. (2016) captured the workload of physicians in outpatient care through a quantitative direct observational time and motion study. Similar to the study of Sinsky et al. (2016), this research aims to investigate how physicians allocate their time, to support the development of a satisfying and efficient scheduling approach. However, this study goes a step further by not only determining how time is allocated, but also actively designing a scheduling solution. While studies such as Sinsky et al. (2016) and Ostberg et al. (2021) provide valuable descriptive insights into physician workload, they do not translate these findings into concrete scheduling solutions. Therefore, this study adopts an active design approach, in which findings from interviews and observations conducted in the hospital are used to iteratively develop scheduling prototypes. Instead of only describing the problem, this study aims to develop a practical solution that connects workload analysis with scheduling practices.

Conclusions and scientific knowledge gap

The literature revealed that there are several studies that aim to create an efficient physician schedule in order to increase job satisfaction (Bagheri et al., 2016; Böðvarsdóttir et al., 2021; Goh et al., 2022; Knust & Xie, 2017; Maenhout & Vanhoucke, 2012; Narlı & Derse, 2025; Rerkjirattikal et al., 2020; Zanda et al., 2018). However, all of these studies have used mathematical models. These models are not well suited to account for the social factors present in a complex environment such as pediatric cardiology. Furthermore, there are studies that do capture the social factors through interviews (Barker et al., 2025; Gerlach et al., 2025; Ostberg et al., 2021; Thomas & P, 2025), yet they primarily describe these factors without producing an implementable scheduling solution. The insights from these studies can be used as input for the design of a new scheduling approach. There is a gap in the literature for research that captures social factors while also being able to create an efficient schedule, as is done in studies that used a mathematical programming approach. However, only one study from this literature review has used this combination (Uhde et al., 2021). Their study uses a design science approach in combination with interviews and focus groups to effectively capture social factors. However, the study of Uhde et al. (2021) focuses on a self-scheduling solution. This study aims to develop several scheduling approach prototypes to determine which best fits the hospital context. The methodology introduced by Uhde et al. (2021) is considered suitable and a similar approach is adopted in this study.

In order to summarize this and identify a clear research gap, the main conclusions from the literature review are outlined. Based on these findings, a research question can be formulated. The following conclusions emerged from the literature:

1. While there is a lot of research on mathematical models, these theories lack a connection to the complex social reality of a hospital.
2. Qualitative research that considers these social factors often stops at descriptive analysis, rather than progressing towards the development of new scheduling approaches.
3. Efficient physician scheduling starts with creating a deeper understanding of physicians actual time allocation.
4. There is limited research on the use of a design science approach in the field of physician scheduling.

These findings highlight a significant gap in the literature: while existing studies either optimize physician schedules mathematically or examine social factors qualitatively, there is a lack of integrated socio-technical approaches that use a design science approach to translate the social complexity of specialized departments into practical scheduling solutions.

1.4. Research objective and main research question

The objective of this research is to design an improved scheduling approach for the pediatric cardiology department of a children's hospital in the Netherlands. By using a socio-technical approach, this study aims to develop a new scheduling approach that captures the needs and preferences of the involved stakeholders and develop a realistic and feasible design solution. This study uses a method that has not yet been widely applied in this field. By using this approach, the study aims to contribute to the literature by accurately capturing the complexity of a real hospital environment and design new scheduling approaches which are feasible to implement in practice. In addition, this study may encourage other researcher to apply this research approach in future studies.

Based on the scientific knowledge gap, the research question is formulated as follows:

- *How can a design science approach contribute to balancing physician satisfaction and institutional efficiency in cardiologist scheduling?*

1.5. Relevance to CoSEM

The problem outlined is a typical CoSEM problem, because it concerns issues related to system design, optimization, human factors, and organizational dynamics. It involves analyzing a complex socio-technical system with interconnected components such as multiple interacting stakeholders, limited resources, and a dynamic environment. Because of this complexity, it serves as an ideal case for ex-

ploring and addressing complex systems issues, making it highly relevant for a CoSEM thesis. The problem tackles both public values, like enhancing the quality of healthcare, and private values, such as improving the working conditions for physicians. This dual impact is relevant to CoSEM's focus on balancing private and public interests.

1.6. Thesis structure

This thesis is structured as follows. The first chapter is the introduction, in which the problem is introduced, the scientific knowledge gap is provided, and the research objective, relevance, and main research question are presented. This is followed by the research methodology chapter, which elaborates on the research approach, methods, and sub-questions.

Subsequently, the third chapter presents the emphasize phase. This chapter consists of a literature review, a stakeholder analysis, an analysis of the different tasks, and an initial problem analysis. The following chapter describes the define phase, in which the problem is further analyzed using Business Process Model and Notation (BPMN) modeling and the Soft Systems Methodology (SSM).

Chapter five covers the ideate and prototype phase, in which prototypes are developed. In chapter six, the test phase, these prototypes are refined into a final design based on user feedback. Finally, the thesis concludes with the discussion and conclusion chapters.

Research methodology

This chapter discusses the research approach, the sub-questions, the research methods, including the analytical approach and the data requirements and sources, and the research flow diagram.

2.1. Research approach

The research approach that was applied to answer the research question is a design science approach. A design approach is needed when there is a gap between the current situation and a desired situation (Johannesson & Perjons, 2014). According to Teperi et al. (2020), a design approach is a structured and collaborative method for developing new solutions, understanding them, and considering their use and context. A design approach is an iterative, solution-focused, and human-centered method guided by users' needs, used to address complex or poorly defined problems (Ilhan, 2025; Teperi et al., 2020). Since this case involves a complex problem that requires a solution addressing multiple factors, including user needs, a design approach is an appropriate research method.

There are different design approaches, and the approach most appropriate for this case is design thinking. Design thinking is used to address wicked problems, with the user and their needs at the center (Groep, 2024). Addressing the scheduling problem in this case requires careful consideration of physicians' needs, as the problem would not exist otherwise. The goal of design thinking is to improve products, services and processes (IDEO, 2025). The design thinking approach consists of five phases:

- **Empathize:** In this first phase, the focus lies on user-centric research. The goal is to understand the user. (Dam, 2025). In this case, this means gaining a deep understanding of both the hospital's operational needs and the physicians' personal needs and preferences. This phase involves initial interactions with the user to gain a deeper understanding of their needs (Haddadian et al., 2019). The data that are gathered in the empathize phase was used as input of the define phase.
- **Define:** In this phase the users' needs and the problem were defined, based on the information gathered in the empathize phase (Dam, 2025). A detailed understanding of the problem was developed. Insights created in the define phase were used as input for the ideate phase.
- **Ideate:** The focus of this phase lies on generating a wide range of potential solutions to the problem statement. The goal is to generate diverse ideas, not to find the right one immediately. (Dam, 2025). In this case, multiple solution ideas were developed to address the scheduling problem at the pediatric cardiology department.
- **Prototype:** In this phase the goal is to identify the best possible solution for the problem statement. The best ideas from the ideate phase were selected and produced in a scaled down/ simplified way. These prototypes can then be tested in the next phase. (Dam, 2025). These prototypes can be anything. A few examples for this case are: a mock-up of a new software interface, a visual representation of a new scheduling template, or a draft of a new scheduling policy.
- **Test:** In the test phase of design thinking the best solutions are tested with the users (Dam, 2025). The aim of this phase is to gain a deeper understanding of the users and to adapt the prototypes as closely possible to their needs and preferences (Dam, 2025). Because design thinking is an iterative process, it is possible to loop back to previous phases and improve the solution further. In this case the prototypes were not tested in practice. Instead, the cardiologists provided feedback to the developed prototypes. This feedback can then be used to refine the solution. A more detailed explanation of this test phase is provided later in this chapter.

The different phases of design thinking can be used to formulate sub-questions. Each phase focuses on a specific aspect of the problem, helping to break it down into smaller questions.

2.2. Sub questions

Based on the chosen research approach, several sub-questions can be formulated to support and contribute to answering the main research question. Figure 2.1 illustrates how the different phases of design thinking are connected to the respective sub-questions. The following sub-questions have been formulated:

- SQ 1: *What factors contribute to an efficient and satisfying schedule?*
- SQ 2: *How is the current scheduling practice organized at the pediatric cardiology department?*
- SQ 3: *What are the underlying problems in physician scheduling in practice within the pediatric cardiology department?*
- SQ 4: *How can the current scheduling approach in the pediatric cardiology department be improved?*
- SQ 5: *How can the prototypes be refined into a final design based on user validation?*

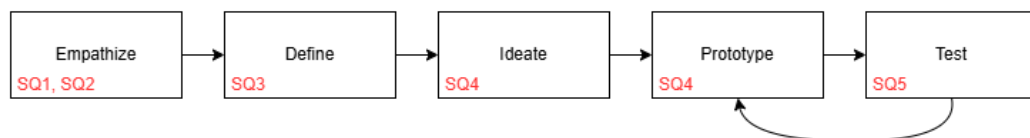


Figure 2.1: Sub questions and design thinking phases

2.3. Research methods

The formulated sub-questions can be answered using various research methods. This section examines the most suitable research methods for each sub-question and the corresponding design thinking phase. This is followed by a subsection that discusses the interviews in more detail and the analytical framework.

2.3.1. Methods

Each sub-question is addressed separately. An overview of all sub-questions, along with their corresponding design thinking phases, data sources, and methods, can be found in the research flow diagram in Figure 2.2.

Sub-question 1: What factors contribute to an efficient and satisfying schedule?

First of all, it is important to start the research with a deep understanding of efficient and satisfying scheduling. Since the aim of the research is to design a physician scheduling design that balances physician satisfaction and institutional efficiency. A suitable method for examining this is to combine direct contact with the users and a literature review. The first sub-question was therefore answered through exploratory conversations and a literature review. According to Snyder (2019), a thorough and well-executed literature review provides a solid foundation for advancing knowledge and supporting theory development. A literature review is therefore an effective method for establishing the underlying principles of an efficient and satisfying schedule. The design thinking phase corresponding to this sub-question is the empathize phase. Determining what factors contribute to an efficient and effective schedule is part of understanding the user.

To answer this sub-question, a stakeholder analysis was also conducted. A stakeholder analysis is used to identify key actors, their interests, and their influence on the project, in order to account for these factors in the design of a new scheduling approach and to assess its feasibility and implementation within the organizational context (Brugha & Varvasovszky, 2000).

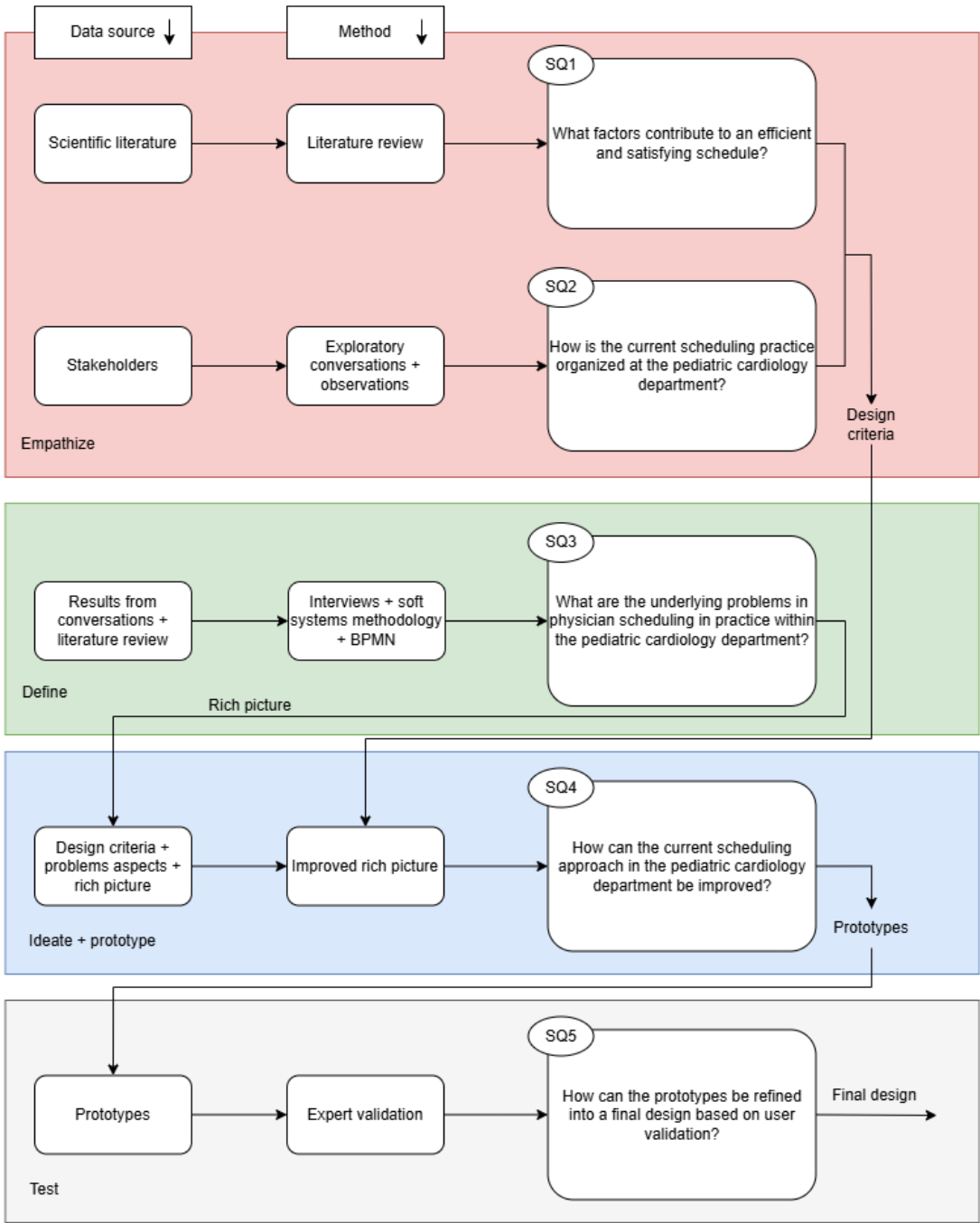


Figure 2.2: Research flow diagram

Sub-question 2: How is the current scheduling practice organized at the pediatric cardiology department?

The literature reviewed to identify the research gap states that the actual workload of physicians is often misinterpreted. In order to create an efficient scheduling approach, it is important to know how physicians allocate their time and which tasks may take longer than expected. In order to answer this sub-question, direct contact with the stakeholders was necessary. This is also done by conducting exploratory conversations with the user. This sub-question is part of the empathize phase, as it discovers the actual time allocation of physicians, in order to create a deeper understanding of the user.

Sub-question 3: What are the underlying problems in physician scheduling in practice within the pediatric cardiology department?

In order to design an improved scheduling process, it is important to have a thorough understanding of the current scheduling process. It is necessary to determine whether the problem originates in the scheduling process, the resulting outcomes, or other contributing factors. Therefore, sub-question 3 can be answered through a process analysis and a context analysis. The goal of this sub-question is to understand how the rostering process at the pediatric cardiology department currently works and what the main challenges are. An analysis of the current roster and its related processes provides the basis for answering this sub-question. The method that was used to analyze this process is BPMN modeling. To generate input for the BPMN modeling, a semi-structured interview must be conducted with the individual responsible for creating the schedule to provide a detailed explanation of the process. The context analysis was conducted using SSM. The input for the SSM also consists of semi-structured interviews. The following paragraph describes the methods that are used to answer this sub-question.

The key stakeholders include the 11 physicians working at the pediatric cardiology department, the individuals responsible for managing the schedule, and the department head. The aim of the interviews is to understand the current scheduling process, how cardiologists allocate their time, what challenges the current scheduling system faces, and what the cardiologists needs and preferences are. This information is necessary to design a new scheduling approach for the pediatric cardiology department. Interviews are an effective method for gathering new information and gaining new insights (Queirós et al., 2017). However, a limitation of conducting interviews is that the findings are not generalizable (Queirós et al., 2017), as not everyone shares the same views on certain issues. In this study, this is not an issue because the research is specifically conducted for the pediatric cardiology department.

Due to the limited time available for this study, it was not feasible to conduct extensive interviews with all of the cardiologists. Therefore, semi-structured interviews with five of the cardiologists were conducted. To ensure anonymity, all participants were assigned identifiers based on their professional role and numbered numerically as Cardiologist, interview 1 through Cardiologist, interview 5. The duration of these interviews was 45 to 60 minutes. To systematically code and analyze the results of the interviews, the software tool Atlas.ti was used. An oversight of the code groups can be found in Appendix G, Table G.1. This appendix also contains a table with the frequency of each code group across the interviews (Table G.2). Throughout the coding process, the researcher's approach evolved from highly detailed coding in the initial coded interview (interview 2) to a more abstract and aggregated coding strategy in subsequent interviews. The interviews were recorded using Microsoft Teams, which provides an automatic transcription function. The recordings were securely stored on TU Delft OneDrive, ensuring that sensitive data was handled in a secure manner. The COREQ checklist by Tong et al. (2007) was considered during the preparation, execution, and analysis of the interviews. The completed checklist is provided in Appendix B to ensure transparent and comprehensive reporting of the qualitative methods used in this study. The interview questions that were used as a basis for the conversations can be found in Appendix C.

The information obtained from these interviews is used as input for the context and process analysis. In this study, the scheduling process was analyzed by visualizing the process using BPMN. BPMN modeling is used to describe and analyze how different activities within complex organizations are organized and structured (Corradini et al., 2017; Ruiz et al., 2012). BPMN models can be used to better understand how certain processes work (Corradini et al., 2017; Ruiz et al., 2012). BPMN is used to determine whether the scheduling process contributes to the problem and, if so, to identify where the process fails and what the problems are.

After the process analysis, a context analysis was performed. The aim of the context analysis is to develop a detailed understanding of the problem. This was done using SSM. Because this research deals with a complex problem, a method for structuring complex problems is required. SSM was developed to address unstructured and complex problems (Checkland & Poulter, 2020; Hindle, 2023). Unstructured problems involve a lot of stakeholders with conflicting interests and different perspectives on the problem (Checkland & Poulter, 2020; Hindle, 2023). Part of the SSM is creating rich pictures. The goal of making rich pictures is to capture the different viewpoints and structures of a complex problem (Checkland & Poulter, 2020). This research uses rich pictures to capture the problem. These were developed based on semi-structured interviews. To answer this sub-question, two rich pictures were developed. An initial rich picture in the emphasize phase and an improved rich picture in the define phase. This is because the rich picture developed in the emphasize phase provides an initial understanding of the problem and was used as input for the interviews to gain a deeper understanding of the problem. The visual representation of concepts and relationships in interviews can help stimulate discussion and bring out ideas that would otherwise remain unexpressed (Crilly et al., 2006).

The first rich picture was developed based on the exploratory conversations. To structure the stakeholder analysis and the insights from the exploratory conversations and link them together, a CATWOE analysis was conducted as part of the soft systems methodology (Checkland & Poulter, 2020; Hindle, 2023). The CATWOE analysis was used to support the development of the initial rich picture.

The artefact developed in this study is a new approach to scheduling. This new approach incorporates the stakeholders needs and preferences and other design requirements. To test the designed prototypes, the designs were presented to several cardiologists, who were asked for their feedback.

This sub-question falls under the define phase. Based on the visualized scheduling process and context, the key challenges of the current schedule can be identified.

Another method used to collect information to answer sub-questions 2 and 3 is through field research. For the study, visits were made to the children's hospital to observe how things operate in practice and to speak with the cardiologists in the department. Field research is an excellent method to gain an in-depth understanding about people and processes, and to better understand their behavior and experiences (Queirós et al., 2017).

Sub-question 4: How can the current scheduling approach in the pediatric cardiology department be improved?

The aim of this sub-question is to design an improved version of the current way of scheduling. Based on the answers to sub-questions 1, 2, and 3 new scheduling approaches can be designed. These generated ideas are the prototypes that were created. The answers to sub-questions 1, 2, and 3 provided insights into the physicians' needs and preferences as well as the hospital's operational requirements, which served as input for the design requirements. The scheduling approach that was designed must meet both hospital requirements and physicians' preferences; otherwise, it cannot be considered an improvement. The design thinking phase associated with this sub-question is the ideate and prototype phase. The designed prototypes are validated by the user in the test phase.

Sub-question 5: How can the prototypes be refined into a final design based on user validation?

The redesigned scheduling approach needs validation. This is part of design thinking's test phase. The improved scheduling approach was discussed with the stakeholders. Based on their feedback the designs were improved further. Due to time constraints, this study did not include practical testing. Practical testing would mean that the users implement the most promising prototypes over a longer period of time (Dam, 2025). The testing phase in this study has been simplified to collecting user validation, followed by iterative improvements of the prototypes from the ideate and prototype phase. These improvements were done based on user validation and an analysis of which prototypes best satisfy the design criteria and problem aspects. The following paragraph describes the testing phase of this study.

Design thinking is an iterative process, and the feedback provided by the problem owner in the ideate and prototype phase formed the first iteration. This initial validation session with the problem owner was intended to refine and prepare the prototypes for presentation to the team. The five prototypes developed during the ideate and prototype phase were presented to the cardiology team during a large

staff meeting. During this meeting, almost all cardiologists were present. This made the meeting a suitable moment for testing. At the start of the presentation, the cardiologists were given the opportunity to scan a QR code that linked to an anonymous Google Forms survey. In this survey, the cardiologists were able to provide feedback and suggestions regarding each prototype. The survey was completely anonymous, meaning that the researcher was unable to identify which participant submitted a particular response. This encouraged participants to provide more open and honest feedback. Based on the feedback received from the survey, the five prototypes were revised and improved.

Furthermore, during the test phase, calculations were performed to estimate the additional Full-Time Equivalent (FTE) required to compensate for the expected reduction in clinical production resulting from the implementation of the proposed final design. The data used for these calculations were provided by the problem owner and confirmed to be accurate. These calculations served as an estimation of the potential impact of the proposed design and were not validated in practice.

2.3.2. Data requirements and data sources

For this study, different types of data were required. First, the interviews provided primary data, which are data collected directly by the researcher as part of the study, rather than obtained from existing literature (Wagh, n.d.). For the literature review, secondary data were needed. This type of data includes government publications, websites, books, journal articles, internal records, etc. (Wagh, n.d.). In case of the literature review, only books and journal articles were used. Additionally, the hospital provided data for the study, including schedules and background information on the scheduling procedures. This is also a form of secondary data.

This research involves data that is obtained from human research subjects. Therefore, approval for human research provided by the Human Research Ethic Committee (HREC) is mandatory (Delft, n.d.). An approval application was submitted to the HREC, including several documents for review. First, a data management plan was provided, outlining the data collected during the interviews, as well as its storage and security. Furthermore, the human research ethics checklist for human research was submitted. This is a document about Risk Assessment and a Mitigation Plan. Finally, an informed consent form was sent to the HREC for approval. This is a document that must be signed by both the participants and the researcher prior to conducting the interviews. It provides consent for the use of the interview data in the study and confirms that the researcher will handle the data responsibly. Ethical approval for this study was granted by the HREC of TU Delft. Confirmation of this approval can be found in under application number 6588.

The research required interviews with the key stakeholders involved in the scheduling process at the pediatric cardiology department. Therefore, the availability of the data needed to be considered. These stakeholders were contacted through the hospital's contact person, who was provided via TU Delft and serves as the problem owner. Throughout the research, there was extensive contact with the hospital, and unrestricted access was available through this point of contact.

During the development of this master thesis AI tools were used (ChatGPT) for language refinement and brainstorming. A detailed explanation of the AI use can be found in Appendix D.

Empathize phase

The goal of this chapter is to develop a deep understanding of the user. In this research, this is achieved by performing a literature review on factors that contribute to an efficient and satisfying work schedule, conducting a stakeholder analysis, and analyzing the different tasks and their required time. This chapter answers research questions 1 and 2, and the findings serve as input for the define phase.

3.1. Literature review

This section answers sub-question 1 by conducting a literature review on the following question: *What factors contribute to an efficient and satisfying schedule?* The literature that has been used in this literature review is not limited to the medical sector, but addresses research on workforce scheduling in general. An overview of the literature review process can be found in Appendix E.

The aim of this literature review is to create a basic understanding of what makes a work schedule efficient or satisfying. First of all, scheduling refers to the process of making decisions about how resources are assigned to tasks or operations over a specified period of time (Novando et al., 2024). Schedule satisfaction is important, as it contributes to employee satisfaction, which is a key indicator of an effective schedule (Lishan et al., 2021).

Evolution of scheduling

Workforce scheduling has been studied for many years, and today the field looks very different from the classical scheduling problems proposed by Dantzig and Edie in the 1950s (Aksu & Dinç, 2025; Metha et al., 2021; Van Den Bergh et al., 2012). During that period, the primary focus of scheduling was on institutional efficiency, cost minimization, and the optimal allocation of resources. Consequently, employees were treated as resources that had to be utilized as efficiently as possible while minimizing costs. At that time, little attention was paid to human factors. Over the years, this way of thinking has evolved and it has become increasingly important to satisfy the needs of employees (Huang et al., 2021; Metha et al., 2021; Van Den Bergh et al., 2012). This can be achieved in various ways. Organizations offer part-time arrangements and flexible working hours, and they incorporate employees' preferences, such as preferred colleagues, shift types, and desired working days (Metha et al., 2021; Van Den Bergh et al., 2012). Next to preference-based scheduling, fairness became an important factor in workforce scheduling. Fairness refers to the equitable allocation of shifts, taking into account employment level, individual needs, and workload balance (Gerlach et al., 2025). Therefore, workforce scheduling has shifted from prioritizing resource efficiency alone to balancing efficiency with human factors. Research of Aksu and Dinç (2025) also confirms this. Their research on fair nurse scheduling emphasizes that fairness is not only about a balanced nurse-to-patient ratio, but also includes consideration of nurses' skills, experience, competencies, and preferences (Aksu & Dinç, 2025). Optimized schedules result in greater profitability and improved customer satisfaction (Novando et al., 2024). While schedules optimized for maximum efficiency from the company's point of view may improve performance, they can reduce employee job satisfaction (Uhde et al., 2021).

Human factors

The literature identifies several factors that contribute to satisfying work schedules for employees, with fairness being the first (Gerlach et al., 2025; Huang et al., 2021; Mohd Razali et al., 2025; Şimşek & Kundakcioglu, 2020; Uhde et al., 2020). This was already briefly mentioned in the previous section. Fairness is a broad concept that includes various aspects. One of these aspects is the fair distribution

of resources (Uhde et al., 2020). According to Uhde et al. (2020), the distribution of resources consists of two concepts: equality and equity. In workforce scheduling, equality means assigning shifts evenly across employees, whereas equity involves allocating shifts in a way that is fair, taking into account differences such as contact hours, workload, or personal circumstances (Şimşek & Kundakcioglu, 2020; Uhde et al., 2020). It is therefore not only important that shifts are distributed equally among employees, but also that they are allocated in a fair manner. For instance, an employee who works part-time should not be assigned the same number of night shifts as an employee who works full-time. Unless they prefer night shifts. This is therefore an important factor for workforce scheduling in hospitals, as work is organized in irregular shifts. Research by Walter et al. (2024) identifies another approach to fair shift allocation. It is not only important to distribute undesirable shifts fairly, but also to ensure sufficient shift rotation. According to their research, repeatedly performing the same task can contribute to psychological stress (Walter et al., 2024). Accordingly, job rotation is considered as an effective strategy to mitigate these negative effects (Walter et al., 2024). Moreover, it allows employees to develop their skills across different work tasks and contributes to higher levels of job satisfaction (Walter et al., 2024). Considering the large number of tasks in the pediatric cardiology department, this is an important consideration. On the other hand, the variability between patients in hospital work makes employees less likely to fall into repetitive routines. In addition, rotating between different tasks helps cardiologists maintain their skills across multiple areas, preventing situations where they do not perform certain procedures, such as echocardiograms, for extended periods of time. Research of Grylls et al. (2025) states that an ideal schedule should support professional development of its employees. According to Şimşek and Kundakcioglu (2020), unfair scheduling leads to lower levels of employee engagement, which in turn increases employee turnover rates and results in additional operational costs for companies.

Another factor that contributes to satisfying workforce scheduling is predictability (Barker et al., 2025; Hossain, 2023; Mott et al., 2025; Schneider & Harknett, 2020). According to Hossain (2023), employees with higher schedule predictability experience lower turnover rates and increased productivity. Schedule predictability can be achieved by publishing the schedules well in advance (Barker et al., 2025; Lambert et al., 2019; Mott et al., 2025). This enables employees to better organize their work and personal lives (Barker et al., 2025). Work-life balance has a positive effect on job satisfaction and employee well-being, which in turn leads to high organizational performance (Bhende et al., 2020; Rohita et al., 2022; Sirgy & Lee, 2017). Nevertheless, creating schedules too far in advance may also cause employee dissatisfaction (Lambert et al., 2019). Therefore, a balance must be established between employee preferences and what is feasible for schedulers and the planning process. Unpredictable scheduling also includes last-minute schedule changes and on-call shifts (Schneider & Harknett, 2020). However, in pediatric cardiology, this unpredictability is an inherent part of the work and therefore cannot fully be prevented. Despite this unpredictability, schedules can still be published well in advance, and the broad outlines of the work can be incorporated into the schedule. A factor closely related to predictability is consistency in workforce scheduling. According to Barker et al. (2025), consistency refers to consistent shift patterns that meet personal needs. For example, a specific day off during the week or consistent night shifts. As a result, consistency in workforce scheduling contributes to higher levels of predictability. In the pediatric cardiology department, this could, for example, be implemented by assigning each cardiologist a fixed outpatient clinic day in the week. A factor closely related to predictability and consistency is flexibility (Barker et al., 2025; Grylls et al., 2025). This is also an important factor contributing to schedule satisfaction. Flexibility can be seen as a form of autonomy over the schedule, where employees have a sense of control and influence over their schedule instead of having it fully determined for them (Grøtting & Øvergård, 2023; Schaepe et al., 2025). An example of this is the study by Grylls et al. (2025), in which a self-rostering system was tested for six months among 18 doctors. After six months, there was a noticeable increase of employee well-being and a better work-life balance (Grylls et al., 2025). However, the main challenge was stakeholder engagement, as several stakeholders were concerned about the potential impact of self-rostering on workload and feared that employees might work fewer hours under this system. This issue was addressed through open communication and transparency. (Grylls et al., 2025). Research by Brauner et al. (2019) also suggests that autonomy in work schedules positively affects job satisfaction. However, their study indicates that a potential risk of autonomy is that employees may extend their working hours when they experience high workload pressure. It can therefore be concluded that flexibility is important, but it must be implemented and maintained through transparency and mutual trust.

Another important factor in workforce scheduling is rest and recovery (Alencar et al., 2025; Barker et al., 2025; Brauner et al., 2019; Daitch et al., 2025; Di Milia & Bjorvatn, 2024; Rohita et al., 2022). This is particularly important in this research, as it focuses on the medical sector, where physician fatigue can negatively impact the quality of care (Di Milia & Bjorvatn, 2024). Fatigue among physicians is associated with impaired cognitive performance and a higher risk of medical errors (Daitch et al., 2025). Furthermore, work in the medical sector often includes night shifts and weekend shifts. Sufficient sleep and rest prevent various medical conditions, such as diabetes, heart diseases and strokes, and reduce psychosocial stress (Di Milia & Bjorvatn, 2024; Grøtting & Øvergård, 2023). According to Daitch et al. (2025), providing sufficient rest and recovery in employee schedules improves employee satisfaction. To account for employee recovery time, it is important to ensure that employees do not have too many consecutive night shifts and that weekend shifts are distributed evenly (Alencar et al., 2025). Research of Brauner et al. (2019) also supports this, as it shows that the timing of work schedules is very important. The timing of work schedules refers to the time available for recovery or private activities.

Trade-off

Overall, workforce scheduling has evolved from a purely efficiency-driven approach toward an approach that incorporates human factors, such as fairness, predictability, consistency, flexibility and sufficient rest. While these factors improve employee satisfaction and well-being, they may also introduce challenges for organizational efficiency (Barker et al., 2025; Gerlach et al., 2025; Schaepe et al., 2025; Şimşek & Kundakcioglu, 2020). According to Barker et al. (2025), healthcare organizations face the complex challenge of balancing organizational goals of cost-efficient rostering, through optimized schedules, with the need to maintain employee well-being through appropriate scheduling. This tension arises primarily because there is often a difference between organizational goals and employee needs, as organizations focus on maximizing shift coverage, while employees prefer to be assigned their preferred shifts (Metha et al., 2021).

This conflict between priorities becomes even more visible when looking at specific examples. More specifically, the study by Schaepe et al. (2025) is particularly relevant to this research, as it focuses on scheduling in the healthcare sector. In their research, physicians observed a misalignment between the organization's stated values and its operational goals (Schaepe et al., 2025). While the stated values emphasized patient care, physician well-being, and teamwork, the organizational goals focused on optimizing efficiency, cost reduction and increasing productivity (Schaepe et al., 2025). This misalignment illustrates how organizational efficiency goals may conflict with employee needs, such as employee well-being and manageable working conditions.

These conflicting interests are a common trade-off in the literature. According to Şimşek and Kundakcioglu (2020), the main motivation behind their research was the trade-off between organizational efficiency and employee satisfaction. Gerlach et al. (2025) also conclude that organizations struggle to balance fairness with organizational efficiency, which often leads to employee dissatisfaction. Research by Barker et al. (2025) supports this statement. According to their findings, organizations that do not take employee needs into account are likely to experience higher turnover rates.

Ultimately, the literature implies that it is necessary to find a balance between organizational efficiency and employee satisfaction. On the one hand, employee satisfaction can enhance organizational productivity (Shuib & Kamarudin, 2018), whereas an excessive focus on employee preferences may reduce operational efficiency, leading to higher costs or inefficiencies. Research by Barker et al. (2025) indicates that effective workforce scheduling requires a combination of conflict management strategies, with a special focus on collaborating and compromising strategies, in order to balance individual needs with organizational requirements.

Conclusion

The conclusion of this literature review is that human factors have become an important consideration in workforce scheduling, whereas it previously mainly focused on operational efficiency and resource optimization. The human factors that contribute to satisfying scheduling are fairness, in the form of equality and equity, predictability, consistency, flexibility, autonomy and sufficient rest and recovery. However, there is a limit to the extent to which these human factors can be applied in a schedule. Therefore, a balance between organizational efficiency and employee satisfaction needs to be found.

3.2. Stakeholder analysis

The previous section identified factors that contribute to efficient and satisfying scheduling according to the literature. These are important considerations that should be taken into account in the design of the schedule. However, it is also important to consider the interests of the stakeholders themselves. Therefore, exploratory conversations were conducted with a few stakeholders to identify their needs for a good schedule and compare them to the findings from the literature. The input of these exploratory conversations were used to conduct a stakeholder analysis.

There are several stakeholders involved in the scheduling process at the pediatric cardiology department of the Children's Hospital. This section gives an overview of all the stakeholders involved and their role, interests and expectations. The identification and understanding of stakeholders is an important part of the process, because all stakeholders have their own expectations and needs that need to be satisfied in order to avoid conflicts (Maqbool et al., 2022). For example, schedules cannot be optimized for physician comfort only, as this would substantially reduce the department's patient treatment capacity. There are two types of stakeholder groups: primary and secondary stakeholders, where primary stakeholders are those most directly affected.

3.2.1. Primary stakeholders

Cardiologists

There are 11 cardiologists working at the pediatric cardiology department. This is the group of stakeholders that is most directly affected by this study, as it concerns their work schedules. Their role is to provide specialized medical care to pediatric cardiology patients and ensure continuity and quality of care. In addition to their clinical responsibilities, cardiologists must be available according to the department's scheduling system.

According to the cardiologists, the main goals of the schedule are to ensure continuity of care, efficiency, and cardiologist satisfaction. This should be achieved through a transparent and balanced workload distribution, improved insight into the scheduling process, and support for a work environment in which cardiologists feel heard and are able to provide the care they aim to deliver. The current system is perceived as lacking transparency, which leads to dissatisfaction. In this context, transparency refers to insight into task distribution and the time required to complete them. Furthermore, the schedule should provide sufficient time for professional development, such as research or other enrichment activities.

Therefore, cardiologists prefer a schedule in which tasks are distributed fairly among them. To achieve this, the intensity and workload associated with different tasks need to be analyzed. By making the workload of different tasks more transparent, the distribution of tasks may be perceived as more fair by cardiologists.

Management

The pediatric cardiology department has a management team, consisting of three cardiologists. One of these cardiologists is also the head of the department. The management team is responsible for overseeing the overall functioning and organization of the pediatric cardiology department. The management team has an interest in efficient staff utilization, high quality and continuous patient care, balanced work distribution, and maintaining employee satisfaction. They also focus on ensuring that departmental operations align with hospital objectives and constraints.

The head of the department is also part of the management team. The head of the department is responsible for the overall leadership and strategic direction of the cardiology department. The head of the department has a strong interest in ensuring continuity and high quality patient care, promoting efficient and well-organized departmental operations, supporting staff well-being, and ensuring that the scheduling system aligns with departmental and organizational goals. The head of the department expects that scheduling supports both organizational needs and staff well-being.

Administrative assistant

The administrative assistant of the pediatric cardiology department is involved in the organizational and administrative processes of the department. Their role includes managing appointments, coordinating staff availability and assisting cardiologists with administrative tasks. The administrative assistant is also involved in the scheduling process. The administrative assistant has several interests. First off all,

having a clear and easy to use scheduling system, which reduces the complexity and workload involved in creating the schedules. The administrative assistant is also interested in minimizing scheduling conflicts and last-minute changes. The administrative assistant expects the scheduling system to be more user-friendly and efficient, in order to reduce the time and effort required to create the schedules.

The scheduling staff

These are the individuals involved in creating the schedule. This is done by two of the cardiologists, together with the administrative assistant. Their role is to create fair schedules for the cardiologists, every 3 months. Their role also includes organizing shifts, ensuring adequate staffing, and fairly distributing weekend shifts among the cardiologists. They ensure that the schedule is balanced and aligned with department requirements. The scheduling staff have a strong interest in creating fair schedules that minimize conflicts. They expect to have a clear, efficient, and user-friendly scheduling system that reduces complexity and workload.

3.2.2. Secondary stakeholders

Patients and parents

In a children's hospital the patients represent the stakeholder group that is the end user of the care provided. Their role is to receive medical care from the cardiologists. This group has an interest in continuity and quality of care. If the schedule is poorly designed, patients may see a different cardiologist each time, or waiting times may increase. This stakeholder group expects the appropriate specialist to be available at the right time and that appointments are not canceled at the last minute due to scheduling errors. This stakeholder group is not directly involved in the scheduling process, but they are indirectly affected by its outcomes.

Other specialty departments

The pediatric cardiology department collaborates closely with other departments within the children's hospital. The pediatric cardiology department exchanges knowledge with the other clinical departments. In complex cases, departments collaborate by providing their specialized expertise when needed. This stakeholder group has an interest in ensuring that time is allocated in the schedule for interdepartmental meetings.

Nurses

In addition to cardiologists, nurses are also involved in providing patient care within the department. Nurses work in close collaboration with cardiologists in both the outpatient clinic and the inpatient ward. The nurses have an interest in clearly knowing which physician is responsible for each patient and which physician is on duty at any given time. An unclear physician schedule can lead to uncertainty and disruptions among the nursing staff. Nurses expect a reliable and clear schedule to know which physician to contact in case of emergencies.

Integrated Capacity Management (ICM)

This stakeholder focuses on coordinating healthcare demand and resource availability throughout the entire hospital. This includes staffing, patient flow, beds etc. They play a central role in balancing demand and available capacity to ensure efficient hospital operations. ICM has a strong interest in organizational efficiency through, for example, optimizing the use of resources and ensuring that staffing levels match demand. ICM expects scheduling systems to support capacity planning.

Hospital board

The hospital board is a powerful stakeholder. They are not directly involved in scheduling but determine the requirements that the schedule must meet. The hospital board is a strategic decision-maker within the organization and is responsible for the overall governance and policy direction of the hospital. It has a strong interest in the efficient and cost-effective use of resources, high-quality and continuous care, and compliance with regulations and internal policies. The hospital board expects the scheduling system to support its interests and to minimize operational risks or disruptions when implementing changes. Additionally, the hospital has contractual agreements with health insurers regarding the number of patients to be treated, based on which the hospital receives funding (Rijksoverheid, 2022). Therefore, a new scheduling approach cannot result in a substantial decrease in the number of patients.

3.2.3. Power-interest diagram

To visualize the stakeholders involved and their level of power and interest in this research, a power-interest diagram was created. The goal of the power-interest diagram is to visualize the power and interest of the stakeholders in relation to developing a new scheduling approach. Thus, a high level of interest indicates that this stakeholder has a strong interest in a new scheduling approach. In addition, a high level of power means that this stakeholder has significant influence over decisions regarding the implementation of a new scheduling approach. The power-interest diagram is presented in Figure 3.1.

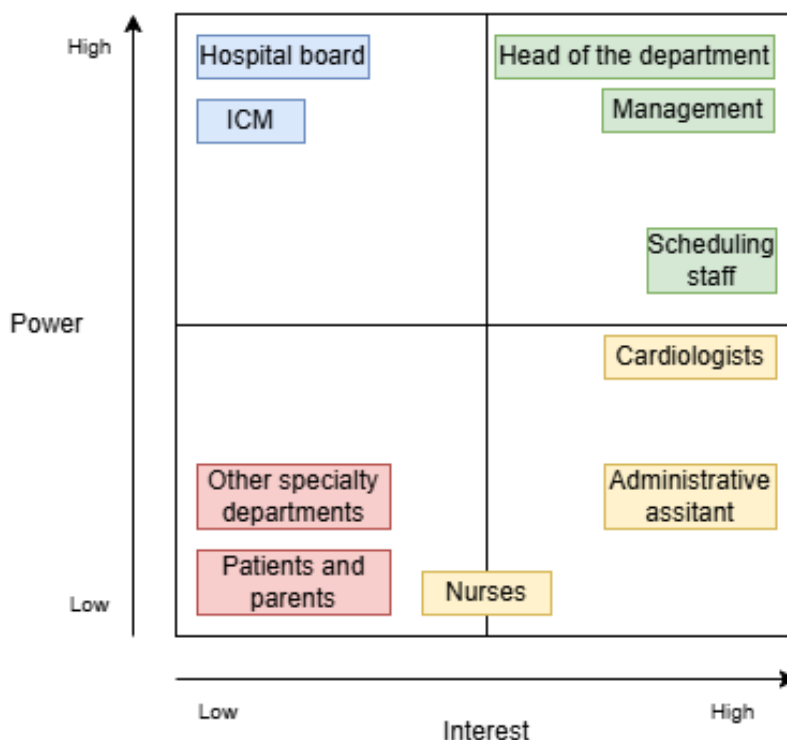


Figure 3.1: Power-interest grid

High power, low interest

According to Maqbool et al. (2022), stakeholders with high power and low interest need to be kept satisfied. This group of stakeholders has a lot of power, but is not interested in the details of the project. In this case these stakeholders are the hospital board and ICM. These stakeholders do not care about how the schedules of the cardiologists are managed, as long as the operational efficiency is not compromised. If the scheduling solution proposed by this research involves high costs or requires significantly more time, they may not approve the solution, and it is unlikely to be implemented. Therefore, the proposed solution must align with the requirements and policies of ICM and the hospital board.

High power, high interest

The stakeholders with high power and high interest are very important stakeholders. These stakeholders are considered key players in the scheduling process (Maqbool et al., 2022). They have significant influence over decision-making and they are directly affected by the scheduling solution. In this case, these stakeholders are the head of the department, the management team and the scheduling staff. These stakeholder groups consist exclusively of cardiologists. That is why they are directly affected by the scheduling solution. The head of the department and the management team aim to meet the efficiency requirements of the hospital board while also ensuring fair and satisfying schedules for the cardiologists in their department. Consequently, these key players act as the essential mediators who have a strong interest in balancing organizational efficiency with the individual well-being of the cardiologists. The scheduling staff have significantly less power than the head of the department and the management team. However, they make the schedule and they can decide how fair they make

the schedules. In principle, they have the power to assign more favorable shifts to their preferred colleagues or themselves.

Low power, low interest

The stakeholders with low power and low interest are not really important for this research. They are indirectly affected by the scheduling solution. Other specialty departments have no interest in how the schedules at the cardiology department are managed, as long as they still ensure time allocated for interdepartmental meetings. However, these departments could offer valuable insights from the new scheduling approach suggested by this research. The patients and their parents also have low power and low interest. They are not involved in this process and they have zero interest in how they schedules on this department are managed. They only care about receiving continuous and high quality care.

Low power, high interest

The stakeholder groups with low power and high interest have a strong interest in an improved scheduling process, as it directly influences them. However, they do not have the power to make final decisions about the scheduling process. In this case the cardiologists have a very high interest, as the research concerns their schedules, and medium power. They have some level of influence, as they can express their opinions and raise concerns if they strongly disagree with the proposed schedule system. The administrative assistant also has a high level of interest and a low level of power. The administrative assistant is interested in an improved scheduling system, as this individual has expressed dissatisfaction with the current process. However, the interest of the cardiologists and the administrative assistant differ from each other. The cardiologists are interested in a fair and satisfying schedule and the administrative assistant is interested in an improved scheduling system. That is also why this individual has less power, since the objective of this research is to improve the scheduling approach for the cardiologists. The nurses are placed in the middle of low and high interest. They do not have zero interest in this research because they are working directly with the cardiologists. They are not interested in how this scheduling process will be improved, they just want happy and satisfied cardiologists on the department.

Conclusion

The conclusion of this stakeholder analysis is that the proposed design should meet the hospital requirements. The hospital board is a stakeholder with high power and low interest. This means that the proposed schedule design should meet the needs and preferences of the cardiologists but it also has to meet the hospital requirements. This means that there are constraints to the design. For example, the proposed schedule design contains less outpatient clinics, in order to give the cardiologists more time for administrative work. This gives the cardiologists more time and flexibility in their schedule. However, the department has a clinical target that needs to be met. The minimal number of outpatient clinics per year, for instance. If the proposed schedule design does not meet these requirements, the management team will not allow this. Thus, the schedule has to meet the hospital requirements and at the same time satisfy the needs of the cardiologists.

3.3. Different tasks

This section outlines the different tasks and provides an estimate of the intensity of these tasks. There are a lot of different tasks and all these different tasks make task scheduling highly complex. This is because there is a difference in the level of predictability of the tasks. Some tasks can be scheduled, such as the outpatient clinic, while other tasks cannot be scheduled, such as emergency care. Furthermore, the department of pediatric cardiology consists of physicians with a range of different skills. Some of them even have specialized skills within a subspecialty, such as the cardiac arrhythmia group, the cardiac catheterization group, or the heart failure group. Additionally, there are also tasks that every physician on the department can perform, such as working in the outpatient clinic and performing echocardiograms in the operating room. This section provides an answer to sub-question 2: *How is the current scheduling practice organized at the pediatric cardiology department?*

There are two different types of tasks: clinical tasks and non-clinical tasks. Clinical tasks involve patient care, while non-clinical tasks include all other activities. First, the clinical tasks are discussed, followed by the non-clinical tasks. An estimation of the intensity of these tasks is also made based on

observations and conversations on the department. According to Hünefeld et al. (2025), work intensity refers to the level of work demands, or as the imbalance between workload, time available, and task complexity. Weights have been assigned to the tasks based on this definition.

3.3.1. Clinical tasks

The clinical tasks consist of several main categories, which can be further divided into sub-tasks. An overview of all clinical tasks can be found in Table 3.1.

Outpatient clinic

The outpatient clinic consists of the general outpatient clinic and the specialized outpatient clinic. The general outpatient clinic is intended for patients with less complex cardiac conditions. These outpatient clinics can be performed by every cardiologist of the department. The specialized outpatient clinics are for more complex heart patients. The different specialized outpatient clinics that exist are: Heart Transplantation (HTx) clinic, cardiac arrhythmia clinic, fetal cardiology clinic, ergo clinic, and Post-Operative Screening (POS) clinic. There is also the Arts in Opleiding tot Specialist (AIOS) outpatient clinic. AIOS clinic refers to an outpatient clinic run by residents, physicians in training to become specialists, under supervision.

The intensity of the outpatient clinic differs depending on the type of outpatient clinic. The general outpatient clinic is not considered a highly intense task. Most consultations involve follow-up or routine appointments, which can usually be handled efficiently. The specialized outpatient clinics can be more complex. These outpatient clinics often involve highly complex patients who require more preparation and follow-up time. In addition, these appointments may take longer due to the many questions from concerned parents, which need to be answered carefully. For example, the arrhythmia outpatient clinic involves patients with chronic cardiac conditions. A major factor contributing to the intensity of the outpatient clinic task is the substantial administrative workload it requires. Appointments need to be documented and entered into the computer system. Furthermore, alongside the patients seen during the scheduled outpatient clinic and administrative tasks, there are often phone appointments that also need to be handled during the same period of time. In addition, some appointments require a significant amount of preparation time. The administrative burden therefore makes the general outpatient clinic a moderately intense task, whereas the more complex outpatient clinics are considered intensive.

Heart Catheterization (HC)

A cardiac catheterization is a procedure in which a thin, flexible tube called a catheter is inserted into a blood vessel in the groin and guided toward the heart. Through the catheter, the cardiologist can examine the coronary arteries, detect narrowing or blockages, measure pressure inside the heart, or perform a treatment, such as placing a stent, opening up a narrowed blood vessel, or closing a hole in the heart. (Erasmus MC, n.d.-a; LeWine, 2025). Cardiac catheterization is a sub-specialization that not all cardiologist can perform. It also involves interventional procedures. Before the procedure, patients attend a preoperative clinic, and a follow-up appointment is scheduled a few weeks after the intervention. During the procedure, at least two cardiologist should be present.

The HC task involves interventional procedures which makes the task highly intense. However, this task involves a significant amount of slack time between steps. But, there are sufficient activities within the HC that this time can be used for. Besides performing the procedure itself, this also includes preoperative screening, postoperative care, and patient discharge, among other responsibilities. It is therefore a relatively extensive task. Another factor contributing to the intensity of this task is the possibility of emergency cases. In such situations, a physician must be available immediately to perform an urgent HC. As a result, part of this task is unpredictable. In addition, the studied hospital is one of the largest and most advanced cardiac catheterization centers in the Netherlands. Consequently, interventional cardiologists are required to keep up to date with the latest developments in this field, which also demands additional time. The HC can therefore be classified as an intensive task, despite involving a fair amount of slack time. There are enough responsibilities within this task that fill this time.

Clinic

The pediatric thoracic center clinic is a pediatric inpatient ward dedicated to the treatment of children treated by specialists in pediatric cardiology, pulmonology and otolaryngology (ear, nose, and throat)

(Erasmus MC, n.d.-b). In the inpatient ward, cardiac patients who cannot go home are admitted for overnight stay. During their stay in the clinic, patients receive continuous care from cardiologists and nurses. In order to provide high-quality care and become familiar with the patients on the ward, cardiologists are assigned to the clinic for a full week. Perioperative care is also part the clinic tasks. Perioperative care is all care provided around the time of surgery. So, before surgery, during surgery, and after surgery. This is partly scheduled, but sometimes performed urgently.

The clinic task is considered a highly intense task. There are several reasons for this, one of which is that this task must be performed throughout the entire week when assigned. This means that even if you would normally have Mondays off each week, you are still required to work if you are scheduled in the clinic. Furthermore, physicians are constantly occupied in the clinic, moving from patient to patient with an ongoing stream of work. In addition, extensive communication with parents is necessary, while continuous care for the patients on the ward must be maintained. This task also involves administrative work, which also takes a lot of time. Sometimes a resident joins the clinic. This can help reduce the overall workload. However, at the beginning, the resident still needs to learn everything, which can actually make this task more intensive.

Imaging

Imaging refers to all techniques used to create images of the body, including echocardiography, MRI, and CT scans. During an echocardiography, an image of the heart is produced. In general, any cardiologist can perform an echocardiogram. However, some cardiologist are specialized in imaging. MRI and CT scans can only be performed by specialized cardiologists. Most echocardiograms and other imaging procedures are routine and can be easily scheduled. However, some imaging is needed in emergencies and must be performed urgently and therefore cannot be scheduled in advance.

The level of intensity of this task varies, as any cardiologist is capable of performing a standard echocardiogram. The standard abnormalities and findings are easy for cardiologists to identify. However, more complex patients require more careful attention. For physicians specialized in this field, imaging is therefore more intensive than general echocardiography. The intensity of this task is also increased by the frequent need to perform urgent echocardiograms. Overall, echocardiography is not a particularly intensive task.

Stand-by

The stand-by task involves covering for sick colleagues or performing emergency echocardiograms. When there are no sick colleagues or emergencies, this time can be used to complete other tasks. For example, cardiologists can use it to finish administrative work. The stand-by task is a very unpredictable task. It can involve a lot of slack time, but it can also be very busy. Stand-by is a general task and every cardiologist is assigned to this task on a regular basis.

When this task involves a significant amount of slack time, it can be quite pleasant, as it provides an opportunity to catch up on other work. It can also happen that physicians have to step in a few times but still have plenty of slack time, or that they are busy the entire time. Thus, it is an unpredictable task, but overall it is considered to be low in intensity. There is also a difference in how each cardiologist spends their time during this task. Some cardiologists are constantly engaged in what is going on in the department, while others take a less extensive approach and spend more time in the office.

Table 3.1: Overview of tasks

Category	Task	Description
Outpatient clinic & specialized outpatient clinic	General outpatient clinic	General outpatient patient care
	HTx clinic	Outpatient clinic for heart transplant patients
	Arrhythmia clinic	Outpatient clinic for cardiac arrhythmias
	Fetal clinic	Care for unborn children with congenital heart defects
	Resident clinic	Outpatient clinic conducted by residents under supervision
	Exercise testing	Cardiac stress testing
	Haven clinic	Outpatient clinic at another cardiology department
	POS clinic	Preoperative screening prior to surgery
Heart catheterization (HC)	Structural interventions	Planned interventions in the catheterization laboratory
	Adult HC	Cardiac catheterization procedures for adult patients
	Rhythm HC	Catheterization procedures focused on arrhythmia-related conditions
	EFO (follow-up echocardiography after HC)	Follow-up echocardiography after cardiac catheterization
	Emergency HC	Acute cardiac catheterization procedures
Inpatient care	OR handover	Handover related to surgical procedures
	PICU handover	Handover of patients in the pediatric intensive care unit
Echocardiography / supervision	Supervision of echocardiograms	Supervising and evaluating echocardiograms
	Specialized echocardiograms	Complex or abnormal echocardiographic examinations
	TEE in the OR (transesophageal echocardiography)	Transesophageal echocardiography during surgery
	Echocardiograms in the PICU	Echocardiography for intensive care patients
	Echocardiograms during HC	Echocardiography during cardiac catheterization procedures
	Emergency echocardiography	Acute echocardiography in emergency situations
MRI / CT	MRI/CT	Cardiac imaging through radiology
Perioperative care	Perioperative cardiology care	Cardiology care before, during, and after surgery
Stand-by	Covering absent or sick colleagues	Availability to take over tasks in case of absence
	Emergency tasks	Deployment in acute and unexpected situations
	Other tasks	Time allocated to other activities in the absence of emergencies or staff shortages

3.3.2. Non-clinical tasks

Non-clinical tasks are all tasks that do not include direct patient care. There are several main categories, which can be further divided into sub-tasks. An overview of all non-clinical tasks can be found in Table 3.2.

Professional development

In order to continue delivering high-quality care, professional development is necessary. This means that doctors must keep learning and stay up to date with the latest developments in the field. This can be done in several ways, such as conducting research, attending conferences, deepening and education.

Research is an important task within the department. As an academic hospital, the hospital studied for this research is required to conduct research and publish in order to continue providing high-quality care. There are cardiologist within the department who have a research profile. This means that they have dedicated research days in their schedule. Cardiologists without a research profile can also conduct research. However, no dedicated time is scheduled for them, so they have to do it in their own time. Research is very important, but not mandatory. This means that it is the first thing to be dropped when workload increases.

To stay up to date with the latest medical developments, cardiologists need to attend conferences. At these conferences, cardiologists have the opportunity to learn from other cardiologists. Every cardiologist is required to attend a conference for at least two weeks per year.

As the studied hospital is an academic hospital, it also provides education. In this context, education includes teaching and supervising medical students, residents (AIOs), and PhD candidates. Not all cardiologists are involved in education, while others are specialized in it.

Professional development is not a particularly intensive task. However, it is very important for the department that cardiologists continue to develop themselves. From the exploratory conversations in the previous section, it appears that this is also something cardiologists consider important. Most professional development can simply be scheduled and carried out during that time. Preparation for educational activities may require more time than anticipated. Because professional development tasks are often deprioritized in favor of more urgent responsibilities, such as administrative work, the intensity can increase for tasks that really need to be completed, such as providing timely feedback for a PhD candidate. Research can be of moderate intensity for physicians with a research profile. This is because they are expected to deliver results, while research is often easily deprioritized, leaving less time to complete their work. Overall, these tasks are low in intensity.

Management

There are also many management tasks within the department. There are a variety of management tasks, such as daily operations, scheduling, the strategic direction of the heart center, etc. There is a management team within the department consisting of three cardiologists, who dedicate a significant amount of their time to this. There are also other cardiologists who take on some management tasks. Management tasks are essential for keeping the department running smoothly.

Management tasks are generally of low to moderate intensity compared to clinical tasks, but they can become more demanding due to multitasking and interruptions.

Meetings

There are many different meetings and discussions within the department. Some meetings are only for a specific sub-specialization or group, while others are for the entire department. Many of the meetings are scheduled at a fixed at a fixed period.

The intensity of meetings depends on the type of meeting, but overall, meetings are not very intensive tasks. Meetings are also tasks that are often quickly deprioritized because other tasks are considered more important. With meetings, the intensity is not the issue, but rather the timing of when they are scheduled. Meetings scheduled at the end of the day often have lower attendance than morning meetings, because many cardiologists are still occupied with tasks that overrun. The research meeting is

also often canceled due to time constraints. This is unfortunate and should be better planned. Meetings themselves are not intensive, but the number of meetings cardiologists are required to attend can be. Therefore, the intensity of the meetings is moderate and it also varies from person to person.

NPGT

NPGT refers to "niet patiënt gebonden tijd" (non-patient-related time), which is time dedicated to activities other than direct patient care. NPGT is a general task and every cardiologist is assigned to this task on a regular basis. During NPGT, cardiologist get the change to catch up on their work or work on their professional development.

This is a very low intensity task and is highly desirable. This task can serve as a buffer for more intensive tasks. It functions as a form of compensation time.

Table 3.2: Non-clinical tasks

Category	Task	Description
Education & development	Professional development	Training and knowledge development
Research	Research	Scientific research
Professional development	Conferences	Attendance at national and international conferences
Management	Head of department	Department head responsibilities
	Executive board	Administrative and managerial responsibilities
	MECO	Medical coordinator
	Schedule planning	Planning and allocation of tasks
	Heart center meetings	Strategic discussions at heart center level
Other	NPGT	Non-patient-related time
Meetings	Monday handover	Patient handover
	Thursday handover	Patient handover
	Patient discussion (MDT)	Multidisciplinary patient discussion
	CTC meetings Tuesday	Discussions on complex congenital heart defects
	CTC meetings Thursday	Discussions on complex congenital heart defects
	Rhythm meetings	Discussions within the arrhythmia team
	Adult patient meetings	Discussions regarding adult patients
	Cardiogenetics meeting	Discussions on genetic aspects of cardiology
	Heart transplantation meeting	Discussions regarding heart transplant patients
	Perinatal meeting	Discussions regarding pregnancies involving fetal heart defects

3.3.3. Cardiologist and sub-specialization

As mentioned before, all cardiologists have their own sub-specialization. In order to evaluate the workload distribution properly, it is important to first examine how the sub-specializations are distributed among the cardiologists in the department.

The sub-specializations are divided into different working groups that are responsible for a specific domain. A working group is a group of people that is specialized in a specific domain. There are a total of 11 cardiologists working in the pediatric cardiology department, and each of them has been assigned

a number to ensure anonymity (C1 through C11). Table 3.3 presents an overview of all cardiologists and all the different domains and the corresponding working groups with their lead. For example, there is a working group that is responsible for the HC domain. This working group consists of a group of cardiologists and a working group lead. This working group lead is the individual that is responsible for this group and this is the contact person for this domain. The purple cells in the table represent the group leads. Some working groups consist of three or four cardiologists; however, most of them consist of only two.

Table 3.3: Different tasks

Domain	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
Imaging											
Cardiac arrhythmia											
HTx											
HC											
MRI											
Foetal											
Ergo											
Research											
Management											
Education											

Table 3.3 shows that the number of specializations differs between cardiologist. Some of them only have one sub-specialty, while others have three or four. The table also shows that some cardiologists have a purely clinical profile, while others perform a combination of both or have a slightly greater focus on non-clinical tasks. Cardiologist who are lead of a working group also tend to have a slightly higher workload for that task. Most cardiologist lead one group, although some lead two groups or none at all. This table therefore shows differences in the number of tasks per cardiologist.

3.3.4. Conclusion

All tasks have been discussed, and it has been confirmed that their number is indeed large. There will also be additional smaller tasks that are not yet included in this list. There are too many to record all of them precisely. However, this represents the majority. An estimation of the task intensity has been made. The intensity of the clinical tasks are illustrated in Figure 3.2a and of the non-clinical tasks in Figure 3.2b. Figure 3.2 shows a comparison of intensity between clinical and non-clinical tasks.

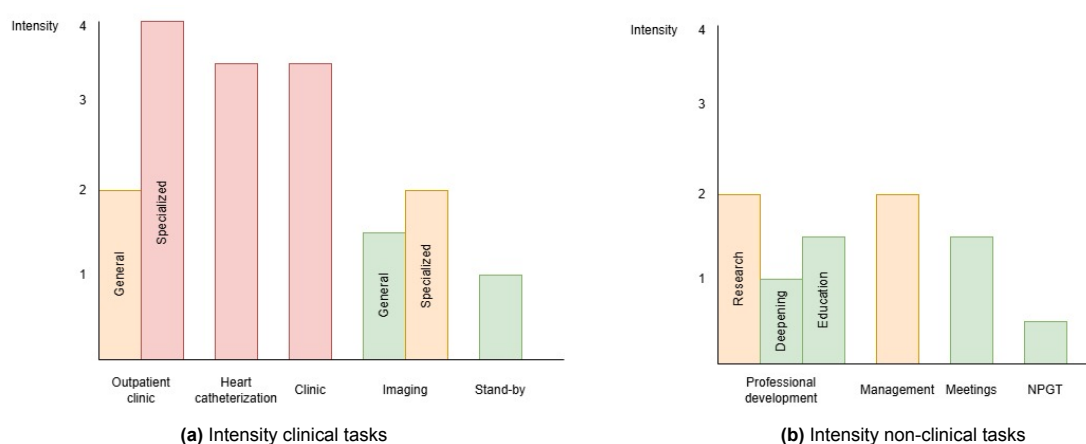


Figure 3.2: Comparison of intensity between clinical and non-clinical tasks

This comparison shows that the intensity of clinical tasks is much higher than that of non-clinical tasks. Moreover, because clinical tasks involve direct patient care and are often more intensive, they frequently overrun, causing non-clinical tasks to be quickly deprioritized. Overall, clinical tasks are generally the

more intensive tasks, especially the specialized ones. This intensity often comes at the expense of non-clinical tasks. The distribution of sub-specialization shows that some cardiologists have a more clinical profile, while others have a combination of both or focus more on non-clinical tasks. This difference may lead to a perception of an unfair distribution of workload.

3.4. The initial problem analysis

Consequently, findings from the previous section represent an initial aspect of the problem faced by the pediatric cardiology department: unfair distribution of tasks. To develop an initial understanding of the problem, a first version of the rich picture was developed based on exploratory conversations with the cardiologists. Before developing the initial rich picture, a CATWOE analysis was conducted. The CATWOE analysis can be found in Appendix F. The CATWOE analysis shows that the key challenge is to create a transparent and fair scheduling system that recognizes all aspects of cardiologists' work while still aligning with clinical and organizational requirements. After the CATWOE analysis, the initial rich picture was developed and can be seen in Figure 3.3. The define phase builds on this initial rich picture and refines it using insights from the interviews.

Section 3.3 highlighted the wide range of tasks carried out within the pediatric cardiology department, as well as the differences in workload intensity. This section already suggested that the allocation of these tasks could be perceived as unfair. The exploratory conversations indicated that some cardiologists believe the tasks are not distributed fairly among the team and that certain individuals are assigned to specific tasks more frequently than others. This causes some of the cardiologists to feel disadvantaged. The reason for this feeling can be explained by the presence of different sub-specializations within the department. Because of these sub-specializations, many tasks can only be performed by specific cardiologists. For example, MRI procedures can only be performed by two cardiologists within the department. Within the schedule, only these two cardiologists can be assigned to this task. General tasks can be performed by every cardiologist and the specialized tasks can only be performed by specific individuals. Because some cardiologists have multiple sub-specializations, they are assigned to specialized tasks more frequently than general tasks. Thus, there is a sense of dissatisfaction, as some physicians feel that the tasks are not distributed fairly among them. This can be explained by the fact that physicians with more sub-specializations are assigned fewer general tasks and more specialized ones.

Another factor contributing to the perceived unfairness in the distribution of tasks is the presence of cardiologists with a research profile. These cardiologists are engaged in major research projects and typically have fewer outpatient clinic responsibilities. However, there are clinical requirements that must be fulfilled, such as a minimum number of outpatient clinics per year. Due to the minimum number of outpatient clinics that must be met per year, the outpatient clinics that research oriented physicians attend less frequently must be covered by other cardiologists. This can feel unfair to other cardiologists. The physicians with a research profile therefore perform less clinical work, and as emerged from the empathize phase, clinical work is more intensive than non-clinical work. One of the cardiologists from an exploratory conversation expressed dissatisfaction with this, as shown in the following quote about cardiologists with a research profile:

"They sit in their offices while we run around all day." - Cardiologist with a clinical profile

Additionally, the cardiologists also do a lot of invisible work that requires a significant amount of time. Invisible work is work that is not specified in the schedule. For instance, the preparation time for a really complex outpatient clinic. There is no allocated time for this in the schedule; however, it may require a significant amount of preparation time. This additional workload is not visible to the other cardiologists. Firstly, there is not a clear understanding of how long tasks actually take or what additional time is needed. Secondly, some cardiologists feel that the rest of the team is not aware of how much work they actually do. Cardiologists experience a lack of transparency in the schedule regarding how tasks are distributed and how much time is required or allocated to specific tasks. All of the issues mentioned above together contribute to the perceived unfairness in the distribution of tasks. The assumptions about each other's workload can lead to a negative atmosphere and dissatisfaction.

In summary, according to the exploratory conversations, the problem within the department is that there is a perception that tasks are not distributed fairly. This is because of the difference between cardiologists

ogists with multiple sub-specializations and one sub-specialization, the cardiologists with a research profile, and the invisible work. A fair distribution of tasks is a broad concept, as each individual has a different interpretation of what is considered "fair". Therefore, during the development of the prototypes, the intensity of the different tasks is taken into account in order to create a distribution of tasks that is as fair as possible. Furthermore, the profile of the cardiologist needs to be taken into account. A cardiologist with a research profile should perform fewer clinical tasks than a cardiologist with a clinical profile.

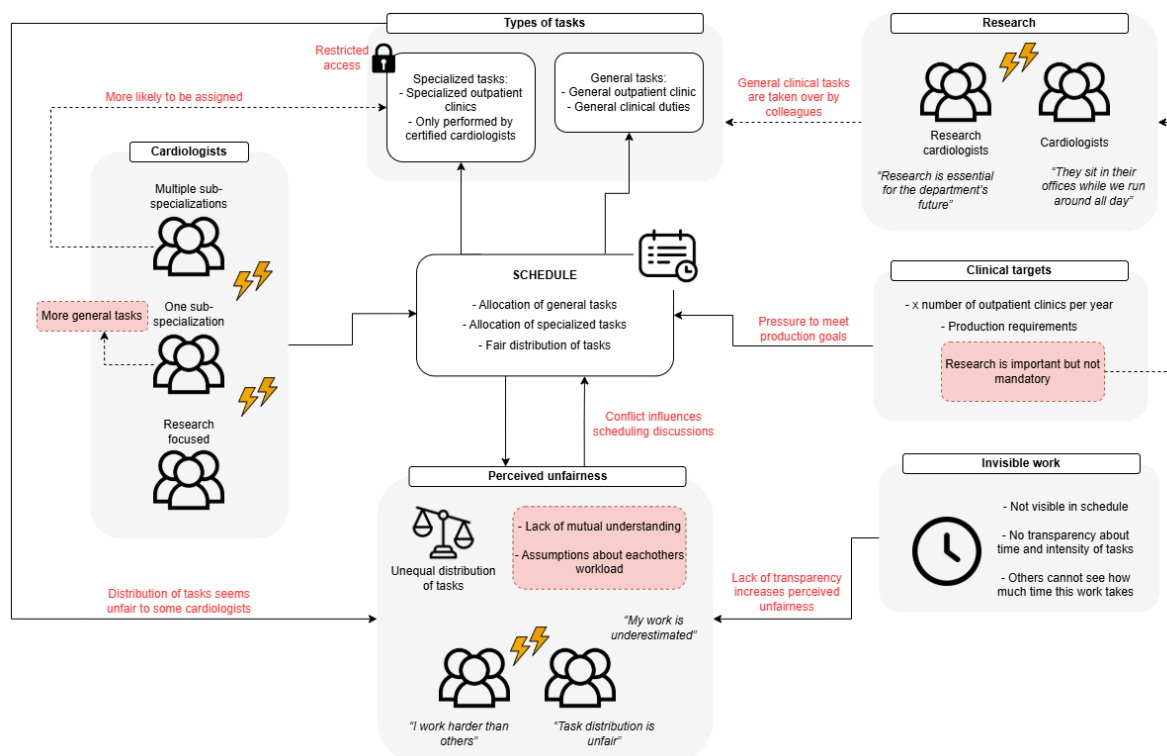


Figure 3.3: Initial rich picture

3.4.1. The outpatient clinic

Based on exploratory conversations with several cardiologists in the department, the current way of scheduling outpatient clinics emerged as a possible cause of the perceived unfair distribution of tasks. In the past, each cardiologist was assigned a fixed day of the week for outpatient clinic. Currently, this is no longer possible because the total number of cardiologists has doubled in the past years. There used to be only 6 cardiologists. This problem could be addressed by scheduling double outpatient clinics, allowing two cardiologists to conduct outpatient clinics simultaneously. However, an outpatient clinic is usually combined with an echocardiogram. The problem is the availability of echocardiography rooms and the individuals performing the echocardiograms. Currently, the outpatient clinic schedule differs every week. As a result, it is difficult to monitor whether the distribution among cardiologists is fair. Therefore, a more effective method must be found to distribute this task fairly among all cardiologists.

3.5. Answer SQ1 en SQ2

This section answers sub-questions 1 and 2. The answers to these questions are used as input for the define phase. Furthermore, the initial rich picture is also used as input for the define phase.

3.5.1. Answer to sub-question 1

Sub-question 1 is formulated as follows: *What factors contribute to an efficient and satisfying schedule?*

First, this question was addressed through a literature review on scheduling in general, not limited to the medical sector. The literature indicates that social factors have become an important consideration

in workforce scheduling, compared to earlier approaches to scheduling. These human factors are the factors that contribute to a satisfying work schedule. The literature revealed several factors that contribute to a satisfying schedule:

- **Fairness:** this is a broad concept consisting of equality and equity. It involves assigning shifts evenly among employees, but also doing so in a fair manner, for example by taking workload into account.
- **Job rotation:** it is important that physicians continue to develop across all aspects of their specialty, while also maintaining their skills. For example, it is not beneficial to assign a physician to the outpatient clinic very infrequently. Job rotation helps maintain skills, while variation in tasks contributes to job satisfaction by reducing monotony.
- **Predictability:** publishing schedules well in advance increases predictability. This contributes to satisfying scheduling, as it allows for the planning of both work and personal life.
- **Consistency:** this results in a more predictable schedule, which contributes to higher satisfaction by allowing cardiologists to anticipate their work patterns. For example, a fixed day off.
- **Flexibility:** this is a form of autonomy, meaning that employees have a form of control and influence over the schedule.
- **Transparency:** open communication about the schedule and the decisions made fosters mutual understanding between employees and schedulers. This reduces conflict and leads to a higher job satisfaction.
- **Rest and recovery:** the schedule should incorporate sufficient rest and recovery time. A schedule that includes sufficient rest and recovery time contributes to higher levels of satisfaction.

However, organizations face the challenge of balancing these human factors with organizational efficiency, meaning that there is often a mismatch between organizational goals and employee needs. Therefore, an efficient and satisfying schedule results from a combination of the human factors identified above and a balanced alignment with organizational goals. In this case, this means that the design of the new scheduling approach must take into account these human factors, as well as hospital regulations and requirements.

Furthermore, sub-question 1 was addressed by conducting a stakeholder analysis based on exploratory conversations with some of the stakeholders. This stakeholder analysis confirmed the findings of the literature review regarding the trade off between institutional efficiency and employee well-being. Cardiologists have the greatest interest in a new scheduling approach, whereas the hospital board holds the greatest power. As a result, the new design must take into account not only the needs of the cardiologists but also hospital regulations and policies.

In additions, the exploratory conversations revealed several needs of the cardiologists regarding a satisfying schedule: a transparent and balanced workload distribution, the schedule must ensure the continuity of care, the schedule must provide sufficient time for professional development, and scheduling decisions should be more transparent.

3.5.2. Answer to sub-question 2

Sub-question 2 is formulated as follows: *How is the current scheduling practice organized at the pediatric cardiology department?*

Cardiologists divide their time between a wide variety of clinical and non-clinical tasks, including outpatient clinics, HC, inpatient ward, imaging, stand-by, professional development, management, meetings, etc. The analysis showed that clinical tasks are generally more intensive than non-clinical tasks. They are more time consuming and more likely to exceed their scheduled duration. As a result, non-clinical responsibilities are often deprioritized despite their importance for the long term functioning of the department. In addition, there is an uneven distribution between clinical and non-clinical tasks. This may create a perception of unfairness. On the other hand, these differences are related to the roles for which cardiologists were hired, and it may therefore present a natural distribution of tasks.

Define phase

This chapter builds on the insights from the empathize phase and further elaborates on the problem. During the empathize phase, an initial assumption was made about the problem within the department. However, it was assumed that the issue might be broader than initially defined. Therefore, the analysis was extended to include the scheduling process and a more in-depth analysis of the problem context. This chapter analyzes the current scheduling process with BPMN modeling. Subsequently, an improved rich picture was created based on the insights from the semi-structured interviews. This chapter answers sub-question 3: *What are the underlying problems in physician scheduling in practice within the pediatric cardiology department?*

4.1. Current scheduling process

To investigate the nature of the scheduling problem in the pediatric cardiology department, a process analysis was conducted. This section explains how the current scheduling process is organized and the challenges it faces.

The pediatric cardiology department currently uses a program named "Matrickx" to share the schedule. Matrickx is a planning tool that was specifically developed for the healthcare sector (Matrickx, n.d.). The schedule is planned three months in advance. Thus, the scheduling process occurs four times a year. Creating the schedule consists of two phases. In the first phase, an administrative staff member is involved. The cardiologists are required to indicate their unavailability in Matrickx and in a separate Excel spreadsheet, shortly before the new schedule will be created. This can relate to time off, such as holidays or attendance at conferences. The administrative staff member either accepts or provisionally approves these requests. Based on these availabilities, the administrative staff member first distributes the inpatient ward cardiologists (the clinic task). Although all cardiologists are qualified to perform this task, it is assigned on a weekly basis, meaning that the assigned cardiologist performs the task for the entire week. 12 weeks must be distributed among 11 cardiologists. Although this seems simple, constraints related to unavailability complicate this process. A conversation with the administrative staff member revealed that this process is done on paper, as it is not possible for them to achieve this within Matrickx. Once this has been fully scheduled, a cardiologist involved in the scheduling assigns the weekend shifts. Weekend shifts must be distributed as fairly as possible among the cardiologists. Once all clinic weeks and weekends have been scheduled, cardiologists can review this preliminary version of the schedule and indicate any objections if necessary. Based on this feedback, the preliminary schedule may be revised.

Subsequently, the second phase of the process starts. In the second phase of the scheduling process the rest of the tasks will be divided. This is done by two of the cardiologists. They finish the schedule together. After the final schedule is published, some complaints may still arise, and adjustments to the schedule may be made. Once all adjustments are completed, the final schedule is confirmed and the outpatient clinics can be registered in HiX. HiX is a Hospital Information System (HIS) that stores patient information. In the outpatient clinic, patients have a designated cardiologist. Therefore, once the outpatient clinic schedule is registered in HiX, appointment confirmations can be sent to patients. The outpatient clinic administration is managed by dedicated staff who schedule patients with the appropriate cardiologist and communicate appointment details. It is therefore crucial that the outpatient clinic schedule is entered in HiX on time, as delays prevent patients from being informed of their appointments on time. If the schedule is finalized later than usual, the administrative staff member managing

the schedule receives inquiries from the outpatient clinic administration. In some cases, cardiologists forget to indicate commitments, such as conference attendance, after the schedule is already finalized. In such cases, the cardiologist's tasks must be taken over, which is often done by the cardiologist scheduled as stand-by. This process is modeled using a BPMN diagram and is presented in Figure 4.1.

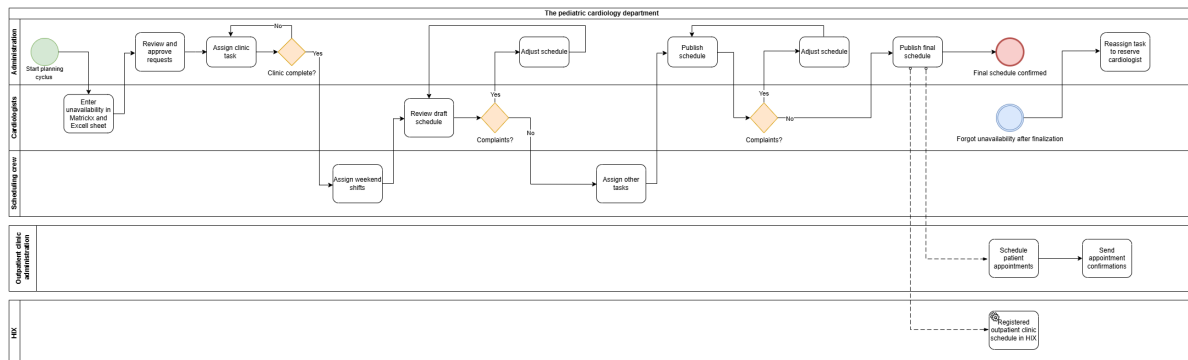


Figure 4.1: BPMN model of the scheduling process

The BPMN diagram reveals several bottlenecks in the scheduling process. First of all, cardiologists have to enter their availability in two separate systems: Matrickx and an Excel spreadsheet. This is unnecessary duplicate work and could be handled more efficiently. Furthermore, the process contains several feedback loops through which cardiologist can communicate their concerns about the schedule. On the one hand, this is beneficial, as it ensures that the physicians' preferences are taken into account. On the other hand, this makes the process long and inefficient. Since the cardiologists have busy schedules, it often takes time before all complaints are collected. Even when the administrative staff member considers the schedule to be finalized, additional complaints may still arise, which makes the process long and exhausting. Additionally, the length of the process also affects the outpatient clinic administration. It is essential that they receive the schedules in time to plan and confirm patient appointments. To find a balance between allowing physicians to submit their preferences and finalizing the schedule, a hard deadline for submitting complaints could be introduced. Another factor that makes the process inefficient is that part of the planning is done by hand. According to the administrative staff member, Matrickx includes an optimization function; however, they do not know how to operate it. Improving familiarity with Matrickx would therefore also improve the process. The current order of scheduling process seems appropriate, as starting with the clinic is efficient given that it is planned for the full week. Scheduling the weekend shifts first is also beneficial, as it allows the remaining tasks to be scheduled while taking into account physicians who have worked a weekend shift. For example, by assigning them fewer clinical tasks on Monday.

Conclusion process analysis

The process analysis revealed that the scheduling process is inefficient. The scheduling process is partially carried out manually, despite the availability of a dedicated software. In addition, the process is time consuming due to multiple feedback loops, which further increases its duration. However, these feedback loops do ensure that the cardiologists' preferences are taken into account as much as possible when creating the schedule. It is therefore a trade-off between improving process efficiency and allowing cardiologists to express their preferences.

In conclusion, the scheduling process is inefficient. However, it does not explain the cardiologists' dissatisfaction with the schedule. Creating the schedules increases employee dissatisfaction among the administrative staff member and the scheduling team, but this is not reflected in the overall physician dissatisfaction. The scheduling process inefficiencies could be addressed by making more efficient use of the Matrickx scheduling software. In order to fully identify the problem, semi-structured interviews were conducted.

4.2. The scheduling problem

This section describes the scheduling problem in more detail. This section builds on the rich picture that was created in the emphasize phase. In the emphasize phase the physician scheduling problem at

the pediatric cardiology department was described based on the exploratory conversations conducted with cardiologists to gain initial insights. In the define phase five semi-structured interviews were conducted with the cardiologists. These interviews gained more details about the scheduling problem at the pediatric cardiology department. Based on these new insights, the rich picture was updated into a more detailed and refined version. A detailed overview of all conducted interviews can be found in Appendix G. Furthermore, the interviews were analyzed using Atlas.ti, to identify common themes and insights. The resulting document groups and codes are presented in section G.2. This section discusses the key insights of the interviews.

4.2.1. Analysis interviews

This subsection presents an analysis of the data collected from the interviews, highlighting key themes and insights. Based on these key themes, the rich picture that was created in the previous chapter will be updated with these new insights. The updated rich picture is presented in Figure 4.2.

Limited control over highly structured schedules

One of the key themes that emerged from the interviews was autonomy and control, which refers to the degree to which cardiologists can manage their time and work. This theme strongly emerged in the interviews. Several respondents indicate that the schedule is highly structured and tightly planned (Interview 2, Interview 3, Interview 5). This leaves little room to complete all tasks on time and offers no flexibility if tasks take longer than expected. However, the tightness of the schedule makes it highly predictable. While the literature suggests that predictability contributes to satisfying scheduling, in practice it does not provide predictable time to complete tasks, leaving work completion uncertain. One respondent describes this experience as follows:

"It feels complicated and like you have little control over your own schedule, at least that's how I personally experience it, and I find that quite frustrating." - Cardiologist, Interview 2

The respondent in interview 2 also indicated that the schedule seems biased by the preferences of its creators, which also creates a feeling of little control:

"I feel like the people who make the schedule also incorporate their own ideas." - Cardiologist, Interview 2

Therefore, the schedule should provide more autonomy and control, rather than being so rigidly planned and overly detailed, which leaves no room for flexibility. At the same time, a balance is needed: the schedule should still provide a degree of predictability, ensuring that there is dedicated time available to complete unfinished tasks.

Overly tight planning leads to disruption of meetings and workload balance

Another prominent theme concerns the planning and structure of the schedule itself. According to one of the participants, the current schedule is outdated and unrealistic:

"For me, this is an unrealistic schedule. I am not able to perform my work properly in this way." - Cardiologist, Interview 5

The schedule does not allow sufficient time to complete all tasks. Consequently, work piles up, which negatively affects the work satisfaction. Because unfinished work has to be completed at other times, priorities are shifted. As a result, meetings scheduled at the end of the day often have a low attendance:

"These kinds of meetings are often scheduled at the edges of the working day. When they are planned at the very beginning of the day, everyone tends to attend, but when they are scheduled at the end of the day, about three-quarters of us tend to drop out." - Cardiologist, Interview 2

Additionally, the research meeting on Monday afternoon is canceled almost every week:

"We also have a research meeting every Monday from five to six, but it is always canceled. I think that is really embarrassing in front of our doctoral candidates." - Cardiologist, Interview 5

Because the schedule is unrealistically full and tasks often cannot be completed within the scheduled time, priorities must be set and trade-offs made. As a result, a research cardiologist, for instance, may regularly have to sacrifice research time.

The required time required for tasks is underestimated

Time allocation emerged as a critical issue, highlighting differences between the time planned for tasks and the time actually required. Respondents in interview 2, interview 3, and interview 5 reported that outpatient clinics and phone appointments, and the related administration, often exceed the allocated time. One of the respondents states:

"I think that overall my outpatient clinic takes more time than is accounted for in the planning."
- Cardiologist, Interview 3

Especially complex patients require more preparation and administration time. Some sub-specialties have a higher proportion of complex patients, which usually means longer preparation times. This leads to tasks spilling over into other periods or finishing work outside scheduled hours. To illustrate the situation, one respondent suggests reducing the clinical production:

"You can choose to finish the outpatient clinic earlier and therefore see fewer patients. That is a disadvantage. But yes, it feels like things are a bit out of control at the moment." -
Cardiologist, Interview 2

Furthermore, a respondent in interview 1 indicated that slack time is unevenly distributed. Some cardiologists consistently receive more flexible tasks than others. These findings indicate that the current system underestimates the time required for complex or variable tasks.

Unequal workload perceptions create friction within the department

Another key theme that emerged from the interviews is workload and task differences. Perceptions of workload differ between sub-specialisms, sometimes causing tension and a sense of inequity within the department (Interview 1, interview 2, Interview 4, Interview 5). Some respondents believe that their sub-specialism has a higher workload than others. One of the cardiologists explained that some patients within a sub-specialisms require substantially more time and emotional involvement:

"These are children who are at risk of suddenly collapsing and dying, and their parents are very worried, so you need to have long conversations with them. That is completely different from seeing a patient who has a simple hole in the heart. Because of this, my outpatient clinics simply take longer than average." - Cardiologist, Interview 2

Additionally, some sub-specializations request more staff for certain tasks, which can lead other cardiologists to think that they consider their own sub-specialism as more important than others and that the additional staff is not actually necessary. As a result, there is a clear friction between the different sub-specialisms, as they often do not understand each other and tend to believe that their own work is more demanding. This imbalance is illustrated by another respondent:

"They sometimes have three or four people in the cath lab, while here on the ward we are left dealing with all the work. Everything goes to the intervention lab, while I have to take over the tasks of an absent cardiologist." - Cardiologist, Interview 5

Furthermore, the interviews revealed that the cardiologists experience a very high workload, which can contribute significantly to stress levels. This high workload is illustrated by one of the cardiologists as follows:

"As a doctor, in addition to all clinical tasks, you also have many management responsibilities. I have a whole portfolio of tasks I need to handle. I am part of the department board, I am responsible for digitization, and I am involved in teaching. I also have, for example, lectures. When I think about it, there are many more tasks, but there are simply a lot of things that you are expected to do." - Cardiologist, Interview 1

Administrative work is insufficiently accommodated in the schedule

There is a lot of administrative work involved in a cardiologist's job and this was highlighted as a recurring challenge. Ensuring this is done properly is crucial for the quality of care. However, it is often left

incomplete and must be finished at a later time. Cardiologists in interview 2, interview 3, and interview 5 reported that there is no explicit time for this in the schedule, forcing them to complete it during slack time or outside formal working hours. This contributes to high work pressure and increases the risk of incomplete documentation. According to one of the respondents, dedicated administration time would improve the work satisfaction:

"I think that if administrative time were actually implemented, at least for me, although that may be different for others, I would work more efficiently. I think it would also reduce some of the pressure." - Cardiologist, Interview 3

Furthermore, there is a significant amount of invisible work in the schedule. According to the respondent in interview 1, this is not a problem as long as sufficient time is allocated to complete it. A large part of the invisible work consists of preparation and follow-up tasks for outpatient clinics. Consequently, the amount of invisible work could be reduced if dedicated time for outpatient follow-up were included in the schedule. However, the schedule is already really full.

Time pressure and workload negatively affect the quality of care

Work performance and quality are factors that are directly impacted by time constraints and workload pressures. Respondents described differences in how thoroughly colleagues complete certain tasks, with some taking more time for detailed work while others prioritize efficiency (Interview 1, Interview 2, Interview 4). When workload is high and tasks begin to pile up, people tend to perform tasks more quickly. One respondent indicated that this way of scheduling is not sustainable for the team and prevents them from delivering the quality of care they aim to provide. However, a respondent stated that this is inevitable:

"One person works in a very driven, precise, and meticulous way, while another approaches things more casually. That is something that will always exist within a group. I do not think you can really prevent that." - Cardiologist, Interview 2

Furthermore, limited time for research was seen as a barrier to maintaining high quality care and keeping up with innovations (Interview 4, Interview 5). A respondent commented as follows on this:

"We are the largest intervention program in the Netherlands for children, and we don't publish anything at all." - Cardiologist, Interview 4

If this is not included in your profile, it has to be done in one's own time. Additionally, enough rest and recovery is an important factor for maintaining the quality of care. Therefore, the work performance and quality could be improved by improving the way of scheduling.

Misalignment in priorities and a lack of shared departmental vision

A lack of mutual understanding and shared vision emerged as a significant theme. Respondents in interview 4 and interview 5 highlighted differences in priorities across sub-specialisms, as well as uncertainty about the department's overall priorities. This misalignment can lead to tension and inconsistent engagement with shared responsibilities. The findings suggest that strengthening collective goals and fostering mutual understanding could improve collaboration and reduce conflicts. This is illustrated by a respondent:

"You need to be able to look each other in the eye, because you are probably not going to agree on everything. But at least everyone should be clear about what they disagree on, and then make a decision together about what to do next." - Cardiologist, Interview 4

Workload and scheduling contribute to emotional stress and reduce physician well-being

The interviews also revealed emotional consequences related to workload and scheduling. Cardiologists reported feelings of frustration, stress, and decreased job satisfaction. An example of these emotions is the following statement by a cardiologist in interview 2 regarding the insufficient time allocated for tasks:

"That is really frustrating, because it makes you feel like you are failing. You start thinking: I take too long, I cannot do it, I am not doing it well." - Cardiologist, Interview 2

Furthermore, fatigue after weekend shifts or night shifts amplifies these emotions. This also has negative effects on the quality of care, as stated by one of the respondents in interview 5:

"At some point, you don't recover from night shifts anymore. Patients still expect you to be friendly, and so do my colleagues. But at a certain point, because of fatigue, I can't do that anymore." - Cardiologist, Interview 5

Therefore, the current scheduling system affects the well-being and motivation of the cardiologists.

Structural limitations and desired improvements in scheduling

During the interviews, the respondents mentioned several desired changes to the schedule. Several respondents indicated that weekend shifts are not compensated, meaning that no day off is provided after working a weekend (Interview 2, Interview 3, Interview 5). Additionally, there is no central system that monitors when cardiologists work on their scheduled days off, for instance during a clinical week. These are days off to which the cardiologists are entitled, but they are often overlooked due to high workload. Properly recognizing these days could help reduce the overall workload. Another theme that emerged from the interviews is the current scheduling process. Cardiologists have to enter their availability twice in different places, and there are also multiple schedules running alongside each other (Interview 1, Interview 3, Interview 4). Respondents also expressed a preference for dedicated time to be scheduled for administrative tasks. All these desired changes indicate that cardiologists need more breathing room in the schedule. However, implementing administration time in the schedule reduced the clinical production. This represents a trade-off that needs to be made. A respondent noted:

"If you really want to do proper scheduling, then some things just cannot be done." - Cardiologist, Interview 5

Positive perceptions of the scheduling process

During the interviews, respondents also mentioned several positive aspects of the schedule. Overall, the cardiologists are satisfied with the schedulers. The cardiologists noted that they make a genuine effort to take their preferences into account. This is also reflected in the scheduling process, which includes multiple feedback loops. Cardiologists are often given the opportunity to indicate when they do not agree with a draft schedule. Furthermore, some of the respondents are happy with the three month scheduling cycle. These positive perceptions confirm that the process inefficiency is not the cause of dissatisfaction among the cardiologists.

Conclusion context analysis

The new rich picture revealed that the problem is much broader than an unfair distribution of the workload. The initial rich picture focused solely on an unfair distribution and mutual blaming. In the initial rich picture, a large part of the problem was attributed to the research cardiologists. However, the interviews revealed that the research cardiologists in turn believe that the problem lies with the HC. The problem therefore does not lie with a specific group, but rather in the fact that the different groups point to each other instead of looking at the overall picture. In the new rich picture, the identification of research cardiologists as a separate group has therefore been revised. What has been added in the new rich picture are mainly different ways of thinking among the cardiologist: differences in workload perception, a lack of mutual understanding and shared vision, and differences in work performance. Therefore, part of the problem is an organizational culture problem. Organizational culture is defined by the shared norms, values, beliefs, expectations, and perspectives that influence the attitudes and behavior of individuals within a group (Chalmers et al., 2025). The beliefs regarding how the department can best provide care are not fully aligned within the group of cardiologists. In addition to its organizational and cultural dimensions, the problem also includes a practical scheduling issue. This also represents a new perspective on the problem in the new rich picture. The schedule is overly tight planned, resulting in tasks not being completed. As a result, work is never finished, which can create a constant sense of time pressure. The tight scheduling of tasks is caused by inaccurate estimates of time allocation and an overall workload that cannot be accommodated within the capacity of the schedule. The interviews revealed several key themes, which formed the basis for the identified problem aspects. The problem aspects are used during the ideate and prototype phase as the basis for the development of the prototypes. Table 4.1 presents the identified problem aspects and shows under which main theme each problem aspect is categorized.

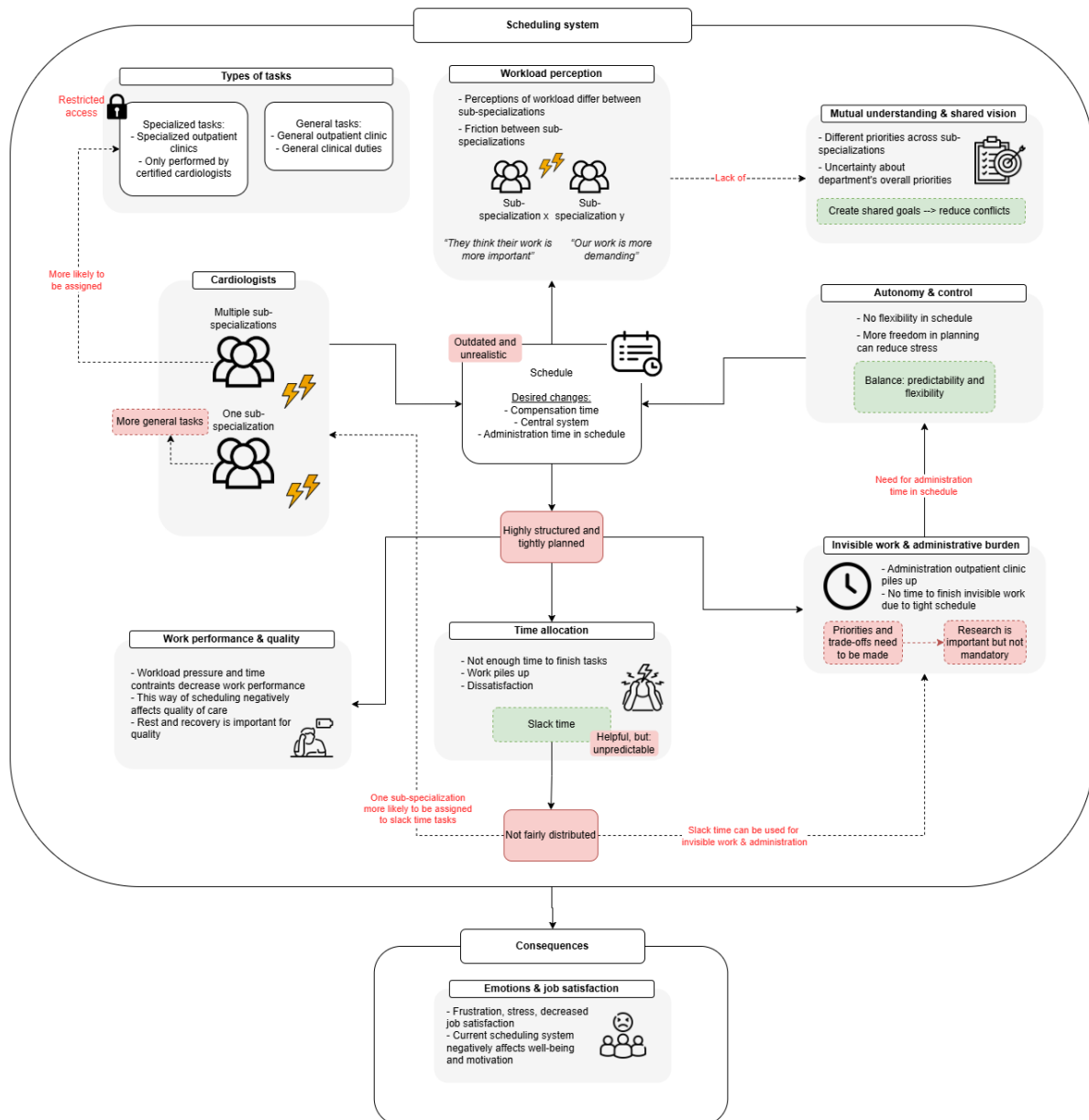


Figure 4.2: Updated rich picture

Table 4.1: Overview of main themes and corresponding problem aspects

Main Theme	Problem Aspects
Organizational culture problem	• Workload and task differences • Work performance and quality • Mutual understanding and shared vision
Schedule related problem	• Autonomy and control • Planning and schedule • Time allocation • Invisible work and administrative burden

4.3. Answer to sub-question 3

Sub-question 3 is formulated as follows: *What are the underlying problems in physician scheduling in practice within the pediatric cardiology department?*

The define phase divided physician scheduling in a process analysis and a context analysis. The process analysis revealed how the scheduling of physicians is currently organized. The context analysis in combination with the process analysis revealed the challenges of scheduling.

The context analysis also revealed several challenges:

- Lack of autonomy and control in the schedule.
- The schedule is outdated and unrealistic. There is not sufficient time to complete all tasks.
- The time allocation is not done properly. There is a difference between time planned for tasks and the actual time required.
- There are different perceptions of workload between different sub-specializations.
- There is a lot of invisible work and a big administrative burden.
- There is a difference between how thoroughly cardiologists handle certain tasks.
- There is a lack of mutual understanding and shared vision

The problem within the pediatric cardiology department can be characterized as an organizational culture problem and a scheduling related problem. The organizational culture problem is related to lack of mutual understanding and a shared vision. The scheduling problem is related to overly tight planned schedules with insufficient time to complete all tasks.

The BPMN model showed that there is also a process inefficiency problem. This relates to the fact that the process of creating the schedules takes longer than necessary. As revealed in the BPMN analysis, the scheduling process contains several feedback loops, and Matrickx is not being utilized to its full potential, resulting in unnecessary delays. However, the process inefficiency problem on the department is primarily experienced by the individuals responsible for creating the schedule, not by the cardiologists themselves. Since the dissatisfaction and tension within the department stem from the organizational culture and the scheduling approach, rather than from the constriction of the schedule itself, the process inefficiency problem is not considered as a contributing factor to the cardiologists' dissatisfaction. For this reason, the decision was made to focus exclusively on the content of the problem and not on the process. Therefore, the prototypes that are developed in the ideate and prototype phase only focus on the organizational culture problems and the scheduling related problems.

Ideate and prototype phase

In this chapter, different ideas for a new scheduling approach are generated based on insights from the emphasize phase, define phase and brainstorming sessions. First, the design criteria and the problem aspects are outlined. The prototypes are based on these criteria. This chapter answers sub-question 4: *How can the current scheduling approach in the pediatric cardiology department be improved?*

Initially, six new scheduling approaches were designed. These six initial ideas were discussed with the problem owner before showing it to the test group. An overview of these six ideas can be found in Appendix H. Based on feedback from the problem owner, five prototypes remained from the initial ideas. These five prototypes are further elaborated in this chapter.

5.1. Design criteria and problem aspects

In this section the design criteria and the problem aspects are outlined. The prototypes are designed based on these elements. The design criteria were established through the literature review conducted in the emphasize phase. Additionally, the problem aspects were identified through the semi-structured interviews in the define phase. They represent the main themes that emerged from the interviews and are also reflected in the second rich picture.

5.1.1. Design criteria

The prototypes were designed to meet as many design criteria as possible. The design criteria also include hospital regulations and policies. This means that certain production requirements must be met, such as the minimum number of outpatient clinics per year. The prototypes are not based on exact numbers. However, it is not feasible to design, for example, a prototype that reduces the current number of outpatient clinics by half. Another example is the requirement that cardiologists must still work a sufficient number of hours.

The design criteria are as follows:

1. **Fairness:** Equality and equity.
2. **Job rotation:** Variation between different tasks.
3. **Predictability:** Knowing schedules and workload in advance.
4. **Consistency:** Standardized expectations for the team.
5. **Flexibility:** Room for personal preferences or changes.
6. **Transparency:** Open visibility of workload and scheduling decisions.
7. **Rest and recovery:** Dedicated time to recover from work.
8. **Professional development:** Opportunities for growth and research.
9. **Hospital regulations and policies:** Institutional constraints and production targets.

5.1.2. Problem aspects

The prototypes aim to directly address multiple challenges identified on the department. The problem aspects are as follows:

1. **Autonomy and control:** The degree of influence physicians have over their schedule.

- 2. Planning and schedule:** Tightly planned and unrealistic schedules.
- 3. Time allocation:** The time planned for tasks is misinterpreted.
- 4. Workload and tasks differences:** Imbalance and perceived variations in task intensity.
- 5. Invisible work and administrative burden:** High workload of unplanned tasks and administration.
- 6. Work performance and quality:** The impact of scheduling on the quality of care.
- 7. Mutual understanding and shared vision:** Shared understanding and alignment of goals and vision among physicians.

5.2. Design concepts

This section presents five prototypes of new scheduling approaches. The prototypes are described in detail, highlighting which design criteria they meet and which aspects of the problem they address.

To make a comparison with the current schedule approach, a simplified representation of the current schedule approach is shown in Figure 5.1. Figure 5.1a shows that a new schedule is created every three months, resulting in four schedules per year. Figure 5.1b shows a day from the schedule, illustrating that each day consists of two four-hour blocks. For example, a cardiologist may have general outpatient clinic during the morning block and be scheduled as stand-by during the afternoon block.



Figure 5.1: Current schedule approach

5.2.1. Prototype 1: Weighted scoring system

The first prototype is a weighted scoring system for the different tasks and is presented in Figure 5.2. In this prototype, each task is assigned an intensity score, and each cardiologist is expected to reach a target workload score per week. These scores are based on the perceived intensity of the tasks, as discussed in section 3.3. The findings in this section indicated that clinical tasks are perceived as more intensive than non-clinical tasks.

Rather than distributing the work solely based on time or number of tasks, this system aims to distribute workload more fairly by taking differences in task intensity into account. To ensure equity, physician profiles should also be considered. Target scores can be adjusted according to the physician's profile, ensuring that differences in clinical and non-clinical responsibilities are reflected in the schedule. Therefore, cardiologists with a clinical profile are required to achieve more points per week than cardiologists with a research profile or a stronger focus on non-clinical tasks.

By assigning workload scores to tasks and defining target ranges for physicians, schedulers are better able to create a balanced schedule while maintaining the overall amount of work. As a result, the system aims to reduce unequal workload distribution without reducing productivity.

The point system is based on current departmental output data. For each task type, the minimum annual volume (e.g. number of outpatient clinics per year) is used to estimate a realistic baseline workload per physician. This baseline is then translated into a weekly target point range, ensuring that the total workload in the system remains aligned with the current clinical capacity.

This prototype is based on section H.1 in Appendix H, in which a complexity score is assigned to patients in the outpatient clinic, in order to distribute patients more efficiently across the available outpatient clinic time. Based on feedback from the problem owner, this prototype was adjusted to ranking tasks instead. Ranking patients is significantly more complex and may also change over time. A patient can go from complex to moderate. In contrast, tasks remain more stable, and therefore are less likely to require further adjustments.

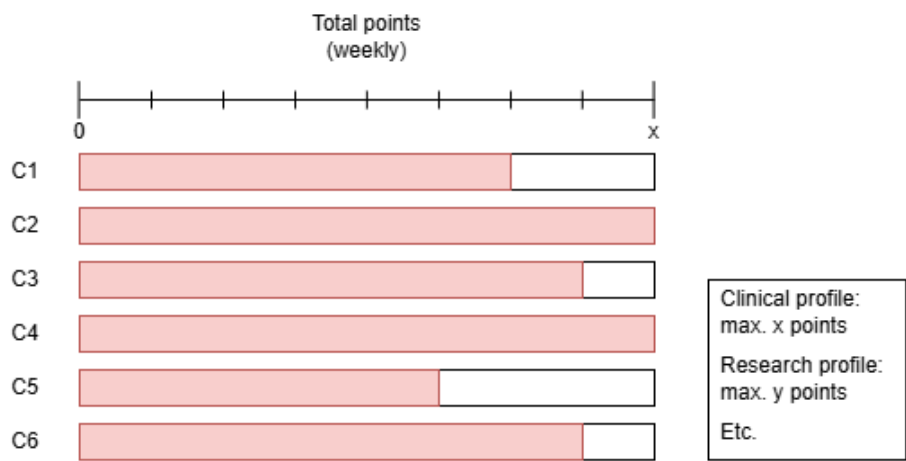


Figure 5.2: Prototype 1: Weighted scoring system. The chart illustrates six cardiologists (C1–C6) and the minimum number of weekly points they are required to achieve. These point thresholds are determined based on each cardiologist’s specific professional profile (e.g., clinical or research).

A disadvantages of this prototype is the big implementation burden. Implementing this prototype requires a significant amount of time and effort. Furthermore, it is possible that not everyone agrees with the raking of tasks, as perceptions of task intensity may differ between individuals.

Design criteria and problem aspects

The design criterion that this prototype most clearly aligns with is **fairness**. Furthermore, it also increases the **predictability** and **consistency** of the schedule, as cardiologists can anticipate their expected workload in advance. This prototype also improves **transparency** by making workload distribution and individual contributions visible across cardiologists. By distributing the workload more fairly, there is also more room for **rest and recovery** in the schedule. This prototype complies with **hospital regulations and policies**.

The different aspects of the problem that this prototype addresses is **planning and schedule, time allocation, workload and task differences** and **mutual understanding and shared vision**. An overview of the design criteria and problem aspects that this prototype covers is presented in Figure 5.3.

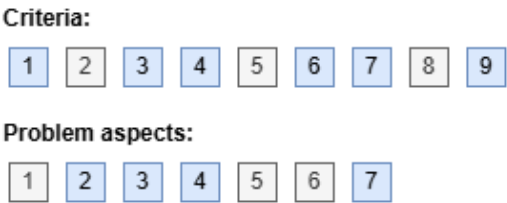


Figure 5.3: Prototype 1: design aspects and problem aspects. Blue blocks indicate that the prototype satisfies the corresponding design criterion or addresses the corresponding problem aspect, whereas gray blocks indicate that it does not.

5.2.2. Prototype 2: 8-hour blocks

In the current schedule, everyday is distributed into two blocks of four hours, as presented in Figure 5.1b. The outpatient clinic is scheduled for one block of four hours and the cardiologists usually see approximately ten patients in this time. In this prototype the four hour blocks for the outpatient clinic are extended to the full eight hours. Thus, when assigned to the outpatient clinic, a full day is dedicated to outpatient care. The goal of this prototype is to reduce the administrative burden associated with the outpatient clinic. The prototype is presented in Figure 5.4. This figure illustrates the current situation, in which there are two outpatient clinic blocks in which ten patients are seen. These blocks are not performed by the same cardiologist. They are simply used to represent a scenario in which both blocks are filled with outpatient clinics. In the new approach, the two blocks are performed by the

same cardiologist. The cardiologist sees more patients on a day than in the current situation, but also has more time allocated for this. In the example of the prototype, a total of 14 patients are seen on a day instead of 20. By structuring the outpatient clinic in this way, more time remains at the end of the day to complete administrative tasks and conduct phone appointments. Another advantage of this approach is that when a consultation takes more time than expected, this does not affect the rest of the day. Overall, this reduces the clinical productivity. However, the current time allocated for outpatient clinics, including administration and preparation, is insufficient. In the long term, this approach may be better for the department, as work is less likely to pile up, resulting in a lower workload. In order to make this prototype more realistic, the department can apply this approach only to the specialization outpatient clinic with more complex patients. This improves the quality of care, as more time is dedicated to complex patients and sufficient time is available to handle administration.

This prototype is based on section H.2 in Appendix H. This first version functions the same as prototype 2, the only difference is that this version has been made more realistic. The initial version had six patients per block of four hours, while in reality this is approximately ten. The improved version also includes breaks. Most specialized outpatient clinics see 10 patients per hour, except for the rhythm and HTx clinics, which see 8 patients per hour. Figure 5.4 is based on 10 patients per hour. However, in the new approach, the clinics that currently see 8 patients per hour are also expected to see 14 patients per 8-hour outpatient clinic blocks.

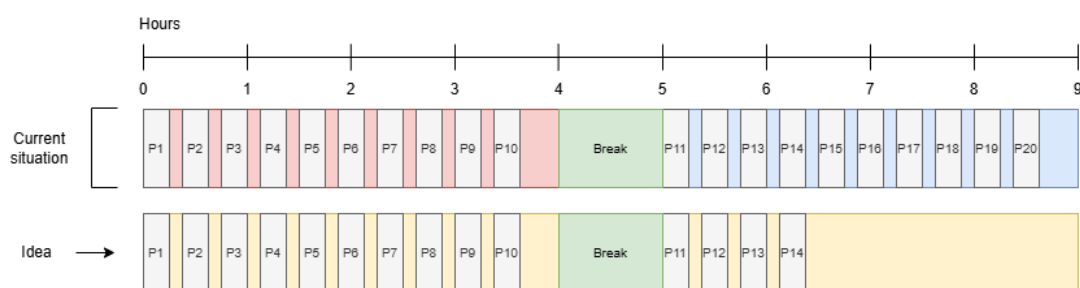


Figure 5.4: Prototype 2: 8-hour blocks. The top timeline (current situation) shows two separate 4-hour blocks managed by two different cardiologists, each seeing 10 patients (20 total). The bottom timeline (proposed idea) presents a single, extended 8-hour block managed by one cardiologist, seeing a total of 14 patients.

Subsequently, the biggest disadvantage of this prototype is the decrease of clinical production. This does not align with hospital regulations and policies. Furthermore, a disadvantage of this approach is that the scheduling process becomes more complex. When a physician is assigned to the outpatient clinic, they are not available for other tasks for the rest of the day. In addition, working in an outpatient clinic for an entire day can be intense.

Design criteria and problem aspects

The design criteria that this prototype aligns with are: **predictability**, **consistency**, **rest and recovery**, and **professional development**. The schedule becomes more predictable. When a physician is assigned to the outpatient clinic, it ensures that sufficient time is available at the end of the day to complete all remaining tasks. Because more time is available to complete all administrative tasks, there is also more time for rest and recovery, as administration no longer needs to be completed outside working hours or during other tasks. This approach also provides more room for professional development. When administrative tasks no longer need to be completed during slack time or other moments, more time becomes available for professional development.

The problem aspects that this prototype covers are **autonomy and control**, **planning and schedule**, **time allocation**, **invisible work and administrative burden**, and **work performance and quality**. Implementing administration time in the outpatient clinic gives physicians more control over their schedule, as they have less work piling up. The outpatient clinic can be finished within the time scheduled for it. By structuring the outpatient clinic like this, the schedule becomes less tightly planned and more realistic. Furthermore, time allocation is improved, as sufficient time is scheduled to complete the task within the allocated time frame. The administrative burden is reduced, resulting in less invisible work.

Finally, work performance and quality of work improves. Because sufficient time is allocated for administration, it can be completed immediately, which improves the quality. In addition, as less work piles up and workload pressure is reduced, physicians are more motivated to perform their work effectively. An overview of the design criteria and problem aspects covered is presented in Figure 5.5.



Figure 5.5: Prototype 2: design aspects and problem aspects (see Figure 5.3 for color coding legend).

5.2.3. Prototype 3: Year schedule with blocks

While the current scheduling system creates detailed schedules for periods of three months, this prototype introduces a global yearly planning approach. The year is still divided into periods of 3 months. However, each cardiologist can indicate in which periods they prefer to do more clinical work and in which periods they want more time for research, administration, management tasks, recovery etc. A representation of this prototype can be seen in Figure 5.6. This allows the workload to vary over the year. The cardiologists indicate their preferences at the beginning of the year and the scheduler will make a fair distribution of the periods. Instead of having a constant, evenly distributed workload, workload fluctuates intentionally over the year, based on the preferences of the cardiologist. This gives everyone:

- Peak periods: periods with a higher clinical workload.
- Moderate periods: periods in which cardiologists do some clinical work combined with other tasks.
- Light periods: periods in which cardiologists do less clinical tasks to give them room to breath and focus on non-clinical tasks.

However, clear rules and arrangements must be established to maintain the department's productivity. Examples include maintaining a minimum number of outpatient clinics per period, limiting the number of cardiologists in their light period at any given time, and restricting holidays during peak periods.

Therefore, the scheduling process takes place on two levels. First, a global schedule for the entire year is created, in which peak, moderate, and light periods are distributed fairly among all cardiologists. Second, every three months a fully detailed operational schedule is created based on the distribution of these periods. For each three month period, the required clinical production targets must be determined to ensure that the overall annual targets can be achieved. For example, the minimum number of outpatient clinics can be distributed among the cardiologists, with those in peak periods assigned more outpatient clinics and those in light periods fewer.

This approach improves the work-life balance, as physicians can choose for themselves in which periods they prefer to work more or less. In this case, physicians know in advance when they will have more time available outside of work, rather than consistently experiencing a high workload throughout the year. Compensating peak periods with light periods can increase motivation by providing something to work toward. Another important aspect of this prototype is that the annual clinical production remains unchanged.

Prototype 3 is based on section H.3 in Appendix H. Based on feedback from the problem owner, this initial idea remained unchanged. The only difference is that it is described in more detail in this section.

However, this scheduling approach requires complex planning and coordination. This results in a more complex and timely scheduling process. Therefore, it must be considered if this approach is worth it or not. Furthermore, a three month peak period can be too long for some individuals. On the other hand, in the current system it is constantly very busy. Some physicians may also disagree with an annual planning approach, as fixing most of the annual schedule in advance reduces flexibility.

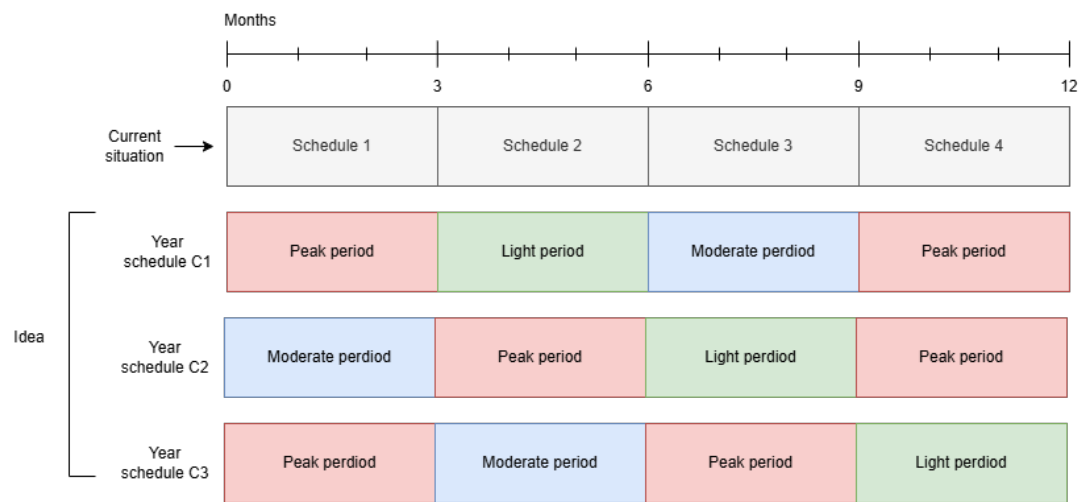


Figure 5.6: Prototype 3: Year schedule with blocks. The top timeline represents the current situation, where a new schedule is created every three months. Below it, three examples of full-year schedules for different cardiologists (C1–C3) are shown. The color coding distinguishes between workload intensities: red indicates peak periods, blue indicates moderate periods, and green indicates light periods.

Design criteria and problem aspects

This prototype aligns with several design criteria. The first one is **fairness**. This scheduling approach makes sure of an equal distribution of clinical and non-clinical tasks among the cardiologists. The **job rotation** criterion is also met in this prototype, as the variation between more clinical and non-clinical work across periods increases job rotation. The **predictability** of the schedule also improves with this approach. **Flexibility** also increases, as the physicians are in control of their peak and lighter periods. Physicians know exactly which periods will be busier and which will be less busy. The **transparency** of the schedule increases because physicians are aware of each other’s peak and light periods, and how the work is distributed among them. Another criterion this prototype aligns with is **rest and recovery**. These light periods offer a longer period of rest and time for recovery. Furthermore, there is time for **professional development** in the light periods. Finally, the prototype meets the **hospital regulations and policies**, as the annual clinical production keeps unchanged.

The different aspects of the problem addressed by this prototype are **autonomy and control, planning and schedule, time allocation, workload and task differences**. In this schedule approach, cardiologists have control over their busier and lighter periods. Distributing the workload ensures that, during light periods, there is sufficient time for tasks for which there is no time during peak periods. An overview of the design criteria and problem aspects covered by this prototype is presented in Figure 5.7.



Figure 5.7: Prototype 3: design aspects and problem aspects (see Figure 5.3 for color coding legend).

5.2.4. Prototype 4: Compensation points

This prototype compensates physicians who want to work extra. In this simple and transparent compensation system, physicians who do not mind can “earn points” for doing extra less popular shifts, such as weekend and night shifts. These shifts typically have a higher impact on work-life balance and recovery. For each extra completed weekend or night shift, a cardiologist receives a fixed number of points. Subsequently, a certain number of points can be traded for a day off or a NPGT day. The aim

of this prototype is to reward physicians who are willing to take on additional weekends and night shifts. In this way, the workload of others is reduced. This system can also be applied to the clinic task or outpatient clinics, which are also high intensity task. Currently, some cardiologists already take on extra work, it would be fair to reward them for it. However, if no one is willing to work additional shifts, the situation remains unchanged and the system continues to operate as it currently does. Furthermore, tasks that are taken over from sick or unavailable colleagues can also be rewarded with points.

In order to make this system work, clear rules and agreements need to be established regarding the exact design of the point system. An example of how this point system could look like is shown in Figure 5.8. Night shifts are assigned 4 points because these shifts have the most impact on fatigue and sleep quality. Weekend shifts are assigned 3 points because these shifts interfere with the work-life balance. However, these shifts are less intense than night shifts, which is why they are assigned fewer points. When a physician chooses to take on additional outpatient clinics, they earn 1 point per four hour block. An extra outpatient clinic is less demanding than a weekend or night shift. The clinic week shift is worth 10 points. This is because this task takes a full week and has a high level of intensity. Subsequently, 12 points can be exchanged for a day off and 10 points for an NPGT day. An NPGT day is assigned fewer points because it is still considered working time, but the physician has more flexibility in how the time is scheduled. The points earned by the cardiologists must be kept up to date in an administration system. When cardiologists wish to take on additional shifts, they can indicate this to the administrative staff member when submitting their availability for creating the new schedule. The type and number of shifts can then be specified. Requests for a day off or NPGT day by exchanging points can also be made to the administrative staff member who maintains the point system.

This prototype is based on section H.4 in Appendix H. The initial prototype has been improved by adding NPGT days as reward and also applying it to the clinic and outpatient clinic. A disadvantage of this system is that it comes with complex administration and implementation. If this system is implemented, all of this need to be tracked, which adds extra work.

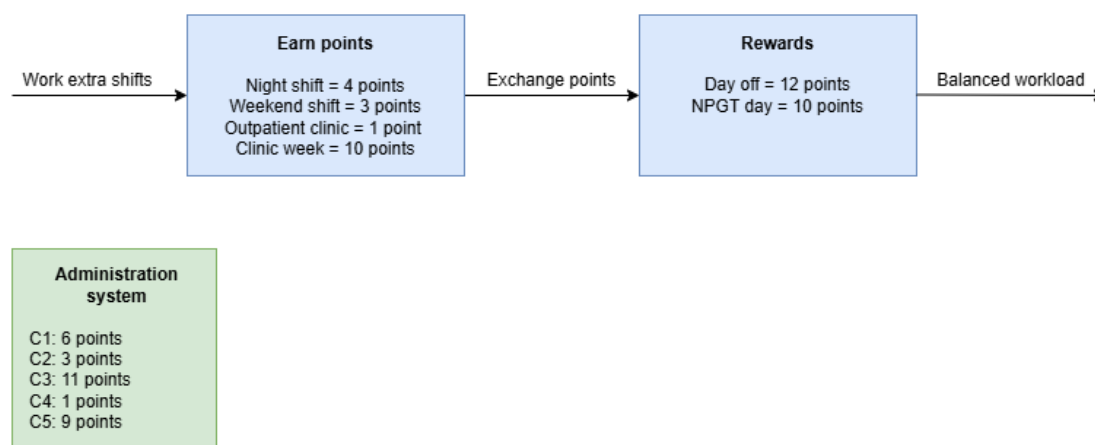


Figure 5.8: Prototype 4: Compensation points. Working extra shifts allows cardiologists to earn points, which can subsequently be exchanged for rewards such as a day off or an NPGT day, ultimately leading to a balanced workload.

Design criteria and problem aspects

This prototype aligns with the criterion **fairness**. Physicians who want to work extra shifts can do so and will be rewarded for it. Those who do not want to work extra shifts are not required to do so. This helps distribute the workload more fairly. This prototype also improves the **flexibility** of the schedule. Physicians can choose whether they want to work extra shifts, and afterwards they can schedule a day off or a NPGT day themselves. The reward system is a **transparent** system. This is also a criterion which aligns with the prototype. Rewarding physicians who want to do extra work with a day off improves **rest and recovery**. The point systems also aligns with **hospital regulations and policies**. Implementing this system does not change the clinical productivity.

The aspects of the problem that this prototype addresses are **autonomy and control**, because physicians have the freedom to make their own decisions regarding extra work and free days. Additionally,

work performance and quality are improved. Rewarding physicians for doing extra work increases motivation. An overview of the design criteria and problem aspects covered is presented in Figure 5.9.



Figure 5.9: Prototype 4: design aspects and problem aspects (see Figure 5.3 for color coding legend).

5.2.5. Prototype 5: Administration time

This prototype is based on information gathered during the semi-structured interviews. During the interviews, several desired changes to the schedule were mentioned. One of these desired changes was dedicated time for administrative tasks in the schedule. In this prototype, every cardiologists receives a half-day of NPGT each week dedicated to administration or other outstanding tasks. To avoid making the scheduling process significantly more complicated, this should be scheduled first, after which the remaining tasks can be scheduled. Implementing administration time in the schedule leads to a reduction of the overall workload. There is time implemented in the schedule to complete outstanding tasks, which creates breathing room for the cardiologists. Work-life balance will also improve, since less work has to be finished outside of working hours.

This prototype is based on section H.5 in Appendix H. According to the feedback of the problem owner this initial idea has changed a little. In the initial version cardiologists received a full day dedicated for administration every two weeks. This has been reduced to half a day per week, as it is best to complete administrative tasks as quickly as possible. It is not favorable to wait two weeks to finish administration.

The biggest disadvantage of this prototype is that it can lead to a reduction of clinical production. Cardiologists have half a day less per week available for other tasks. However, the dedicated administrative time gives the physicians the opportunity to complete their work within working hours and thereby reducing workload. In the long term, this may lead to higher motivation and productivity. Another disadvantage is that creating the schedule becomes more complex. NPGT has to be scheduled and the work planned in this time has to be covered on different days.

Design criteria and problem aspects

This prototype improves the **predictability** and **consistency** of the schedule. Every week there is dedicated time scheduled for administrative tasks. Dedicated administration time also improves **rest and recovery** in the schedule. There is time in the schedule to finish administration, which means that less work has to be finished outside of working hours.

The aspects of the problem that this prototype aligns with are **autonomy and control**, **planning and schedule**, **time allocation**, **invisible work and administrative burden**, **work performance and quality**, and **mutual understanding and shared vision**. Implementing administration time in the schedule gives a sense of control. There is more time to complete tasks and stay on schedule. This also makes the schedule more realistic and less tightly planned. Administration time in the schedule makes the time allocation more realistic. It also improves work performance and quality, as there is sufficient time for administrative tasks. As a result, work piles up less, which leads to higher motivation and job satisfaction. When physicians experience a more consistent lower workload, there is also more room for mutual understanding and a shared vision. Currently, there is no room for mutual understanding and a shared vision because everyone is so busy with their own tasks, that they do not have the capacity to pay attention to others as well. An overview of the design criteria and problem aspects covered is presented in Figure 5.10.



Figure 5.10: Prototype 5: design aspects and problem aspects (see Figure 5.3 for color coding legend).

5.3. Answer to sub-question 4

Sub-question 4 is formulated as follows: *How can the current scheduling approach in the pediatric cardiology department be improved?*

The ideate and prototype phase revealed five different ways in which the current scheduling process in the pediatric cardiology department can be improved. The prototypes are designed based on design criteria and problem aspects that emerged in the emphasize and define phase. The five designed prototypes are as follows:

- **Weighted scoring system:** This prototype gives the different tasks a score based on their intensity. The cardiologists are assigned a target score based on their profile. This prototype improves fairness, predictability, consistency, transparency, recovery and rest and aligns with hospital regulations and policies. The problem aspects that this prototype covers are planning and schedule, time allocation, workload and task differences, and mutual understanding and shared vision.
- **8-hour blocks:** In this prototype the outpatient clinic is scheduled for a whole day, instead of blocks of four hours. This gives the cardiologists more room to complete administrative work. This prototype improves predictability, consistency, rest and recovery, and professional development. The problem aspects that this prototype covers are autonomy and control, planning and schedule, time allocation, invisible work and administrative burden, and work performance and quality.
- **Year schedule with blocks:** This prototype divides the year in peak, moderate, and light periods to distribute the workload. Physicians are allowed to give up their preferences for the distribution of periods. This prototype improves fairness, job rotation, predictability, flexibility, transparency, rest and recovery, and professional development. This prototype also aligns with hospital regulations and requirements. The problem aspects that this prototype covers are autonomy and control, planning and schedule, time allocation, and workload and task differences.
- **Compensation points:** This prototype compensates physicians who are willing to take on extra shifts. The physicians can earn points by doing extra shifts and trade points for a day off or a NPGT day. This prototype improves fairness, flexibility, transparency, and rest and recovery. This prototype also aligns with hospital regulations and policies. The problem aspects that this prototype covers are autonomy and control and work performance and quality.
- **Administration time:** This prototype offers half a day of NPGT time per week to all cardiologists. This time can be used to finish administrative tasks. This prototype improves predictability, consistency, and rest and recovery. The aspects of the problem that this prototype covers are autonomy and control, planning and schedule, time allocation, invisible work and administrative burden, work performance and quality, and mutual understanding and shared vision.

Test phase

This chapter first describes the testing process, followed by a presentation of the feedback on the prototypes, an analysis of the design criteria and problem aspects of the prototypes, and concludes with an improved final design. This chapter answers sub-question 5: *How can the prototypes be refined into a final design based on user validation?*

6.1. User validation

This section summarizes the feedback of the users gathered with the survey. The complete answers to the survey can be found in Appendix I.

6.1.1. Prototype 1: Weighted scoring system

This prototype received generally positive feedback, particularly regarding its potential to improve transparency and fairness in workload distribution. Several participants described this scheduling approach as realistic and potentially beneficial for overall satisfaction. At the same time, there are some concerns about the practical implementation of the weighted scoring system. Respondents emphasized that ranking the tasks would require a clear and well-defined framework accepted by all cardiologists. Additionally, participants noted that perceived workload may differ significantly between individuals. This could limit the effectiveness of the approach. Therefore, careful consultation with the team is required when assigning final scores to tasks. Participants also questioned whether this method is used in other departments and, if so, whether their experiences could be used to further develop the system. The main concern with this system lies in how points can be assigned to tasks in a realistic and fair manner. If this can be achieved effectively, it could be an effective solution.

6.1.2. Prototype 2: 8-hour blocks

Overall, the feedback provided on this prototype was very positive. Respondents considered it a simple, effective, and practically feasible idea. The survey indicated that respondents were very positive about including administration time in the outpatient clinic. However, some concerns were raised about production loss and the frequency of outpatient clinics, which are closely linked to each other. These concerns were also identified as limitations in the ideate and prototype phase. This is a trade-off that needs to be made. Either keep the current situation, with consistently insufficient time for administrative work, or accepting a slightly lower clinical productivity in exchange for more time to finish tasks properly. As previously mentioned, to address this concern, this approach will only be implemented in sub-specialization outpatient clinics. General outpatient clinics would be scheduled in four-hour blocks to compensate for the resulting loss of clinical productivity.

6.1.3. Prototype 3: Year schedule with blocks

The feedback provided for this prototype varies. The respondents are not fully convinced. There are several concerns regarding this prototype. One of the concerns is the implementation of the prototype. This seems complex and unrealistic. Another respondent struggles with the long term planning. Deciding in which periods they have their peak or light periods at the beginning of the year seems difficult. Another concern is the duration of the peak periods. One of the respondents thinks three months is a too long time for a peak period. A peak period that lasts too long can also negatively affect work performance due to exhaustion. An important insight from the feedback is that dividing the year into different periods is not feasible for everyone. For example, in fetal care. Babies are born the entire

year, and Table 3.3 shows that there are only two cardiologists specialized in fetal care. With only two physicians capable of performing this task, it is impossible to alternate between peak, moderate, and light periods. Therefore, this prototype will need to be adjusted, as it cannot be implemented in this way. In order to make it feasible, the different periods could be shortened. However, this would make the implementation even more complex. The survey results also included several suggestions for adjustments to this prototype. A suggestion given by one of the respondents is making this system for the night and weekend shifts. With these adjustments, differences between sub-specializations become irrelevant. Another suggestion is combining this approach with prototype 1. To ensure fairness, everyone must reach a specified number of points by the end of the year.

6.1.4. Prototype 4: Compensation points

Part of the respondents think this is a good and realistic idea, while the other part thinks it is unrealistic. The respondents like the idea of rewarding cardiologists who do some extra work. The main concern is the determination of the intensity of the tasks, because the workload of tasks can vary from person to person. If this is properly discussed with the entire team, agreements can be reached that satisfy everyone.

6.1.5. Prototype 5: Administration time

All responses to this prototype were positive. The cardiologists emphasize that they really need this time. However, it was noted that this is not a very innovative idea. But if a simple solution works, that is also fine. Another comment from one of the respondents is that this time would be helpful after the outpatient clinic. If this time is only scheduled after the outpatient clinic, it would resemble prototype 2. The administration time is intended for administrative work, which is most common in outpatient clinics. It should therefore be considered how effective the administration day is if it is not scheduled at a convenient time. Ideally, this time should be scheduled as close as possible to when you have seen patients.

6.2. Prototype analysis

To determine which prototypes are the most effective, an assessment is also made of which prototypes meet the most design aspects and problem aspects. The previous chapter contains different overviews of the extent to which the prototypes meet the design criteria and problem aspects. This section compares these overviews to determine which designs are effective and which are less effective, based on the insights from this research. This comparison is presented in Figure 6.1. This analysis was then compared with the results of the user validation in order to come up with the final designs.

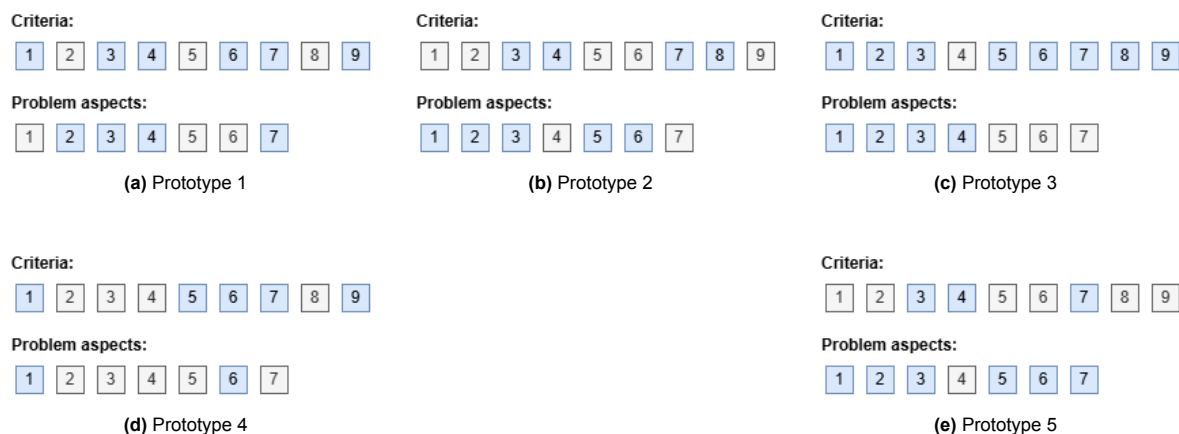


Figure 6.1: Comparison of design aspects and problem aspects across all prototypes

The findings in chapter 4 revealed that the problem aspects that are taken into account during the design process are organizational culture issues and scheduling related challenges. This must be taken into account in the final design.

By evaluating the design criteria for creating a satisfying schedule, prototype 3 meets the most criteria (see Figure 6.1c). This is prototype 3: the year schedule with blocks. This prototype also meets four of the problem aspects. While the prototype satisfies the theoretical requirements, it is not feasible in practice. Implementation is unfeasible due to the cardiologists' sub-specializations. Because it is a good idea on paper, this concept could be applied in a different way. For example, as suggested in the survey, it could be used for weekend and night shifts. In addition, the interviews revealed that there currently is no compensation for the weekend and night shifts. It would be a good idea to distribute the workload of weekend and night shifts throughout the year. However, it is not desirable to have a very high number of weekend shifts and night shifts for three months in a row, even if this is balanced by three months with fewer shifts. There is a significant risk that fatigue and lack of free time reduce the quality of care. Shorter alternating periods were considered, but this would make the scheduling process too complex. For this reason, this prototype was not included in the final design.

Prototype 1 also satisfies a large portion of the design criteria and problem aspects (see Figure 6.1a). This prototype is the weighted scoring system which focuses more on the organizational culture part of the problem. Ideally, the final design would both improve organizational culture and address the scheduling challenges, resulting in a more realistic schedule. The prototypes that focus on making the schedule more realistic are prototypes 2 and 5: 8-hour blocks and administration time. When comparing the problem aspects presented in Figure 6.1b and Figure 6.1e, it shows that these two prototypes cover a big part of the problem. Consequently, elements of these prototypes should be integrated in the final design. Another finding is that both approaches do not meet criterion 9, hospital regulations and policies. Currently, there is a structural lack of time in the schedules, and improving this will therefore require a slight reduction in clinical productivity. Of course, this will not be a significant reduction. Based on the design criteria and problem aspects, the final design requires a combination of prototypes to achieve the most effective solution. The prototypes that address the organizational culture problem are prototypes 1 and 4. These will be combined with the prototypes that focus on making the schedule more realistic, which are 2 and 5. When comparing the design criteria of prototype 4, compensation points (Figure 6.1d), with those of prototype 2 or 5, there is a strong alignment.

6.3. Final design

The final design of a new scheduling approach combines elements of the five prototypes presented in the ideate and prototype phase. This section presents the final design. In order to address the scheduling challenges either prototype 2 or 5 will be integrated in the final design. Based on the user feedback, prototype 2 is a better fit. In this prototype, administrative time is directly linked to the outpatient clinic, whereas in prototype 5 it is scheduled as a separate NPGT day part. Since this time is intended for administrative tasks, it should be scheduled as close to patient consultations as possible to ensure its effectiveness. Additionally, a concern of the user was the loss of clinical production, which is also a design criterion. The loss in productivity is smaller with the 8-hour outpatient clinic blocks than with scheduling half a day of NPGT per week per cardiologist. Therefore, part of the final design will be the 8-hour outpatient clinic blocks. To make it more feasible the 8-hour blocks will only be applied to the specialized outpatient clinics. This will not create additional work when creating the schedule, as the schedule in Matrickx already makes a distinction between different types of outpatient clinics.

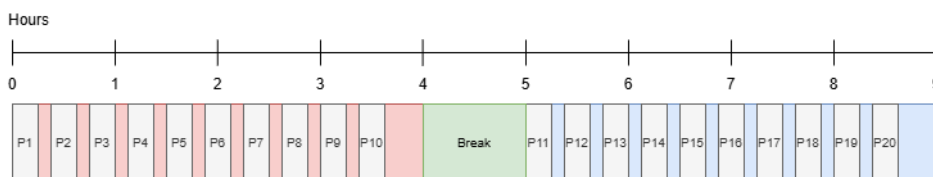
To tackle the organizational culture problem, elements of prototype 1 and 4 will be integrated in the final design. Both of these prototypes involve assigning points to the different tasks. A major concern of the user is the allocation of points to the tasks. First, this can be properly established through consultation and agreements within the team. In addition, this can be simplified by only assigning points to clinical tasks. The emphasize phase indicates that clinical tasks are perceived as more intensive. It is therefore important that these tasks are distributed fairly. The compensation points prototype already focuses solely on clinical tasks. Limiting scoring to clinical tasks simplifies both the implementation and the allocation of points. However, a concern is that assigning points only to clinical tasks may feel unfair to cardiologists with different profiles. Therefore, the minimum number of points required for each cardiologist is determined on their profile. The objective is to achieve a fair distribution of clinical tasks that reflects the cardiologist's specific profile. Assigning points exclusively to clinical tasks makes it possible to account for differences in cardiologists' profiles when distributing the workload. As a result, cardiologists with a lower minimum clinical point requirement will automatically take on more non-clinical

tasks.

In addition, the final design combines prototypes 1 and 4. Each cardiologist must achieve a minimum number of points, which can be obtained by performing clinical tasks. In addition, extra clinical tasks can be undertaken, for which additional points can be earned. Any points above the required minimum can be exchanged for a day off or an NPGT day. To simplify the administrative process, the period in which the minimum number of points must be achieved is extended from one week to three months. This period corresponds to the scheduling cycle. The minimum number of points that must be achieved varies per profile. Physicians with a clinical profile will be required to collect more points than physicians with a research profile, for example. Every three months, when the schedule is created, cardiologists are assigned clinical tasks based on their minimum number of points. In addition, cardiologists can indicate whether they wish to take on extra clinical tasks during that period, as well as the type of tasks they prefer. In this way, elements of prototype 3 are incorporated into the design. Cardiologists can create their own "peak periods" and subsequently exchange points to create "light periods". The point system ensures a fair distribution of clinical tasks among the cardiologists.

Thus, the the final design consists of two parts. First, specialized outpatient clinics are scheduled in eight hour blocks, including administration time. Furthermore, clinical tasks are allocated points. Each cardiologist is required to achieve a minimum number of points per three month period. This number is based on their profile. In addition, cardiologist can earn extra points by performing additional clinical tasks. These points can subsequently be exchanged for days off or NPGT days. A representation of the two parts of the final design are presented in Figure 6.2 and Figure 6.3.

General outpatient clinic:



Specialized outpatient clinic:

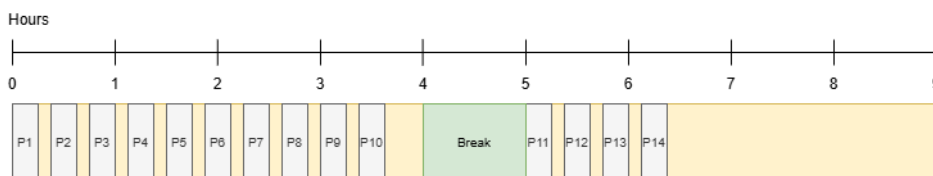
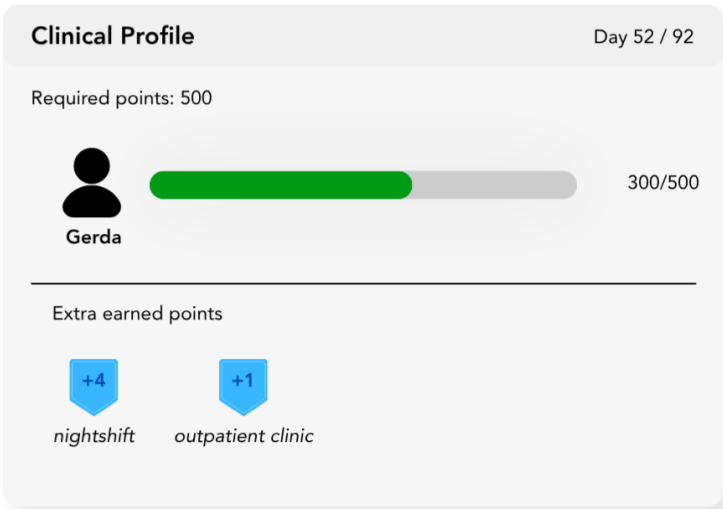
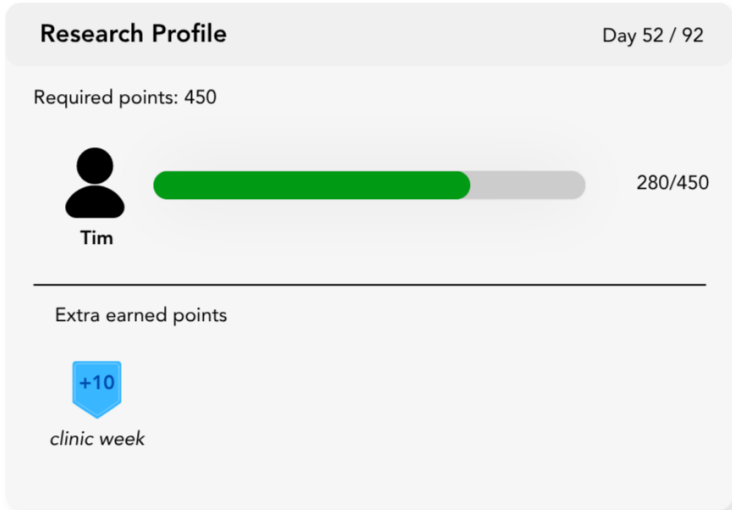


Figure 6.2: Final design: part A. The top timeline shows the general outpatient clinic, which remains unchanged from the current situation, featuring 4-hour blocks per cardiologist with 10 patients each. The bottom timeline illustrates the specialized outpatient clinic, where the schedule is extended to a single 8-hour block with 14 patients, creating designated time for administration and unexpected delays.

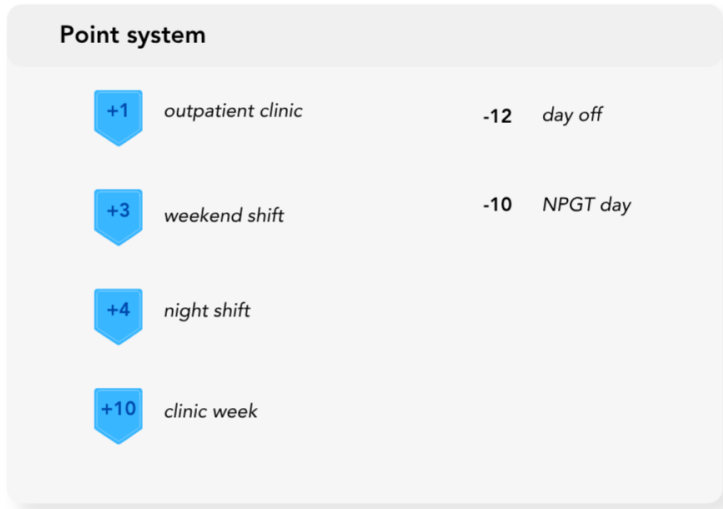
The biggest disadvantage of this design is the reduction in clinical production. As previously discussed, this is the only way to address the unrealistically overloaded schedule. Because a trade-off must be made between physician well-being and organizational efficiency, a balanced solution should be developed. Therefore, this reduction will be compensated for. To reduce the decrease in clinical production, the 8-hour block is applied exclusively to specialized outpatient clinics. Furthermore, by improving physician satisfaction with the schedule, for example by adding extra time for the outpatient clinic, this is expected to lead to higher motivation and improved job performance in the long term (Hossain, 2023). To determine the reduced institutional efficiency of the final design, the number of additional FTE required to compensate for the reduced production was calculated. The full calculation is presented in Appendix J, showing that the implementation of the final design requires 0.43 additional FTE. To put this in practical perspective, 0.43 FTE is about 17.3 hours per week (assuming a 40-hour workweek). This increase could be covered by hiring a new cardiologist, assuming the department's clinical production remains the same. As a result, the loss in patient volume can be fully compensated. Overall,



(a) Clinical profile



(b) Research profile



(c) Point system

Figure 6.3: Final design: part B. Overview of the point system interface, displaying a clinical profile (a) and a research profile (b) with their required three-month point thresholds and any extra points earned through additional tasks, alongside the specific point values assigned to tasks and rewards (c).

this investment offers a practical solution for the production loss while keeping the main benefits of the final design, such as more administration time and more buffer time for patient overruns. Because the specialized outpatient clinics require specific expertise and cannot be performed by every cardiologist, hiring one additional cardiologist would not fully resolve the capacity constraints. Nevertheless, it would increase scheduling flexibility and help mitigate the resulting loss in clinical production.

Another disadvantage of this design is that implementing the point system requires considerable effort and time. The presented system in Figure 6.3 serves as an example of how the point system could be implemented in practice. Developing a fully integrated digital system may require external software support or further technical development. However, the system could initially also be managed through a simpler administrative approach. The distribution of points in this example is based on an initial estimation and serves as an illustrative example. In practice, this should be determined more accurately based on clinical output data. To develop an appropriate point allocation for the different tasks, data on FTE allocation and the number of hours required for each task would be needed. However, collecting and analyzing these data is beyond the scope of this thesis. The weighting of different tasks and the number of points per profile should also be determined in collaboration with the team. It is important to reach an agreement with the team on the point allocation for the different tasks. If there is no agreement on this, dissatisfaction and perceptions of unfairness may still arise. However, if the point allocation is supported by calculations based on hospital output data, consensus among stakeholders can be achieved more efficiently. Therefore, the hospital first needs to determine the point allocation based on hospital output data, followed by a meeting with the team to discuss the point allocation and come to an agreement. Furthermore, during the development of the point system, cardiologists can pay closer attention to how they spend their time in order to support a more meaningful team discussion.

Impact final design on other stakeholders

This study has demonstrated that many different stakeholders are involved. This section reflects on the impact of the final design on two important stakeholders: the head of the department and ICM. These two stakeholder have a high level of power within this project.

First, the impact on the head of the department. The implementation of the final design will lead to a reduction in clinical production, which represents a direct threat to this stakeholder's interests. However, implementation of the final design is estimated to require an additional 0.43 FTE per week. Since the department has a vacancy for a new pediatric cardiologist that has been open for some time, which could fulfill this additional 0.43 FTE (if the clinical production of the department remains unchanged), this may serve as a motivation for the head of the department to pursue this further. Furthermore, the reduction in clinical production should be weighted against the final design's expected benefits. The implementation is expected to increase physician satisfaction, which improves the quality of care. Therefore, the head of the department faces a trade-off between short term investment costs and maintaining the current situation.

Additionally, the impact of implementation of the final design on ICM. The final design reduces clinical production, which is intended to be compensated by hiring an additional cardiologist instead of increasing the workload of existing staff. From ICM's perspective, this is less efficient because the same output is achieved with more staff, which goes against the goal of using resources as efficiently as possible. However, implementing the final design may also result in higher employee satisfaction, which in turn may increase their willingness to work harder.

Design criteria and problem aspects

Compared to all prototypes, this design shows a substantial improvement in terms of the design criteria and problem aspects. The design improves the **fairness** of the schedule, on the condition that the points are allocated in a fair manner and that there is consensus among all cardiologists. The most intensive tasks, clinical tasks, are distributed fairly among the cardiologists through a point based system. In addition, extra work is rewarded. This design also improves the **predictability** and **consistency** of the schedule, by including administration time after the outpatient clinic. Giving the cardiologists the opportunity to do extra work, or not, increases the **flexibility** of the schedule. Two other design criteria that are improved by the point system are **transparency** and **rest and recovery**. The point system is a transparent system in which the cardiologist know that the workload is distributed evenly. The earned days off support rest and recovery, as does the administration time included in the outpatient clinic. As

as a result, less work needs to be completed outside working hours. Furthermore, there is room for **professional development** in the final design. Cardiologists who wish to undertake additional outpatient clinics or clinic weeks have the opportunity to do so and are rewarded for this. In addition, the point system ensures a fair distribution of clinical responsibilities, allowing cardiologists with a research profile to devote adequate time to research. The 8-hour outpatient clinic blocks result in a slight decrease in clinical production. However, this is compensated by applying them only to specialized outpatient clinics, and the point system allows physicians to take on additional work. With the appropriate measures, this reduction in clinical production can be managed, for example by hiring an additional cardiologist. Therefore, the final design complies with **hospital regulations and policies**.

The aspects of the problem that this design aligns with are **autonomy and control, planning and schedule, time allocation, workload and task differences, invisible work and administrative burden, and mutual understanding and shared vision**. The opportunity to earn extra points increases autonomy and control. In addition, the inclusion of administration time provides greater control over the schedule. The inclusion of administration time also makes the schedule more realistic and tackles the administrative burden. Assigning points to clinical tasks provides better insight into time allocation, workload, and task differences. Finally, the point system provides insights into the distribution of workload, which contributes to better mutual understanding. An overview of the design criteria and problem aspects that this design covers can be found in Figure 6.4.

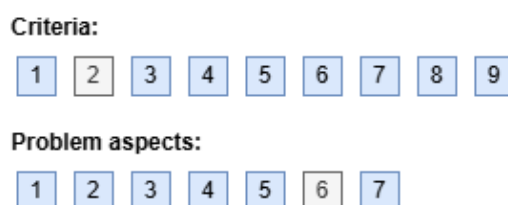


Figure 6.4: Final design: design criteria and problem aspects

When looking at the design criteria and problem aspects, the final design is a strong concept. However, implementation will not be possible immediately, as further development is still required. For the 8-hour outpatient clinic blocks, a new cardiologist will need to be hired if the hospital does not want to reduce clinical production. In addition, the point system still needs to be fully developed. Therefore, this study also provides a short-term solution that can be implemented immediately, while the final design is being further developed.

The short-term solution will function as a quick fix. The interviews revealed considerable frustration among the cardiologists, indicating that changes should be implemented as soon as possible. The survey shows that the cardiologists were very positive about prototype 5, administration time. This is a simple measure that can be implemented immediately. However, this quick fix only addresses the scheduling aspect of the problem, namely the lack of time available to complete all tasks. Therefore, it is also recommended to schedule a big staff meeting in short term to discuss organizational culture and improve mutual understanding. An external facilitator could also be hired to lead a workshop on this topic. This short-term solution can be tested while the final design is being developed, which is expected to be the more structural and sustainable solution.

To do list for implementation

If the department decides to implement this final design, several steps need to be taken:

1. Implement the short term solution immediately: adding administration time in the schedule and organize a big staff meeting about organizational culture.
2. If the reduction in clinical production is a problem for other stakeholders, such as the head of the department, try to hire a new cardiologist.
3. The 8-hour outpatient clinic blocks can be implemented if the hospital hires an additional cardiologist or if a reduction in clinical production is considered acceptable.

4. The clinical output per three months needs to be calculated, after which it can be translated into a corresponding point distribution per clinical task.
5. The minimum number of points per three-month period for each profile must be determined.
6. The results of step 2 and 3 must be discussed and approved by the team, after which any necessary adjustments can be made.
7. The system must be implemented administratively.
8. Make a decision on whether the system should be further developed by outsourcing its implementation.

6.4. Answer to sub-question 5

Sub-question 5 is formulated as follows: *How can the prototypes be refined into a final design based on user validation?*

The final design was created by combining elements of the five prototypes developed during the ideate and prototype phase. Based on user validation and an analysis of the design criteria and problem aspects, elements of the prototypes were adapted and combined into a final design. Comparing the design criteria and problem aspects of the prototypes showed that combining the prototypes addressing scheduling issues with those addressing organizational culture results in the highest alignment with both the design criteria and the problem aspects. The user feedback also revealed that the implementation of prototype 3 is not feasible, even with potential adjustments.

The final design consists of two parts:

1. **8-hour outpatient clinic blocks:** Specialized outpatient clinics will be done in blocks of 8-hours, including administration time.
2. **Point system:** Clinical tasks will be assigned points. Each cardiologist is required to reach a specified number of points every three months. This number is based on their profile. Additionally, extra points can be received by working extra shifts. Extra points can, in turn, be traded for a day off or a NPGT day.

This design satisfies almost all design criteria and problem aspects. However, there are two limitations. The first limitation is that scheduling 8-hour blocks for the outpatient clinic results in a reduction in clinical production. This is compensated by only applying this to specialized outpatient clinics. Furthermore, allocating additional time in the schedule for administrative tasks cannot be achieved without a reduction in clinical productivity. The interviews and user validation show that this additional time is indeed necessary. To compensate for the additional 0.43 FTE created by the final design it is recommended to hire an additional cardiologist. The second limitation of the final design is that the implementation of the point system is a complex and time-consuming process. The department can decide whether and how to implement this, either internally or outsource the development to professionals.

Because the development of the final design is a time consuming process, this study also provides a short term solution that can be implemented immediately. This short term solution consists of implementing prototype 5, adding administration time to the schedule, and organizing a big staff meeting to discuss the organizational culture.

Discussion

First, deeper insights into the content of this research are discussed, followed by methodological insights derived from a comparison with other studies, as well as the limitations and future research. This chapter finishes with the scientific contribution of this study.

7.1. Comparison to literature about scheduling

The findings of this study confirm that the factors identified in the general scheduling literature, such as fairness, predictability, and sufficient recovery, are also applicable to the pediatric cardiology department. However, the complexity of this department makes the scheduling problem fundamentally different than in most existing studies. Many studies on workforce scheduling, such as the studies by Aksu and Dinç (2025), Metha et al. (2021), and Mohd Razali et al. (2025), focus on nurse scheduling. The findings of this study suggest that the presence of sub-specializations and the differences in task intensity make the scheduling problem for medical specialists much more complex than assumed in those studies. Santos and Eriksson (2014) confirm this observation by stating that nurse scheduling has been studied extensively, whereas physician scheduling has received much less attention. In the literature about nurse scheduling, the focus is often on the fair distribution of shifts (Aksu & Dinç, 2025). However, this study suggests that the problem extends beyond an unfair distribution of shifts. The scheduling problem at the pediatric cardiology department also involves organizational culture problems and process inefficiencies, and an overly full, unrealistic schedule.

Additionally, a key finding of this study is that the scheduling problem in the pediatric cardiology department is not mainly a distribution problem, but also a capacity problem. The number of tasks and responsibilities is consistently higher than the available time of the cardiologists. This makes this study different from most existing literature about scheduling, where mathematical models and AI-based systems are used to distribute tasks in an optimal way, assuming that the total capacity is sufficient (Gerlach et al., 2025; Mohd Razali et al., 2025; Renggli et al., 2025; Walter et al., 2024). In this situation, optimization could improve the distribution of tasks, but it cannot solve the underlying capacity problem. The problem would therefore not disappear, but simply move to a different point in the schedule or to a different cardiologist. Therefore, this study examines a new scheduling approach that improves unrealistic scheduling. Furthermore, this study shows that designing a satisfying and efficient schedule does not necessarily require mathematical optimization models. Instead, significant improvements can be achieved by making relatively simple adjustment to the way of scheduling. The final design demonstrates how these pragmatic adjustments to the scheduling approach can make the schedule more realistic and ensures a more fair distribution of tasks. This implies that organizations do not always need to rely on advanced AI or mathematical models to achieve positive outcomes when it comes to scheduling.

Furthermore, a major theme in workforce scheduling literature is finding a balance between employee well-being and organizational efficiency (Barker et al., 2025; Gerlach et al., 2025; Schaepe et al., 2025; Şimşek & Kundakcioglu, 2020). These two factors are often considered as conflicting priorities. However, the findings of this study suggest that this can be viewed from a different perspective. In the final design, extra administration time was added to the outpatient clinic, in order to decrease the tightness of the schedule. While adding extra time in the schedule might look like a decrease of efficiency, existing literature about scheduling supports the idea that this approach benefits organizations in the long term (Aksu & Dinç, 2025; Hossain, 2023). By reducing a structural workload pressure, physician satisfaction

improves, which improves the quality of care. Therefore, this suggests that making the schedule more realistic not only benefits the employees, but also the organization in the long term.

Another important finding of this study is that clinical tasks are often prioritized over non-clinical tasks because they involve direct patient care. As a result, important but non-mandatory tasks, such as research, are often the first to be deprioritized. This issue has not really been addressed in the literature. Previous studies, such as the study of Nohara et al. (2014) and Santos and Eriksson (2014), address the different responsibilities of physicians, such as patient care, education, research, professional development, and administration. However, it does not discuss the prioritization of clinical tasks. The final design indirectly addresses this issue. By allocating additional administration time in the outpatient clinic, work can be completed during the scheduled hours, thereby reducing the need to finish these tasks during time scheduling for other, non-clinical tasks.

7.2. Methodological insights

This study used a socio-technical approach to develop a new scheduling approach that balances human factors with organizational efficiency. As mentioned before, mathematical approaches are dominating the field of scheduling (Bagheri et al., 2016; Knust & Xie, 2017; Maenhout & Vanhoucke, 2012; Metha et al., 2021; Mohd Razali et al., 2025; Narlı & Derse, 2025; Zanda et al., 2018). Previous studies that developed a scheduling system using mathematical programming often struggled with applying them to real hospitals (Drake, 2013). According to Böðvarsdóttir et al. (2021), only a fraction of the research done on nurse scheduling is implemented in practice. A key reason for this is that mathematical models simplify the scheduling problem into measurable constraints, which make it difficult to capture the real complexity of a hospital environment (Knust & Xie, 2017). Research of Böðvarsdóttir et al. (2021) supports this statement and argues that developing the mathematical model is not the biggest challenge. According to their research the biggest challenge is incorporating all the informal considerations that are not documented. The socio-technical approach used in this study does not face this limitation. This study explores the nature of the scheduling problem faced by the pediatric cardiology department first, before developing a solution. After examining the problem, targeted prototypes were developed. The study of Böðvarsdóttir et al. (2021) also confirms that open dialogue with the users during the development of the new scheduling approach is necessary to capture all their needs and preferences. In this study, this is done through the iterative prototyping process. The feedback provided by the cardiologists led to adjustments to the prototypes that would not have been made if the research was based on the literature only. Although the final design has not been tested in practice, it is considered applicable within the hospital. However, the approach used in this study can be applied in other hospitals.

Additionally, a study that used a similar approach as this study is that of Uhde et al. (2021). This study designed a self-scheduling app for healthcare workers, that focuses on employees well-being using a socio-technical approach. In order to design an effective scheduling tool, interviews and focus groups were conducted with the healthcare workers (Uhde et al., 2021). The design criteria that emerged from the interviews of this study align with the findings of Uhde et al. (2021), for example, predictability, allocation of workload, and rest and recovery. However, there is a difference in how these are implemented in the schedule design. The study by Uhde et al. (2021) adopted a self-scheduling approach from the beginning of the study. By applying a self-scheduling approach, their main focus lies on autonomy and improving work-life balance. In this study, the SSM provided insights into how to deal with a group of stakeholders with conflicting interests and perspectives on the problem. This resulted in a wide range of problem aspects, resulting in a wide range of different prototypes. These prototypes all focus on different aspects of the problem. Furthermore, the first feedback of the problem owner stated that a self-scheduling system is not feasible on the pediatric cardiology department. A self-scheduling system was one of the initial prototypes (see Appendix H). Therefore, using SSM provided additional insights into designing a broader solution space and identifying appropriated solutions for a complex environment. Uhde et al. (2021) assume that dissatisfaction with the schedule is primarily caused by scheduling practices that focuses on organizational efficiency and do not incorporate employee well-being. This study found that the problem goes beyond this, and is also about process inefficiency, organizational culture, and capacity issues (i.e., tight schedules). However, this is specific to the department involved in this study. In the study by Uhde et al. (2021), the problem may have been limited to a lack of autonomy. Consequently, this study develops a broader solution space in which users are

able to provide feedback on the designed prototypes. This iterative process resulted in a final design that best addresses the specific problems of the department.

Furthermore, Uhde et al. (2020) also acknowledges that the scheduling problem goes beyond an optimization problem, in contrast to many mathematical studies. This study of Uhde et al. (2020) also uses a socio-technical approach, in which in depth interviews were conducted to design a sketch for a fair scheduling system and they also summarize usable findings for designers. The main goals of this sketch are equality, equity, transparency, and conflict resolution. This study confirms these factors and extends the analysis by demonstrating how they can be implemented in actual scheduling prototypes. Findings from Uhde et al. (2020) also show that healthcare workers prefer scheduling decisions that are made together with colleagues rather than by computers alone. This supports the use of SSM, which focuses on involving different stakeholders in the decision-making process.

7.3. Limitations

Despite the valuable insights provided by this study, several limitations should be acknowledged. One limitation of this study is related to the literature search strategy. The literature review identified several factors that contribute to a satisfying schedule, such as predictability, consistency, and flexibility. However, no additional literature search was conducted using these specific terms. Consequently, relevant literature may have been missed, which could have led to blind spots in the findings.

Another limitation of this study is related to the semi-structured interviews. Only five out of the eleven cardiologists were interviewed. The aim of the study was to interview approximately half of the cardiologists, which was achieved. However, it is possible that the views, preferences, and needs of all cardiologists are not fully represented in the findings. Due to time constraints, the decision was made to interview approximately half of the cardiologists. Furthermore, participation was voluntary, and five cardiologists chose to participate. Therefore, data saturation was not reached, meaning that additional interviews may have yielded new insights. The findings of this study should be interpreted with caution, as they may not fully capture the complete range of perspectives within the department. Another limitation of this study is the possibility of a researcher bias during the interviews. Certain responses may have been interpreted as more important than others. Furthermore, unconscious bias could have influenced the interpretation of participants' responses. Another limitation is that some participants may have expressed their opinions more clearly and more extensively than others. As a result, certain perspectives may have been represented more strongly in the findings. In addition, some participants may have felt more comfortable sharing their opinions openly than others, which could have influenced the depth and variety of the collected data.

Furthermore, a limitation of this study is related to the generalizability of the findings. Since the study was conducted within a single department of a hospital, the findings may not be applicable to other settings. However, the method used in this study can be applied in other settings. Furthermore, the study developed a lot of prototypes, not all of which were suitable for the pediatric cardiology department. However, the ideas behind these prototypes may still be applicable to other hospitals or sectors.

Due to time constraints, the prototypes and final design were not tested in practice. Ideally, the design would have been implemented within the department. Followed by an evaluation of their effectiveness. In this study, the test phase was based on user feedback on conceptual prototypes rather than long-term practical use. As a result, the actual effectiveness and usability of the design in daily practice are not certain.

A further limitation of this study concerns the involvement of the various stakeholders in the validation of the final design. Throughout this study, the design was developed and evaluated exclusively with the direct users of the final design, the cardiologists themselves. While this ensured that the final design fits the needs and constraints of its direct user, it also means that the design was never critically evaluated by other stakeholders with different roles and responsibilities. Since the design was developed and validated by the same group, there is a risk that the validation process confirmed the assumptions of those involved rather than critically challenging them. Stakeholders such as the head of the department, the hospital board, or ICM may have fundamentally different perspectives on the proposed scheduling approaches. Therefore, involving these stakeholders in the testing phase could result in stricter constraints and may have led to a different or further refined final design. Therefore,

it remains uncertain whether the final design is feasible. For instance, the hospital board or ICM may find the reduction in outpatient clinic capacity financially unacceptable given the production targets and agreements with health insurers (Rijksoverheid, 2022). ICM may also raise concerns about how the reduced clinical production affects planning and capacity on other departments in the hospital. Because prototypes were only validated by cardiologists, this study focuses more on physician satisfaction and less on institutional efficiency.

This limitation is particularly relevant when considering a key trade-off in the final design, namely the reduction in clinical production resulting from the final design. From the perspective of the cardiologists, this trade-off is acceptable, as it reduces structural workload pressure and is expected to improve physician satisfaction. However, this conclusion does not consider stakeholders for whom clinical production is of greater importance. While this introduces a bias that should be acknowledged, the findings from this study suggest that the reduction in clinical production is caused by a structural problem rather than a design flaw. Workload pressure is structurally high and physicians are forced to complete work outside of scheduled hours. This is not limited to this department but this is also seen in other hospitals. A small reduction in clinical production may therefore be necessary, not because clinical production is not important, but because the current level of clinical production appears to be unfeasible. These stakeholders were not directly involved in validating the final design, and the proposed reduction in clinical production conflicts with their priorities. However, this study may help them recognize the seriousness of the issue.

This raises an important question for the broader Dutch healthcare context: what does it mean if maintaining clinical production requires accepting structurally unsustainable working conditions? Dutch hospitals are funded by health insurers based on their clinical production. Therefore, if a hospital sees fewer patients, it also receives less funding. This also highlights why broader stakeholder involvement is necessary for the feasibility of the final design. In addition, healthcare is a fundamental right, and everyone has the right to access it. By seeing fewer patients, waiting times in the department will increase. However, maintaining maximum clinical production at the expense of physician well-being also carries risks. Physicians who are constantly exposed to high workload pressure have a higher risk of burnout and dropping out, and thereby potentially reducing the quality of care. Ultimately, this trade-off cannot be addressed by the department alone. The final design offers a solution for the cardiology department studied in this research, but the structural mismatch between healthcare demand and physician capacity requires action at a higher level.

7.4. Future research

Based on the findings and limitations of this study, suggestions for future research can be made. To address the limitation of the literature review, future research could perform a more iterative literature search strategy, including targeted searches based on emerging factors. This may result in a more detailed list of design criteria. In addition, larger samples of physicians could be included to ensure a broader representation of perspectives on the problem. In order to create a broader solution space and gain insights from real-world examples, future research could examine how other hospitals address this problem. Furthermore, future research could explore the application of this approach in other 24/7 high pressure environments, such as emergency services, air traffic control, or control rooms in critical infrastructure.

A potential next step for this research would be to implement and evaluate the prototypes within the department. In this way, the applicability in a real-life setting can be tested. Based on the testing, an additional iteration step can be added to the process to further improve the design solution. Furthermore, the prototypes should be validated by a broader range of stakeholders, not only cardiologists. Another way to build on this research is by applying this research approach in other hospitals to improve the generalizability of the findings. An additional next step in this research would be to further develop the point system that is part of the final design. This could be done by turning it into a fully operational system that can be implemented and used within the hospital. Subsequently, the implementation of this system could be studied by examining its impact on organizational culture and the potential barriers that may arise.

7.5. Scientific contribution

This study contributes to the scheduling literature by employing a design science approach, which has not been widely used in this field (Abdullah et al., 2024). Rather than developing a mathematical optimization model, this study took a different approach by designing scheduling prototypes based on the needs and preferences of the users involved. The main difference is that this study does not aim to develop optimized schedules or scheduling tools, but it explores different scheduling approaches. An additional contribution of this study is that it examined the underlying problem in more detail instead of assuming that it was a purely technical scheduling problem. This demonstrates that relatively simple solutions can already address part of the problem and that a complex mathematical model is not always required. In addition, the final design results in a reduction of clinical production, which conflicts with existing optimization models. However, this study highlights the structurally high workload in academic hospitals, where there are too many tasks for too little time available. By balancing employee satisfaction with organizational efficiency, this study also shows what is needed to compensate for this reduction in clinical production: hiring an additional cardiologist.

Therefore, this study contributes to the literature by introducing a new approach to the physician scheduling problem, in which the problem is defined using SSM, followed by the design of specific prototypes.

Conclusions

This chapter first answers the main research question, followed by recommendations for the problem owner.

8.1. Conclusion

This section answers the main research question: *How can a design science approach contribute to balancing physician satisfaction and institutional efficiency in cardiologist scheduling?* To answer this question a socio-technical approach was used that combined a design science approach with interviews and the soft systems methodology.

The pediatric cardiology department of a children's hospital in the Netherlands is experiencing physician scheduling problems. The aim of this research was to identify the exact nature of this problem and based on this design a new scheduling approach.

The first part of this study resulted in a set of design criteria and identified key problem aspects. These are summarized below:

Design Criteria

1. Fairness
2. Job rotation
3. Predictability
4. Consistency
5. Flexibility
6. Transparency
7. Rest and recovery
8. Professional development
9. Hospital regulations and policies

Problem Aspects

1. Autonomy and control
2. Planning and schedule
3. Time allocation
4. Workload and task differences
5. Invisible work and administrative burden
6. Work performance and quality
7. Mutual understanding and shared vision

The findings of the study show that the scheduling problem within the pediatric cardiology extends beyond a scheduling problem alone. The problem also involves an organizational culture problem and an inefficient process problem. However, the inefficient scheduling process does not contribute to the dissatisfaction among the cardiologists. In the next phase of this study, several prototypes were designed and reviewed by the user and the problem owner. Based on the user feedback, the final design was developed. The final design meets almost all design criteria and addresses most of the identified problem aspects.

The final design consists of two parts. The first part involves changing the four-hour outpatient clinic blocks to eight-hour blocks. This approach incorporates administration time into the outpatient clinic. This solution is easy to implement and ensures that physicians can complete the administrative work of the outpatient clinic within the allocated time. Currently, there is often insufficient time for this, requiring them to complete the administration during other moments. Less time is available for other tasks, such as research, because administrative work still needs to be completed or is done outside of working hours. However, including administration time in the outpatient clinic results in a reduction of clinical production. Because this time is crucial for cardiologists, this approach was chosen. To minimize the impact, this approach is only applied to specialized outpatient clinics. Furthermore, calculations were conducted to estimate the impact of implementing dedicated administration time within the outpatient clinic blocks. The results indicate that an additional 0.43 FTE would be required to accommodate this change, which corresponds to approximately 17.3 hours per week. Therefore, it is recommended to

hire an additional cardiologist. This part of the solution mainly addresses the scheduling problem. A representation of this scheduling approach can be found in Figure 8.1.

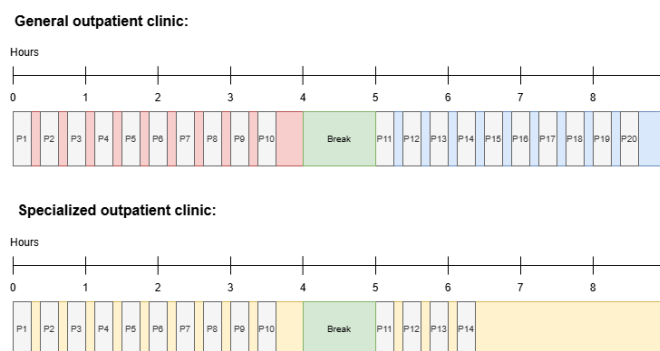


Figure 8.1: Final design: 8-hour blocks

The second part of the final design addresses the organizational culture problem. This design solution is a point system that assigns points to clinical tasks. Each cardiologist is required to achieve a certain number of points over a three-month period, based on their profile. It was decided to assign points only to clinical tasks, as they are perceived as more intensive. Assigning points to tasks was a concern for the cardiologists. This approach makes that easier and ensures that the most intensive tasks are distributed fairly. Every three months, a new schedule is created, and cardiologists are assigned to clinical tasks based on their specified minimum number of points. Furthermore, cardiologists can earn additional points by taking on extra shifts. However, this is not mandatory. Extra points can be exchanged for a day off or a NPGT day. By implementing this part of the final design, tasks are distributed more fairly among cardiologists, which is ultimately expected to improve the working atmosphere within the team. However, this effect will not be immediate. Therefore, it is also recommended to organize a training on organizational culture and mutual understanding. The aim of this training is to remind the cardiologists' about the shared vision of the department and the goal to deliver high quality care together. The challenge with this part of the final design is its implementation. This is a complex and time-consuming process. An example of what this point system could look like it presented in Figure 8.2.

Thus, the final design involves two key limitations that both involve organizational efficiency. However, both limitations address organizational efficiency in different ways. These limitations clearly show the challenge that this study addresses: balancing physician satisfaction and institutional efficiency.

Because implementation of the final design is time consuming, it is recommended to immediately implement the short-term solution. The short term solution is implementing prototype 5: administration time.

The design science approach contributed to balancing physician satisfaction and institutional efficiency in several ways. First, this approach does not focus on optimization only, which is common in mathematical approaches to scheduling problems. By moving away from pure optimization, the focus is no longer on organizational efficiency only, but also on physician well-being. Modern studies that used mathematical optimization tried to incorporate physician well-being into their models. However, a big limitation of these studies is the implementation of the scheduling solutions in practice. The design science approach does not face this limitation, because of the extensive stakeholder interaction throughout the process. By identifying the nature of the problem first, before developing a solution, targeted and feasible prototypes could be developed. In the literature, the physician scheduling problem is often conceptualized as a purely scheduling-related issue. The extensive stakeholder interaction also made it easier to balance organizational efficiency with physician well-being, because the needs and constraints of both sides were deeply understood. Additionally, the design science approach uses an iterative process. This ensured that the process that led to the final design was constantly refined based on user input. This resulted in a fitting and realistic final design. Therefore, using a design science approach in physician scheduling results in a scheduling approach that fits the specific context of a department, while also aiming to balance physician satisfaction and institutional efficiency.

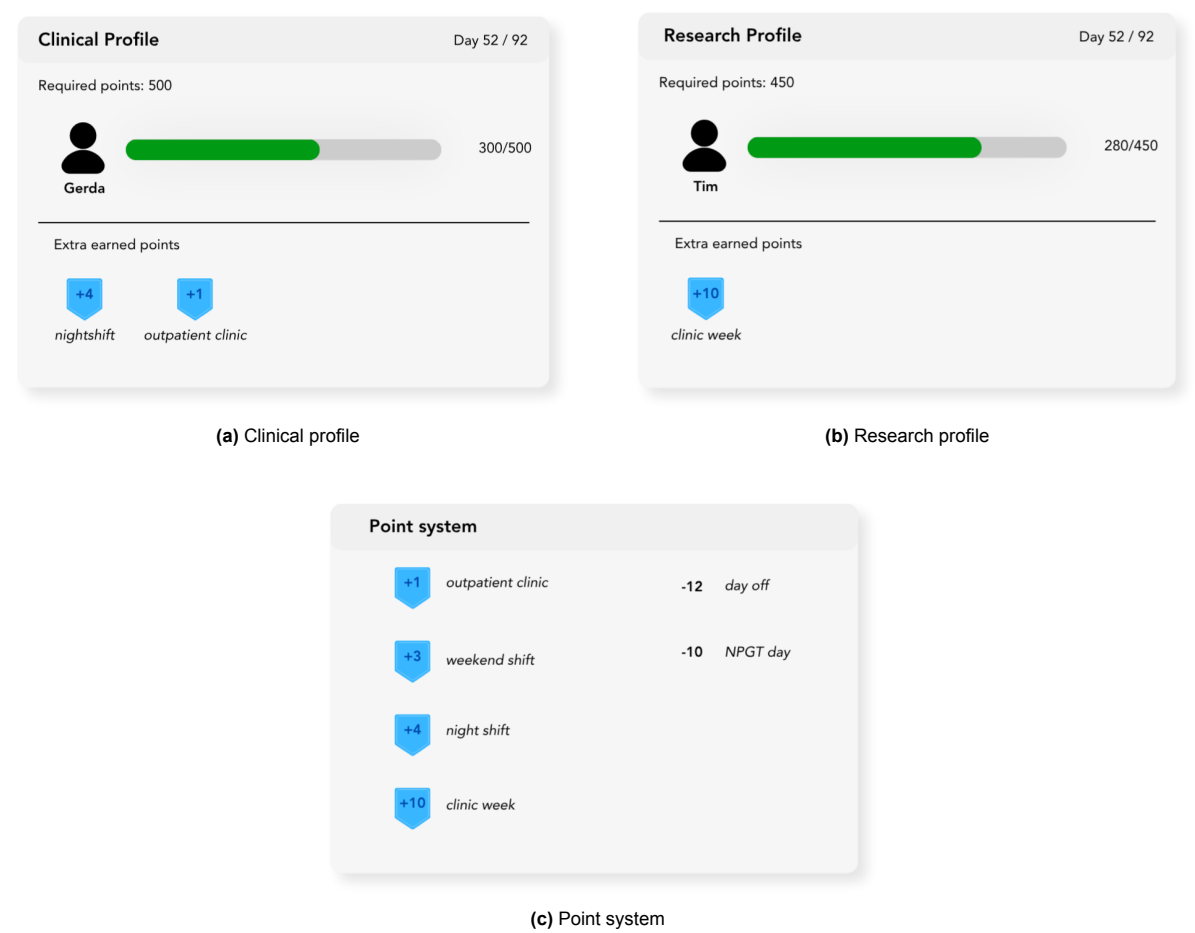


Figure 8.2: Final design: point system

However, balancing physician satisfaction with institutional efficiency turned out to be challenging. First of all, satisfying all cardiologists is not possible, as every cardiologist has a different way of working. Some of the cardiologists will consider the final design as a satisfying solution, while others disagree. These different perspectives make it hard to balance physician satisfaction with institutional efficiency. Furthermore, the findings of this study show that part of the scheduling problem is also a capacity problem. For example, the outpatient clinic is not scheduled realistically. There is not sufficient administration time allocated in the schedule. This causes work to pile up, and forces cardiologists to complete administration at other moments. As a result, certain tasks, such as research, are frequently deprioritized. This increases the workload and decreases physician satisfaction. To address this, the final design incorporates dedicated administration time into the outpatient clinic blocks. However, this reduces clinical production, and therefore institutional efficiency. This illustrates that sacrifices have to be made when balancing the two. In order to limit the reduction of clinical production, the additional administration time is only applied to specialized outpatient clinics. This illustrates a trade off: accepting a reduction in clinical production in order to improve physician satisfaction. However, this study suggested a different perspective to this trade-off. While adding administration time reduces the clinical production in short term, reducing structural workload pressure improves physician satisfaction, which in turn benefits the long term institutional efficiency. This suggests that physician satisfaction and institutional efficiency are not purely conflicting priorities.

Furthermore, an important finding of this study is the differences in the intensity of tasks. Overall, clinical tasks are considered as more demanding. This causes dissatisfaction among the distribution of those clinical tasks. Additionally, clinical tasks are often prioritized over the non-clinical tasks. This is due to the direct patient contact that clinical tasks involve. For this reason, non-clinical tasks are structurally deprioritized. For example, the weekly research meeting is canceled almost every week. Moreover,

while clinical work is highly important for the department, non-clinical work is also essential to the department and contributes to the organizational efficiency. For instance, a cardiology department that delivers high-quality care, produces a substantial amount of research, and operates efficiently through a strong management team is more likely to achieve a balance between organizational efficiency and physician satisfaction. Therefore, the intensity of tasks and the distribution of these tasks should be considered when creating physician schedules. In addition, task allocation should be evaluated carefully to ensure a realistic workload distribution that allows all responsibilities to be fulfilled effectively.

An important limitation in answering the question if balancing physician satisfaction with institutional efficiency is achieved in the final design is that the final design has not been tested in practice over a longer period of time. Therefore, the conclusions drawn in this study remain theoretical. Implementing and evaluating the final design within the pediatric cardiology department would provide insights that go further than the theoretical level. In addition, the balance that was aimed for in this study is specific to this department. Therefore, the findings are not fully generalizable.

To answer the main research question: a design science approach contributes to balancing physician satisfaction and institutional efficiency by moving the focus from pure optimization to deeply understanding the specific context through stakeholder interaction, and iteratively developing a feasible solution. However, the final design does not achieve a balance. The reduction in clinical production does not align with organizational efficiency. Nevertheless, this study demonstrates that a more balanced situation can be achieved by hiring an additional cardiologist. It also shows that there is a structural capacity problem. There is too much work for the time available. This suggests that a reduction in clinical production may be necessary, even though this conflicts with production requirements.

8.2. Recommendations for the problem owner

This section provides an overview of recommendations for the next steps for the problem owner.

- Implement prototype 5 immediately, adding administration time in the schedule. This is the short-term solution.
- Organize an organizational culture/mutual understanding workshop, mandatory for all cardiologists. The department needs a reminder of effective collaboration and shared values.
- Organize a Matrickx training for the creators of the schedule to make the process more efficient.
- Hire an additional cardiologist. This will compensate for a part of the reduction clinical production. Even if the final design will not be implemented, this could help with reducing the workload pressure.
- If an additional cardiologist is hired, implement the 8-hour outpatient clinic blocks.
- Start collecting data about the clinical output immediately. This data can be used to translate them into a corresponding point distribution per clinical task. Also make calculations about the minimum number of points assigned to each cardiologist.
- If there is a point allocation, discuss this with the entire team and make sure everyone agrees.
- Develop the complete point system, implement it in the department, and test it for a longer period of time. Evaluate after six months and one year whether any improvement has occurred and which factors are contributing to it.

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General literature review

To gain a better understanding of the literature and obtain a broad perspective, the database Google Scholar was initially used. This database was used to become familiar with the existing literature and to identify relevant search terms for a comprehensive literature search. The first search term that was used was: "Physician scheduling". By starting with an examination of the literature found under this search term, additional search terms emerged. Ultimately, the following search terms were used:

- ("scheduling" OR "rostering") AND ("health care" OR "hospital" OR "physician" OR "doctor")
- (physician OR specialist OR "medical staff") AND ("work satisfaction" OR "well-being") AND ("scheduling" OR "rostering") -algorithm

This initial search resulted in several relevant publications. However, a more targeted and domain specific literature search was conducted after this, using the database PubMed. PubMed was chosen because it is a medical database that provides access to high-quality, reliable medical literature. Furthermore, in PubMed you can use MeSH terms, which help improve the accuracy of the literature search by identifying more relevant articles. The search on PubMed resulted in a large proportion of the identified literature. The search term that resulted the highest number of relevant literature was:

- ("Personnel Staffing and Scheduling"[Mesh] OR "Physician scheduling"[tiab] OR "Rostering"[tiab]) AND ("Efficiency"[tiab] OR "Efficiency, Organizational"[Mesh]) AND ("Job Satisfaction"[Mesh] OR "Professional Autonomy"[Mesh] OR "Work-life balance"[tiab])

Using this search term, 68 results were identified, limited to publications between 2016 and 2026. Relevant articles were also found through "snowballing", in which the references of selected articles were examined for additional useful literature. All of the literature was first selected based on its title and abstract. Subsequently, the relevant articles were read in full. This search resulted in 11 more relevant studies.

Subsequently, the database Scopus was used. As PubMed primarily focuses on medical literature, Scopus was additionally consulted to broaden the scope of relevant sources. The articles identified here provide a valuable addition to the other sources. The search term that was used in Scopus to identify useful literature was:

- ("Personnel Staffing and Scheduling" OR "Physician scheduling" OR Roster* OR Shift schedul*) AND (Efficien* OR Productiv*) AND ("Job Satisfaction" OR "Professional Autonomy" OR "Work-life balance" OR "Work satisfaction")

This search term resulted in 91 articles, limited to publications between 2016 and 2026. After reviewing the titles and abstracts of these articles, a selection of 11 relevant articles remained.

In this literature review, 32 relevant articles were selected and analyzed. An overview of these articles can be found in Table A.1. This literature review aims to identify common themes, debates, and research gaps to formulate a research question for the scheduling problem at the pediatric cardiology department.

Table A.1: Literature Review Overview

Literature Review Details	
Glass and Knight (2009)	<i>Method: Mixed integer linear programming</i>
Goal: Critically analyse the structural properties of rostering problems.	
Themes: Quality of the roster; Four benchmark problems; Real rosters are not isolated periods.	
Challenges: Only a few papers are based on real world data or address development rostering systems for implementation in hospitals; The model does not consider personal preferences.	
Ernst et al. (2003)	<i>Method: Literature review</i>
Goal: Provide a review of the field of staff scheduling.	
Themes: Roster requirements; Different modelling techniques; optimization methods.	
Challenges: Each industry sector presents a specific set of challenges and should be considered independently; The complexity and scalability of the problem in real-world data.	
Goh et al. (2022)	<i>Method: Hybrid heuristic/optimization model</i>
Goal: Find a feasible roster satisfying all hard constraints.	
Themes: Feasibility and optimization.	
Challenges: The method is tested on a benchmark dataset.	
Ngoo et al. (2022)	<i>Method: Literature survey</i>
Goal: Review solution methods for medical rostering.	
Themes: Solution methodologies; Mathematical optimization and heuristics; benchmark datasets.	
Challenges: A lot of solution methods struggle with large or realistic examples; Real world hospital rostering problems may differ significantly from benchmark instances; Gap between benchmark-based research and real applications.	
Drake (2013)	<i>Method: Combining qualitative and quantitative data; interviews</i>
Goal: Examine how well the theoretical medical rostering from operational research maps onto real-world rostering practices in hospitals.	
Themes: Informality and politics in rostering; Rosters are not made strictly by optimization criteria; Use of real-world data; Rostering is not purely a technical optimization problem but a social and political process.	
Challenges: Many hospitals do not have well-documented rostering rules; There is a need for better designed roster policies at organizational level.	
Böðvarsdóttir et al. (2021)	<i>Method: Mixed integer programming</i>
Goal: Develop a practical rostering system to generate medical schedules that are realistic and for real hospitals.	
Themes: Real world applicability; Promote healthy work schedules.	
Challenges: Adoption in other hospitals. Building a one-size-fits-all model is hard.	
Knust and Xie (2017)	<i>Method: Mathematical optimization and heuristics</i>
Goal: Proposing a flexible, realistic rostering model that can capture complex and real-world rostering constraints.	
Themes: Test on benchmark instances and on real-world data; Applying optimization research directly in real hospital rostering software.	
Challenges: The solution can be very expensive, depending on the size of the real-world instances; The solution is good for finding feasible solutions quickly, but it does not guarantee optimality.	
Bagheri et al. (2016)	<i>Method: Stochastic programming</i>
Goal: Develop a stochastic optimization model that produces physician schedules.	
Themes: Uncertainty in healthcare demand; Making a cost-efficient model; Generate a schedule that is robust against demand uncertainty; More focused on the patients stay than on the doctors preferences.	

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Literature Review Overview – Continued from previous page

Challenges: Stochastic programming can be time-consuming; This model requires patient data; Number of constraints makes it challenging.

Zanda et al. (2018)

Method: Linear integer programming

Goal: Develop a long-term physician scheduling system that handles a planning horizon rather than only short term rosters.

Themes: Long term scheduling; Decision support systems; Balancing different goals: fairness, working-hour balance, days-off; Comparing with previous studies.

Challenges: The decision support system needs up to date data. This can be difficult in real life; Integer programming is computationally heavy.

Maenhout and Vanhoucke (2012)

Method: Mathematical optimization

Goal: Develop and test an integrated staffing + scheduling methodology.

Themes: Policy analysis; trade-off management.

Challenges: Integrating staffing and rostering produces a large optimization problem, this can be computationally demanding.

Narlı and Derse (2025)

Method: Integer programming

Goal: Create an automated an optimal nurse scheduling system.

Themes: Healthcare management; Work-life balance; staff well-being.

Challenges: The complexity of implementing constraints and fairness.

Ostberg et al. (2021) *Method: Mixed methods: quantitative analysis and qualitative assessments (interviews)*

Goal: Quantify and evaluate staffing levels in a pediatric intensive care unit.

Themes: Workload measurement; Quality of healthcare; Resource management; Job satisfaction.

Challenges: Accounting for hidden tasks that are often overlooked.

Sullivan et al. (2022)

Method: Survey study

Goal: The evaluate the effects of flexible scheduling and the use of telemedicine.

Themes: Physician well-being; Digital healthcare; Autonomy.

Challenges: Flexible scheduling does not directly impact burnout rates.

Barnes-Farrell et al. (2008)

Method: Cross-sectional survey study

Goal: Examine how various shiftwork characteristics influence off-shift well-being.

Themes: Work-life balance; Physician well-being.

Challenges: Multifaceted nature of shiftwork.

Sinsky et al. (2016) *Method: Quantitative direct observational time and motion study and self-reported diary*

Goal: Quantify how physician time is spend in outpatient care.

Themes: Electronic health record burden; Physician burnout; Operational efficiency; Work-life balance.

Challenges: A lot of time of the physician is spend on the computer rather than face-to-face interaction.

Anderson et al. (2021)

Method: Literature review

Goal: Define the state of well-being and work-life integration.

Themes: Work-life balance; Burnout and mental health; individual vs. organizational responsibility.

Challenges: The traditional medical culture that always overworking is something good.

Wynendaele et al. (2021)

Method: Survey study

Goal: Compare the effects of self-scheduling vs. fixed scheduling.

Themes: Self-scheduling and autonomy; Organizational justice; Workplace dynamics; Flexibility and control.

Challenges: Self-scheduling can feel unfair or lead to conflicts within the team.

Table continued on next page...

Literature Review Overview – Continued from previous page

Abuhalimeh and Brunton (2024)	<i>Method: Literature review</i>
Goal: Offer strategies to reclaim work-life balance, reduce burnout.	
Themes: Physician well-being; Burnout; Practical resilience; Productivity and efficiency.	
Challenges: The unpredictable and high-pressure environment of physicians.	
Al-Busaidi et al. (2025)	<i>Method: Comprehensive review and analysis</i>
Goal: Explore the root cause of burnout among physicians.	
Themes: Systematic vs. individual change; Burnout; Emotional exhaustion; Individual resilience.	
Challenges: The risk that focussing just on individual resilience may lead to organizations to overlook their responsibility to improve the working conditions.	
Khan and Vinson (2020)	<i>Method: Literature review</i>
Goal: Providing a foundational understanding of physician well-being.	
Themes: Organizational culture; Efficiency; Self-care and resilience; Social support.	
Challenges: It is difficult to make permanent structural changes in hospital management.	
Patel et al. (2019)	<i>Method: Literature review</i>
Goal: Identify the key drivers of physician burnout and evaluate intervention strategies.	
Themes: Burnout; Individual focused strategies; Organizational focused strategies.	
Challenges: The difficulty of implementing organizational changes in high pressure healthcare environments with limited resources.	
Gerlach et al. (2025)	<i>Method: Interviews and focus groups</i>
Goal: Explore nurse perspectives on AI-based scheduling.	
Themes: Balancing individual needs and collective fairness; Transparency.	
Challenges: Lack of human nuance; Data privacy concerns.	
Barker et al. (2025)	<i>Method: Interviews</i>
Goal: Explore how preferences and constraints of hospital staff interact and influence decision making regarding the schedule.	
Themes: Balancing choice, consistency, and predictability; Rest and recovery; Job satisfaction.	
Challenges: Complexity of balancing individual vs. organizational needs.	
Thomas and P (2025)	<i>Method: Mixed methods: quantitative surveys and qualitative interviews</i>
Goal: Provide recommendations to improve job satisfaction, mental health and working conditions.	
Themes: Work-life balance; Irregular work schedules; Job satisfaction; Institutional support.	
Challenges: High workload; Understaffing; Lack of organizational support.	
Renggli et al. (2025)	<i>Method: Focus group interviews</i>
Goal: Integrating nurse preferences into AI-supported scheduling.	
Themes: Well-being; Individual preferences; Job satisfaction; Autonomy and transparency; Participative scheduling.	
Challenges: AI reliability, human oversight and adaptability to individual needs.	
Lutsenko et al. (2024)	<i>Method: Qualitative and comparative legal research methodology</i>
Goal: Evaluate the regulation of working hours during the transition to flexible work.	
Themes: Legal standards for flexibility; Balancing fairness and productivity; Work-life balance.	
Challenges: Balancing labour rights with flexibility.	
Yasmine et al. (2024)	<i>Method: Quantitative case study: integer linear programming</i>
Goal: Optimize workload balancing in nurse scheduling to reduce burnout and improve quality of care.	

Table continued on next page...

Literature Review Overview – Continued from previous page

Themes: Fair workload distribution; Operational efficiency.

Challenges: Complexity of balancing clinical constraints with nurse well-being.

O'Connell et al. (2024)

Method: Mixed methods systematic review

Goal: Assess the impact of electronic and self-rostering on staff and organization.

Themes: Flexibility vs. organizational needs; Autonomy and empowerment; Job satisfaction.

Challenges: Risk of unfairness in self-scheduling.

Emmanuel et al. (2023)

Method: Cross-sectional survey

Goal: Identify the most important factors nurses consider when choosing shift patterns.

Themes: Job satisfaction; Shift lengths; Work-life balance; Flexibility.

Challenges: Trade-offs between flexibility and financial needs.

Walter et al. (2024)

Method: Design science/ prototyping

Goal: Design and test an AI-supported scheduling tool that prioritizes user needs.

Themes: Human-centered design; Job satisfaction and productivity.

Challenges: Balancing technical AI-optimization with user-friendly interfaces.

Uhde et al. (2021)

Method: User-centred design + interviews

Goal: Design an interactive scheduling system that prioritizes employee well-being over management efficiency.

Themes: Autonomy and control; Self-scheduling; Well-being.

Challenges: Social pressure and reputation; Unequal planning skills among staff.

Rerkjirattikal et al. (2020)

Method: Goal programming and interviews + surveys

Goal: Develop a model for scheduling that considers individual preferences and workload fairness.

Themes: Job satisfaction; Personal preferences.

Challenges: Mathematical models can become too complex for real time changes.

B

COREQ checklist

This appendix contains the COREQ checklist. The checklist has been adapted from and completed based on this checklist developed by Tong et al. (2007).

Table B.1: COREQ checklist

Criterion	Inclusion in this thesis
1. Interviewer	The interviews were conducted by the researcher, Ilja van der Heide.
2. Credentials	BSc Systems Engineering, Policy Analysis and Management at Delft University of Technology.
3. Occupation	Full time master student in Complex Systems Engineering and Management at Delft University of Technology.
4. Gender	Female.
5. Experience and training	The researcher had some training in qualitative research during courses that were part of the bachelor and master program.
6. Relationship established	The researcher had no prior relationship with the participants.
7. Participant knowledge of the interviewer	Before the interviews took place, participants were informed about my presence in the hospital and the purpose of the research through an email sent by the problem owner to the team. In addition, a brief introduction to the study and the interview procedures was provided prior to each interview, as well as an informed consent letter.
8. Interviewer characteristics	The researcher had no medical or clinical background. As mentioned in section 7.3, the researcher acknowledges a potential risk of unconscious bias, where certain themes may have been interpreted as more important than others.
9. Methodological orientation and theory	The semi-structured interviews were analyzed using thematic analysis with the support of Atlas.ti. The broader study employed SSM as a conceptual framework to structure the complex, multi-stakeholder problem.
10. Sampling	The problem owner sent an email to all eleven cardiologists, inviting them to voluntarily contact the researcher if they were willing to participate in an interview. Five cardiologists responded to this invitation and agreed to take part in an interview.
11. Method of approach	Participants were approached via email.
12. Sample size	Five participants were interviewed.

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Table B.1: COREQ checklist (Continued)

Criterion	Inclusion in this thesis
13. Non-participation	None of the participants dropped out. However, six of the eleven cardiologists did not respond to the interview invitation.
14. Setting of data collection	The interviews were conducted at the hospital in the pediatric cardiology department. They took place in the participants' offices.
15. presence of non-participants	During the interviews, no one else was present in the room except for the researcher and the participant.
16. Description of sample	All five participants were pediatric cardiologists working at the cardiology department. Details regarding the sub-specialization cannot be provided due to anonymity.
17. Interview guide	A semi-structured interview guide was developed with open-ended questions and prompts. The interview guide can be found in Appendix C. The guide was not formally pilot tested due to time constraints.
18. Repeat interviews	No repeat interviews were performed.
19. Audio/visual recording	The interviews were recorded (audio).
20. Field notes	No field notes were taken during the interviews. The audio recordings were sufficient for later analysis.
21. Duration	The interviews took 45-60 minutes.
22. Data saturation	Data saturation was not reached. Due to time constraints, only five of the eleven cardiologists were interviewed. This is acknowledged as a limitation of the study.
23. Transcripts returned	The transcripts were not returned to participants for comments and/or correction.
24. Number of data coders	The researcher was the only one who coded the data.
25. Description of the coding tree	An overview of the coding tree is provided in Appendix G.
26. Derivation of themes	The themes were derived from the data.
27. Software	The software Atlas.ti was used to manage the data.
28. Participant checking	The participants provided feedback on the findings. This feedback can be found in Appendix I.
29. Quotations presented	The researcher included quotes to support the findings. These quotes were identified using the corresponding interview number.
30. Data and findings consistent	The findings and interpretations were derived directly from the interview data. The reasoning was made explicit throughout the analysis to ensure transparency between the data and the interpretations.
31. Clarity of major themes	Major themes were clearly presented in subsection 4.2.1 with supporting quotes and descriptions.
32. Clarity of minor themes	Minor themes and diverse cases are described.

Interview questions

1. Hoe zou u het huidige planningsproces binnen de afdeling omschrijven?
 - (a) Wat gaat er volgens u goed en waar liggen de belangrijkste knelpunten?
2. In hoeverre heeft u het gevoel dat het werk eerlijk wordt verdeeld onder de cardiologen?
3. Is het voor u duidelijk hoe beslissingen over de planning worden genomen?
4. Kunt u een typische werk week beschrijven?
 - (a) Welke taken kosten u meestal de meeste tijd?
 - (b) Zijn er taken die in de praktijk vaak meer tijd kosten dan er in de planning voor staat?
5. Doet u ook werk dat niet zichtbaar is in de officiële planning?
 - (a) Denkt u dat uw collega's zich ervan bewust zijn hoeveel tijd dat werk kost?
6. Hoe beïnvloedt de verdeling van onderzoekstijd de klinische werklast van andere cardiologen?
7. Als u één ding zou mogen veranderen aan het huidige planningssysteem, wat zou dat zijn?

All interviews were conducted in Dutch. Therefore, the interview questions were originally formulated in Dutch. An English translation of the questions is provided below. The translation was generated with the assistance of an AI tool and reviewed for accuracy. These questions served as a guide during the interviews. The interviewer remained flexible and adjusted follow-up questions based on the participant's responses and emerging topics during the conversation.

The translated interview questions are as follows:

1. How would you describe the current scheduling process within the department?
 - (a) In your opinion, what works well and what are the main challenges or bottlenecks?
2. To what extent do you feel that the workload is distributed fairly among the cardiologists?
3. Is it clear to you how scheduling decisions are made?
4. Could you describe a typical work week?
 - (a) Which tasks usually take up most of your time?
 - (b) Are there any tasks that, in practice, often take more time than is allocated in the schedule?
5. Do you perform work that is not reflected in the official schedule?
 - (a) Do you think your colleagues are aware of how much time this work requires?
6. How does the allocation of research time affect the clinical workload of other cardiologists?
7. If you could change one thing about the current scheduling system, what would it be?

AI-statement

During the development of this master thesis, I used ChatGPT to support brainstorming, review language, check for typographical and grammatical errors, and broaden my perspectives. Additionally, I used DeepL to improve my language throughout the writing process. All suggestions provided by these tools were critically reviewed, verified against academic sources, and adapted as necessary to maintain the originality and quality of my work.

All content of the core research activities, such as the literature review, interpreting the results, the analysis, the final conclusion, the development of arguments, were developed by the author independently.

The following examples illustrate the type of prompts used during the writing process:

- Check this section for grammatical and typographical errors.
- Give me suggestions for a structure of this section.
- Brainstorm innovative approaches to hospital scheduling that could be explored through prototype development. This was done by giving detailed descriptions of a problem aspect and give my initial ideas. This would lead to additional ideas or suggestions.
- Suggest academic alternatives for the word “thus” in English.

Literature review about satisfying scheduling

This literature review used Scopus as a scientific database. This database was used because the literature review focused on general scheduling. This means that literature about scheduling outside healthcare was also used in the literature review. However, additional searches were conducted on PubMed. This resulted in some relevant articles. To identify the most relevant articles, initial searches were conducted using predefined search terms. Subsequently, these search terms were continuously refined based on the search results, ultimately leading to the most relevant search term. This process is presented in Table E.1.

The final search term led to 868 results, from which 26 relevant references were selected for the literature review. The selection was based on reading the abstract and conclusion of the articles. The 26 selected references were then read completely. The most important insights were documented, and a clear structure emerged.

Structure literature review

1. History of scheduling: First scheduling was purely efficiency-driven. Employees were seen as resources (1950s). Later this developed to scheduling based on balancing efficiency and social factors, such as employee well-being.
2. Over time, social factors became more important.
3. Different factors that improve efficient and satisfying schedules: Transparency, consistency, flexibility, etc.
4. However, trade-off between organizational efficiency (time and money) and employee well-being.

Table E.1: Search terms

Search terms	Results	Comments
(schedule* OR scheduling OR timetable* OR "work schedule*" OR planning) AND (efficien* OR effectiveness OR performance OR productivity OR optimization) AND (satisfaction OR "job satisfaction" OR well-being OR wellbeing OR "work-life balance") AND (trade-off* OR balancing OR compromise* OR tension* OR "competing demands" OR multi-objective)	1732	
(schedule* OR scheduling OR "work schedule*" OR planning) AND (efficien* OR performance OR productivity OR optimization) AND (satisfaction OR well-being OR wellbeing OR "work-life balance")	13393	Too many results.
(schedule* OR scheduling OR "work schedule*" OR planning) AND (efficien* OR performance OR optimization) AND (satisfaction OR well-being OR wellbeing) AND (trade-off* OR balancing OR tension*)	701	
(schedule* OR scheduling OR "work schedule*" OR "shift schedule*" OR roster*) AND (efficien* OR performance OR productivity) AND (satisfaction OR well-being OR wellbeing OR "work-life balance") AND (work* OR employee* OR organization* OR human*)	2860	Too general. A lot of articles are about other form of scheduling. Not workforce scheduling.
("shift schedule*" OR "work schedule design") AND ("job satisfaction" OR "employee satisfaction" OR wellbeing)	35	Most of these articles are about the medical sector. Small number of results.
("work schedul*" OR "shift schedul*" OR shiftwork OR roster* OR "staff schedule*" OR "workforce schedule*" OR "employee schedul*") AND (efficien* OR performance OR productivity OR optimization OR optimisation OR trade-off* OR balance*) AND (satisfaction OR well-being OR wellbeing OR "work-life balance")	868	This is the most effective search term.

CATWOE analysis

Customers (those who benefit/suffer from transformation):

- Cardiologists: these are the stakeholders that are directly affected by workload distribution and fairness.
- Scheduling staff

Actors (those who operate and implement scheduling system):

- Scheduling staff
- Head of department
- Management team
- Cardiologists

Transformation process:

- The current scheduling system lacks transparency, as it is unclear how tasks are allocated among cardiologists. As a result, many cardiologists perceive the distribution of tasks as unfair. Furthermore, invisible work is not explicitly incorporated into the schedule. This contributes to a situation in which cardiologists feel that they are working harder than their colleagues, leading to tension. In addition, there is an ongoing tension between meeting clinical production requirements and allocating time for research.
- This situation needs to be transformed into a transparent and balanced workload distribution system. The scheduling process should explicitly account for invisible work and research responsibilities, ensuring these activities are recognized. At the same time, the system must remain aligned with clinical production targets and organizational requirements. Ultimately, the objective is to reduce conflict, enhance perceived fairness, and improve collaboration within the department.

Worldview:

- In professional healthcare organizations, scheduling is not just a technical planning task but also a social and organizational issue. How work is distributed affects trust between colleagues and collaboration within the department. Therefore, transparency, recognition of invisible work, and perceived fairness are essential for maintaining performance.

Owners (they can stop or change the system):

- Head of department
- Management team
- Hospital board

Environmental constraints (constraints the system cannot easily change/system boundaries):

- Clinical production targets such as minimal number of outpatient clinics per year
- Sub-specialization specific tasks can only be performed by specialized cardiologists
- Academic hospital needs to deliver research and innovation

Roof definition: a scheduling system within the pediatric cardiology department that is owned by the departmental management team and operated by cardiologists and scheduling staff, with the purpose of distributing tasks in a transparent and fair way, while meeting production targets and acknowledging professional and organizational constraints.

Insights interviews

G.1. Insights interviews

G.1.1. Insights interview 1

- **Current schedule process:** The current scheduling process is outdated. Additional tasks have been added to the schedule and this is causing some friction. Previously, not all tasks were scheduled, and you would take care of things in between. Nowadays, they try to fit everything into the schedule, but in reality, it is not really feasible.
- **Slack time:** There are tasks with a lot of potential slack time and tasks with no slack time at all. Slack time can be used to finish other tasks, such as administrative work. There are certain tasks which typically have a lot of potential slack time, such as echo supervision and stand-by. However, these tasks are very unpredictable. Sometimes they have a lot of slack time and sometimes there is no time left to finish other tasks.
- **Distribution slack time:** The distribution of tasks with a lot of slack time is not balanced. Some cardiologists mainly perform tasks that are so demanding that there is no slack time at all. These are, most of the time, cardiologists with many sub-specializations. This is because they are assigned less to general tasks, such as echo-supervision and stand-by. Other cardiologists perform more tasks with a lot of potential slack time. Overall, these cardiologists have more time to finish invisible tasks.
- **Invisible work:** Invisible work is not an issue, as long as there is enough time in the schedule to finish it. This cardiologist suggests that there should be fixed time implemented in the schedule for everyone to finish invisible work, such as administration.
- **Work ethics:** There are differences in how detailed everybody handles certain tasks. For example, part of the stand-by task is doing the emergency echo-supervision. This can be done very detailed and taking a lot of time, but it can also be handled very quickly. If this task is done quickly, there is more time for finishing other tasks. There is also a difference between the different generations. The younger generation usually has more clear boundaries.
- **Support demanding tasks:** Sometimes demanding tasks are supported by a fellow (doctor in training). This can be very helpful to take some pressure off the cardiologist's shoulder during clinic weeks. The clinic tasks are typically a very demanding task. However, in the early stages this can also be a burden for the cardiologist, because the fellow still needs to learn everything and is not yet able to work individually.
- **Perception of task importance:** Some cardiologists consider certain tasks as more important than others. According to this cardiologist, the people who perform HC see this as more important than the other tasks. They are demanding for more people than they need for certain interventions and this results in a shortage of staff in the rest of the department.

G.1.2. Insights interview 2

- **Control:** The schedule is planned very tight and rigid, leaving little room to complete unfinished tasks. This results in a small amount of flexibility and control over your own schedule. This cardiologist suggests that there should be two or three day parts per week designated for non-clinical tasks.

- **Unrealistic schedules:** According to this cardiologist, the current schedule is unrealistic, as there are too many tasks allocated for too little time. This has a negative impact on the work-life balance. The unrealistic planning results in increased work pressure, which negatively impacts job satisfaction.
- **Biased schedule:** The schedule is somewhat biased by the cardiologists who create it. This cardiologist thinks that they unconsciously reflect their own preferences into the schedule. For example, if the cardiologist that creates the schedule has a research profile, the schedule will be more research based.
- **Weekend shifts:** Weekend shifts are not compensated within the current schedule. This means that cardiologists with a weekend shift do not get Monday or Tuesday off. They have to be at the hospital again at Monday morning. However, the schedulers try to give them only non-clinical tasks on Monday after a weekend shift.
- **Predictability:** The schedule is published well in advance. This makes it easy to plan around tasks. This is something that goes well in the current scheduling process.
- **Meetings:** There are a lot of meeting that are scheduled on the start of end of the day. Meeting planned at the start of the day often have a higher attendance then meetings planned on the end of the day. This is because people are still completing unfinished tasks, leaving them too busy to attend the meeting. The research meeting that is planned every Monday afternoon from 5-6 is always canceled.
- **Differences in intensity:** The duration of an outpatient clinic varies per specialism. For example, with ritme poli, more time is often required to inform parents and answer their questions because these conditions can be life-threatening. This also depends on the work ethic of the cardiologist. Some cardiologists do their outpatient clinic more detailed than others. This cardiologist suggests that the schedule should take this into account.

G.1.3. Insights interview 3

- **Enter availability:** The cardiologists have to enter their availability before a new schedule will be created. They need to indicate their availability in multiple places. They have to enter it in Matrickx, but there is also a separate Excel sheet in which they need to fill in their availability. This cardiologist suggests that there needs to be a central place for this.
- **Administrative burden:** There is no designated time for administration in the schedule. Complex outpatient clinics require preparation time and also time to work it out. This often does not fit in the time designated for the outpatient clinic. This cardiologist believes that they would do their work more efficient if there would be designated time for administration in the schedule. This ensures that you have fewer tasks to handle on the side. Right now the outpatient clinic is scheduled in day parts of 4 hours. This is not always realistic if you include the preparation time and the administration time that goes with it.
- **Compensation time:** This cardiologist also discussed the weekend shifts, noting that these are not properly compensated in the schedule. Furthermore, when a cardiologist is assigned to clinic duties, they are required to perform this task for the entire week, even if they normally have a specific day off during the week. While this day is technically compensated, individuals must track it themselves, as there is no central system to monitor this. According to this cardiologist, this puts everyone in disadvantage, as such days are often overlooked.
- **Phone appointments:** Some outpatient clinics are done by phone. This prevents that the patient has to come all the way to the hospital for a short conversation. These phone appointments are scheduled for only five minutes, but they often take up to twenty minutes. When several phone appointments are scheduled consecutively and each runs longer than five minutes, it creates significant delays. Phone appointments can be very useful and efficient, as long as they are scheduled realistic. Furthermore, some cardiologists handle these phone appointments in more detail than others. This cardiologist suggests that there should be room in the schedule for these differences.

G.1.4. Insights interview 4

- **Multiple schedules:** There are multiple schedules running next to each other. There is a shift schedule and a daytime clinical schedule. In addition, some sub-specialties, such as intervention cardiology, have their own separate schedules next to the main schedule. Next to this, some of the sub-specialisms like the intervention cardiology have sub-schedules. Furthermore, these different schedules are not connected to each other. As a result, cardiologists have to enter their availability in multiple places.
- **Perception workload:** According to this cardiologist, their sub-specialism has a higher workload than others. They believe their sub-specialism should take on fewer general tasks, as there is currently not enough time to keep up with innovations in their field. There is a difference in the perception on the workload of different sub-specialisms. According to this cardiologist, there is not enough time in the schedule to prepare, perform and do the administration of their sub-specialism and also conduct research to keep track of innovations and deliver high quality care. The center is expected to adopt the latest technologies, yet research must be carried out on their own time.
- **Shared vision:** There is no shared vision of what is important on the department. There is a lack of alignment between people's perceived priorities and what they consider important. This cardiologist believes a shared vision needs to be reestablished, with a clear and well-defined departmental mission.
- **Tension:** During the interview, tension between two sub specialisms was observed. This is related to the perception of workload and the different perceptions of importance of sub-specialisms. There is a lack of mutual understanding on the department.
- **Clinical and non-clinical time:** There are many different tasks defined in the schedule. Over the years, this number has grown, and more and more tasks have been specified. This cardiologist suggests that the schedule should only contain clinical and non-clinical time. Naturally, the outpatient clinics, the clinic weeks, and similar duties need to be scheduled, but this cardiologist would like more autonomy in organizing all the individual tasks.

G.1.5. Insights interview 5

- **Need for healthy scheduling:** This cardiologist indicated that there is a need for healthy scheduling on the department. According to them, the current schedule is not sustainable, as there is insufficient time to complete everything they aim to accomplish. Furthermore, the available workforce is insufficient to cover all tasks effectively. This leads to everyone prioritizing their own work and pushing for additional staff for their own responsibilities. In order to create healthy schedules, choices need to be made about what to prioritize and what may need to receive less attention.
- **Outpatient clinic administration:** There is a lot of administrative work that comes with the outpatient clinic. After the outpatient clinic, all information must be documented, and follow-up plans need to be discussed and communicated. This process typically takes time, especially for complex patients. Sometimes, cardiologists have to see 10 patients in an afternoon, conduct 8 phone consultations, and also prepare and document everything afterwards. Finishing all these tasks within the allocated time is often not possible. As a result, administrative work must be completed in the cardiologist's own time. Therefore, this cardiologist suggests that dedicated administrative time should be implemented into the schedule. They suggest that everyone should be allocated one day of administrative time in their schedule per week, or every two weeks. There must be a clear description of this time to ensure it is used for its intended purpose.
- **Compensation research time:** This cardiologist has a research profile. This means that they are hired to conduct research for the department. The number of dedicated research days per week is discussed with the research cardiologist. According to this cardiologist, there are many weeks in which they are unable to meet the agreed number of research days. These days are not compensated in the weeks after. Consequently, this cardiologist does not have enough time to complete the required research.
- **Recovery time:** In order to deliver high quality care, cardiologists need adequate rest and recovery after a weekend or night shift. Cardiologists perform complex and vital work, making it crucial that they get sufficient rest. Age also plays a role, as older physicians often require more time to recover. Working under fatigue also reduces work satisfaction.

- **Natural distribution tasks:** Within the team, each team member has their own working style. Some enjoy staying busy and taking on extra work, while others with young families aim to get home on time. According to this cardiologist, the task distribution is not unfair. Everyone works hard, each with their own working style and approach.
- **Team spirit:** According to this cardiologist, many colleagues tend to retreat into their own sub-specialization in order to avoid taking on broader, general responsibilities. According to this cardiologist, there is a shared responsibility for both the clinic and the outpatient clinic, and this needs to be properly organized. Therefore, the most important thing is to collaborate in a spirit of solidarity to deliver high-quality care.

G.2. Code manager Atlas.ti

Table G.1: Atlas.ti code manager

Document Group	Codes	Code
Workload & task differences	26	• 5 minutes per phone appointment planned • Differences in intensity of tasks • Differences in task duration • Different visions • Echo supervision duration differences • Equal importance tasks • Everyone has invisible tasks • General outpatient clinic vs specialized • General tasks and individual tasks • Getting home late • HC • High workload • Intervention vs research • No problem with general tasks • No slack time • Outpatient clinic overruns • Patient-dependent duration of outpatient clinic • Planned vs. unplanned tasks • Research cardiologists • Some people need more administration time • Subspecializations • Takes longer than is scheduled for • Unequal workload perception • Unfinished tasks • Unpredictability tasks • Workload

Table continued on next page...

Document Group	Codes	Code
Planning & schedule	23	• 5 minutes per phone appointment planned • Canceling meetings • Clear tasks in schedule • Clinic tasks • Efficiency • Frequent outpatient clinics for good care • Importance meetings • Improved productivity because of non clinical time in schedule • Invisible tasks • Meetings • More outpatient clinics • Non-clinical tasks after weekend shift • Non-clinical time in schedule • Not realistic planning • Out-dated planning process • Planning meetings • Rigid work schedule • Several schedules next to eachother • Stacking tasks for efficiency • Stand-by task • Tight planning • Timely planning • Unrealistic task planning
Autonomy & control	7	• Autonomy • Creating flexibility with phone appointments • Lack of control • Low flexibility • No own priorities in schedule • Personal bias in planning • Predictability
Work Performance & Quality	9	• Clear agreements • Current schedule not sustainable for team • Delivering high quality care • Improved productivity because of non clinical time in schedule • Inability to perform effectively • Individual differences in work style • Work ethic • Work importance perception • Working more efficient

Table continued on next page...

Document Group	Codes	Code
Emotions	17	• Bad mood because of fatigue • Crossing boundaries • Defending own interests • Dissatisfaction • Fatigue • Feeling heard by planners • Feeling lost • Feeling of failure • Frustration with planning support • Inability to perform effectively • No everyone will agree • Research driven department • Research focused department • Schedule gives stress • Self doubt • Unfairness • Wondering if it's fair
Time allocation	28	• Allocation of tasks • Allocation research • Clinical and non-clinical time • Different tasks • Distribution general tasks • Distribution slack time tasks • Fair distribution of tasks • Finish outpatient clinic in research time • Finishing administration in weekend shift • Finishing tasks in the evening • Finishing tasks on the side • Finishing tasks outside planned time • Getting home late • Importance meetings • Lot of different tasks • Misjudged task duration • Natural distribution • No difference in schedule in different kinds of cardiologists • No research time for non-research profile • No slack time • No time for research • Outpatient clinic overruns • Priorities • Research time is dropped • Sacrifice research time • Slack time • Time allocation patient care vs research • Work-life balance
Mutual understanding	6	• Clear agreements • Lack of understanding of task demands • Misjudged task duration • More mutual trust • Mutual trust • Subspecialization

Table continued on next page...

Document Group	Codes	Code
Constraints	20	• Cardex • Costs are higher than value • Different generations • Fellow physician • Flight to own profile • Give up availability on several spots • Hard to combine • Hard to schedule • Minimum number of outpatient clinics • More schedules • No compensation for research time • No own priorities in schedule • Number of patients • Open position not filled • Research meeting is always canceled • Shortening patient time • Staff shortage • Sub-specializations • Too less staff • Too less time in a week
Desired changes	22	• 5 minutes per phone appointment planned • Administration time • Canceling meetings • Central system for availability • Compensation days • Compensation of weekend shifts • Current schedule not sustainable for team • Cut things for healthy scheduling • Description administration time • Healthy scheduling • Lack of control • Less general tasks to ensure quality • More transparency • No administration time in schedule • No changes by cardiologists in schedule • No compensation for research time • No general tasks for HC • Outpatient clinic administration time • Quality of care decreases • Reconsider distribution tasks • Recovery time • Shared vision needs to come back

Table G.2: Frequency of coded segments across interviews

		1: Interview 1 11 37	2: Interview 2 11 84	3: Interview 3 11 18	4: Interview 4 11 31	5: Interview 5 11 26	Totals
Autonomy & control	7 11	2	9			2	11
Constraints	20 23	6	6	1	4	6	23
Desired changes	22 35	4	10	6	6	9	35
Emotions	17 26	3	14		4	5	26
Mutual understanding	6 8	1	6		1		8
Planning & schedule	23 39	6	26	4	2	1	39
Time allocation	28 52	14	20	4	8	6	52
Work performance & quality	9 20	5	10	3	2		20
Workload & task differences	26 46	10	22	5	7	2	46
Totals		49	123	23	34	31	260



Initial prototypes

H.1. Weighted scoring system

The current system treats every patient encounter as equal. This system introduces a weighted scoring system for the outpatient clinics. Instead of scheduling a fixed number of patients, the schedule is based on a maximum number of points per block.

Each patient is assigned a complexity score (1, 2, or 3) in their medical record. This number refers to the expected time and administrative effort for each patient. The cardiologist can assign a score to their patients and this score can also change over time.

- Score 1 (low complexity): these are routine follow-ups or quick checks. These appointments require minimal preparation and documentation time.
- Score 2 (moderate complexity): these contain standard consultations that require average time for physical examination and administrative follow-up.
- Score 3 (high complexity): these are complex cases that require extensive preparation, long consultation times, and significant administrative work.

Instead of assigning 10 patients per block, there is a maximum of points that a cardiologist can handle per block. For example, if the maximum is 10 point per block, a cardiologist could see ten 1-point patients, five 2-point patients or a combination of two 3-point patients and two 2-point patients.

Advantages:

- Creating a more realistic schedule. According to the interviews the current schedule is unrealistic.
- The perception of workload improves.
- There is more time to finish complex patients. Less work piling up.

This approach may give the impression of a lower overall number of patients seen, but it also allows for smarter scheduling, providing insights into which patients will require longer appointments and which can be handled more quickly. The figure shows three examples of how this might look. The figure demonstrates that with smart scheduling, you can see the same number of patients, or even more, than under the current system.

H.2. Change 4-hour blocks

Currently, every day in the schedule is divided into two blocks of 4 hours per day. One 4-hour block in the morning and one 4-hour block in the afternoon. For example, a cardiologist can have outpatient clinic in the morning and echo supervision in the afternoon. This idea lets go of these 4-hour blocks.

For example:

The outpatient clinic is currently scheduled as a 4-hours block. This could be redesigned into a full outpatient clinic day, divided into one 5-hour block and one 3-hour block (roughly). During the first 5 hours, the cardiologist sees patients, while the remaining 3 hours are reserved for administration. In this way, sufficient time is reserved to complete all administrative work, and delays in the outpatient clinic are less likely to affect the rest of the day. In the current schedule, a cardiologist can have two 4-hour blocks per week for outpatient clinics. In this proposal, cardiologists would have a full day dedicated

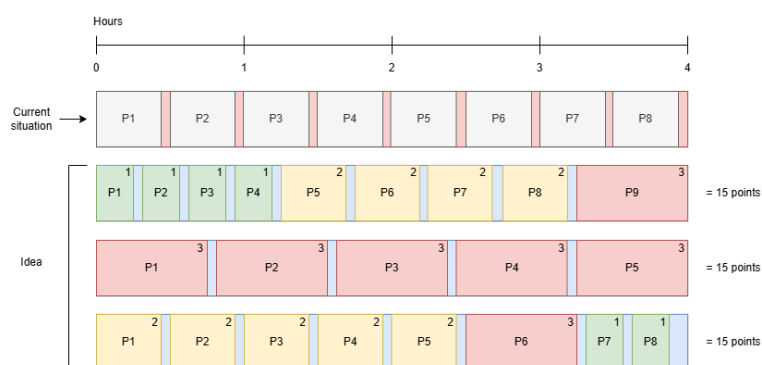


Figure H.1: Idea 6: outpatient clinic with points

to outpatient clinics. The figure shows that, overall, cardiologists may see slightly fewer patients, the difference is not big. However, if physicians work more efficiently in this setup, it could ultimately be more effective and less administrative work would pile up and has to be finished in other hours. To make it more feasible: apply this only to the complex sub-specialization outpatient clinics which are often taking more time than scheduled for, and schedule the general outpatient clinics in standard 4-hour blocks.

Advantages:

- Administration time implemented in the schedule.
- Decreased workload.
- Delays in the outpatient clinic do not interfere with the remainder of the day schedule.

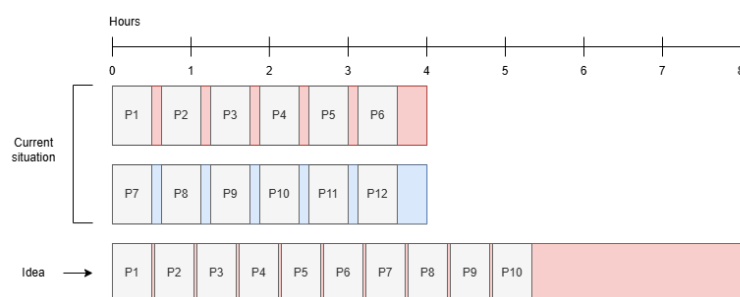


Figure H.2: Idea 4: outpatient clinic day

H.3. Year schedule with blocks (high/medium/low blocks)

The current schedule is planned for a period of 3 months. Instead of a 3 month planning period, change it to a year planning. This year is still divided into periods of 3 months. However, each cardiologist can indicate in which periods they prefer to do more clinical work and in which periods they want more time for research, administration, management tasks, recovery etc. This allows the workload to vary over the year. The cardiologists indicate their preferences at the beginning of the year and the scheduler will make a fair distribution of the periods.

This gives everyone:

- Peak periods: periods with a higher clinical workload.
- Light periods: periods in which cardiologists do less clinical tasks to give them room to breath and focus on non-clinical tasks.
- Moderate periods: periods in which cardiologists do some clinical work combined with other tasks.

Key idea: instead of having a constant, evenly distributed workload, workload fluctuates intentionally over the year, based on the preferences of the cardiologists.

Advantages:

- Increased autonomy and control over the schedule.
- Higher predictability.
- Clinical targets are still met. You don't decrease the number of outpatient clinics, you just distribute them differently.
- Heavy periods can be compensated with lighter periods.
- Heavy periods have an ending.

However, you need to make sure that there are clear rules and arrangements to retain the productivity of the department. For example, there needs to be a x number of outpatient clinics per period, there can only be a x number of cardiologists in their light period at the same time, holidays during peak periods etc. The figure gives a visualization of this idea.

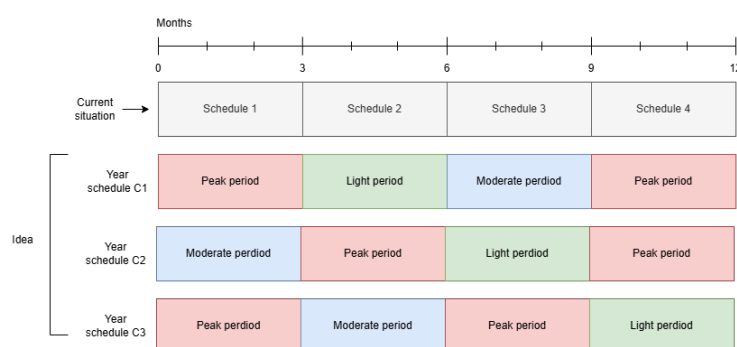


Figure H.3: Idea 1: peak periods

H.4. Compensation days

Create a simple and transparent compensation system in which you can “earn points” for doing less popular shifts, such as weekend and night shifts. These shifts typically have a higher impact on work-life balance and recovery. For each completed weekend or night shift, a cardiologist receives a fixed number of points. If you have earned a x amount of points you can trade them for a day off. The goal is to provide a clear and meaningful reward for doing more demanding shifts and thereby increase motivation among cardiologists.

Advantages:

- Increased motivation.
- Improves perceived fairness.
- supports recovery.
- Increases autonomy and sense of control.

H.5. Administration time

Every cardiologist receives one full day (or two half-days) every two weeks dedicated to administration and other outstanding tasks. During this time, the cardiologist can complete pending work and create some breathing room. This approach gives cardiologists the opportunity, every two weeks, to relieve the pressure of their workload. This solution means that the department will be slightly less clinically productive overall, but in the long run it will result in less overworked and therefore more productive employees.

H.6. Semi self-scheduling

Only schedule the tasks which are dependent on other people, like outpatient clinics and meetings. The individual tasks are not divided in the schedule. Instead, cardiologists have the flexibility to plan these tasks around their fixed clinical activities. To maintain predictability, key activities such as outpatient clinics can be scheduled on fixed days. Fixed outpatient clinics: The department used to do this. However, the number of cardiologists on the department has doubled, making it hard to assign everyone to a fixed outpatient clinic day. This problem could be addressed by scheduling double outpatient clinics, allowing two cardiologists to conduct outpatient clinics simultaneously. However, an outpatient clinic is usually combined with an echocardiogram. The problem is the availability of echocardiography rooms and the individuals performing the echocardiograms.

Advantages:

- Increased autonomy and control.
- Increased flexibility. Physicians plan their own work and work according to their own preferences.
- Scheduling individual tasks becomes less complex.

However, clear rules must be established to ensure that all tasks are completed and to prevent physicians from becoming less engaged due to the self-scheduling. Furthermore, management must trust that physicians will handle this responsibility in a professional manner. Instead of a detailed schedule, cardiologists could be provided with a weekly or biweekly set of tasks to complete, with the flexibility to decide when to complete these tasks.

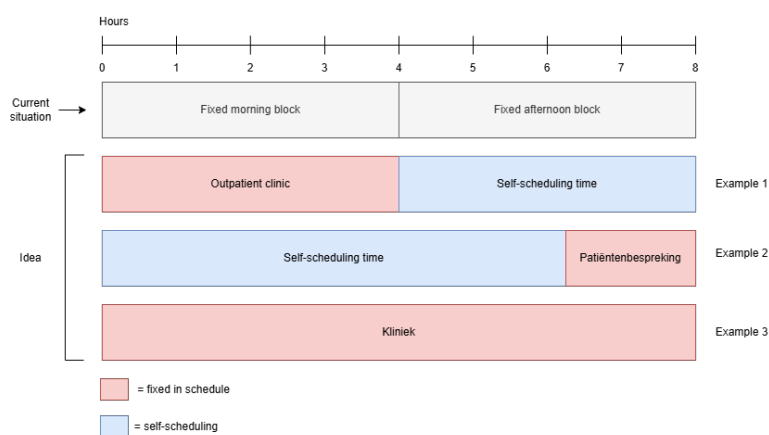


Figure H.4: Idea 2: self-scheduling

Output survey

The survey responses were originally in Dutch. An AI tool was used to assist with translation and the correction of spelling and grammatical errors. The content of the answers remained the same.

I.1. Feedback prototype 1: weighted scoring system

- Not the highest priority; I do not think this will yield a significant improvement. However, it will make things more transparent.
- Good idea. The details of the ranking system are important.
- Be cautious, as the perceived burden will vary between individuals. This raises doubts about whether it will work in practice. Are there examples from clinics that use this approach? It may be useful to gather such experiences.
- Interesting concept, but it requires careful consideration; the implications are not yet fully clear. How do we score the burden of specific tasks?
- Strong idea. It could reduce perceptions of unfairness regarding the distribution of workload. It allows for better comparison, but a solid framework must first be established and agreed upon by everyone.
- Fine and realistic. It may contribute to increased satisfaction.

I.2. Feedback prototype 2: 8-hour blocks

- Good idea if it is practically feasible.
- Simple and effective idea. Follow-up time is directly linked to the outpatient clinic. Good plan!
- Very good, as it also includes follow-up time, which is necessary and justified. A full outpatient clinic day is perfectly feasible.
- Also a good idea. A balance between CPTel/PVC and administrative work is essential. Production would be lower...
- No opinion: I do not work in outpatient clinics, so I cannot assess this.
- Unrealistic. Outpatient clinics would then occur even less frequently.

I.3. Feedback prototype 3: year schedule with blocks

- Very good idea, if it is practically feasible. Service blocks could also be considered.
- I would find it difficult to plan (and think) that far ahead.
- Careful consideration is needed regarding how long the peak period would last, as it needs to be sustainable. Alternatively, can individuals indicate their preferred duration? This seems complicated for scheduling if everyone is allowed to set their own preferences.
- Not very realistic. Not my preference. Clear definitions are important.
- Good idea in combination with idea 1: a certain number of points is achieved by the end of the year, equally for everyone.

- We only have peak periods. Children are born even during holidays. An annual schedule is a good idea, but there should also be room for accepting invitations (e.g. to other centers) and other spontaneous activities. Otherwise, it is still worth considering.

I.4. Feedback prototype 4: compensation points

- Not a bad idea.
- Could work! A good idea to reward people for extra effort.
- Perfect, as it can provide individual benefits based on what each person values. Discussion is needed about how heavy different tasks are perceived to be.
- Not very enthusiastic. I find it hard to imagine that this would work.
- It again comes down to assessing the burden of tasks (see 1). It is fine as long as the team agrees on this.
- Not plannable. In my view, not realistic.

I.5. Feedback prototype 5: administration time

- Would be nice.
- Good plan, especially if full days can be scheduled in pairs (for colleagues living outside Rotterdam).
- Perfect plan to start until another idea is developed and implemented. This can be scheduled immediately, so it should be done right away. Very necessary for outpatient clinic preparation and further development. Please start as soon as possible.
- After the outpatient clinic is very nice. Not very innovative. What is the goal: administration or in-depth work?
- Half per FTE is realistic and necessary.

Calculations institutional efficiency

The problem owner provided data on the outpatient clinics and the FTE allocations. This data was used to calculate the impact of the reduction in clinical production of the final design. Table Table J.1 shows the total number of FTE's and the corresponding hours per year. Based on this the hours per year of 1 FTE are calculated. Additionally, the table shows the number of patients seen per block in both the current and the new model. In the current situation, HTX and rhythm outpatient clinics see an average of 8 patients per four-hour block, while the other outpatient clinics see 10 patients per four-hour block.

Table J.1: Basic parameters for outpatient clinic scheduling

Parameter	Category / Type	Value	Note / Calculation
Staffing & Availability			
Number of cardiologists	FTE	10.0	Incl. 0.8 FTE fellow
Working weeks (regular)	weeks/yr	42.0	52 – 6 holiday – 2 conf. – 2 other
Working weeks (special)	weeks/yr	50.0	
Total available hours	hours/yr	15,120.0	42 wks × 10 FTE × 40 h – 10% acad.
Available hours per FTE	hours/yr	1,512.0	Total hours ÷ 10 FTE
Current Model (Patient flow)			
Regular / foetal / POS / etc.	pt/h	2.50	1 block = 4 h (10 patients)
HTX / Rhythm	pt/h	2.00	1 block = 4 h (8 patients)
New Model (Patient flow)			
Special outpatient clinics	pt/h	1.75	1 block = 8 h (14 patients)
Regular outpatient clinic	pt/h	2.50	Unchanged

The second table (Table J.2) shows the different outpatient clinics and their corresponding number of hours per year. This data on the total annual hours was provided by the problem owner. Based on this, the total number of patients seen per year in both the current and the new system can be calculated by dividing the total annual hours by the number of patients seen per hour in each system. The difference between these values represent the total loss in patients, which can subsequently be converted into the total loss in hours. The total loss in hours can be used to determine the additional FTE required to compensate for the reduction in clinical production. Table J.3 shows that the additional FTE required to compensate for the loss in clinical reduction is 0.43 FTE.

Table J.2: Impact of the new scheduling model on annual patient volume and clinical hours

Clinic	Total h/yr	Pt/h cur.	Pt/h new	Pt/yr cur.	Pt/yr new	Loss (pt)	Loss (h)
<i>Regular clinic</i>							
Regular	2,520	2.50	2.50	6,300	6,300	0	0.00
<i>Special clinics</i>							
HTX	400	2.00	1.75	800	700	100	57.14
Rhythm	300	2.00	1.75	600	525	75	42.86
Foetal	400	2.50	1.75	1,000	700	300	171.43
POS	100	2.50	1.75	250	175	75	42.86
Resident	200	2.50	1.75	500	350	150	85.71
Ergo	200	2.50	1.75	500	350	150	85.71
Haven	400	2.50	1.75	1,000	700	300	171.43
<i>Subtotal Special clinics</i>				4,650	3,500	1,150	657.14
Grand Total				10,950	9,800	1,150	657.14

Note: $\text{Loss (h)} = \text{Loss (pt)} \div 1.75 \text{ pt/h}$

Table J.3: FTE impact of the new scheduling model

Parameter	Value	Note / Calculation
Loss in patient volume	1,150 pt/yr	From Table J.2
Required special clinic hours	657.14 h	Lost patients $\div$ 1.75 pt/h (new special clinic rate)
Available hours per FTE/yr	1,512 h	See Table J.1
Additional FTE required	+0.43 FTE	$657.14 \text{ h} \div 1,512 \text{ h/FTE}$
Total FTE required	10.43 FTE	10 current + 0.43 additional