AN ASSESSMENT OF OPERATING ROOM SCHEDULING PRACTICES IN DUTCH HOSPITALS

Why is surgery scheduling still a manual task?

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Abstract

Despite the evident importance of effective scheduling practices, manual scheduling processes persist in numerous healthcare settings, revealing a significant gap between theoretical advancements and practical implementation. While academia offers sophisticated algorithms and decision support systems for optimizing operating room (OR) scheduling, their adoption remains limited in real-world settings. Bridging this gap is crucial for enhancing the efficiency, effectiveness, and financial viability of surgery scheduling processes.

This research explores the factors contributing to the gap between theoretical literature and practical implementation in surgery scheduling, identifying key barriers and facilitators for the adoption of advanced models in Dutch hospitals. Our study examines decision-making processes, handling of uncertainties, management of constraints, and use of performance measures, highlighting discrepancies between theoretical models and practical applications, and offering recommendations for improvement.

Through semi-structured interviews with 24 respondents across nine Dutch hospitals, the study reveals that while theoretical models emphasize sophisticated techniques such as stochastic programming and predictive analytics, none of the hospitals employed algorithmic support for scheduling. Practical OR scheduling relies heavily on expertise and intuitive adjustments, with uncertainties managed through ad-hoc solutions. Performance measures in practice focus mainly on OR utilization, with minimal attention to other metrics like waiting times and cancellation rates, which are emphasized in the literature.

The study highlights the reliance on manual processes, primarily due to system limitations and staff preferences for intuitive methods. Many hospitals face problems with their electronic health record (EHR) systems, which do not support complex planning needs or flexible adjustments, such as defining gross cutting times and changeover times, or predicting operation times based on patient characteristics. Respondents expressed a need for more advanced predictive models within their EHR systems to better anticipate patient needs, but barriers such as resistance to technological change from staff, distrust in systems, data quality issues, and a lack of training and understanding of advanced tools hinder their adoption.

However, the study also identifies facilitators that could support successful implementation, such as leveraging predictive analytics, enhancing training on advanced models and upgrading EHR systems to support complex planning needs. Researchers should develop user-friendly interfaces for predictive models and standardized performance measurement frameworks. Hospitals are encouraged to improve cross-departmental coordination, invest in comprehensive performance monitoring, and facilitate better knowledge transfer between research and practice to foster innovation. By bridging the gap between theory and practice, it enables the translation of theoretical advancements into effective, practical applications.

1. Introduction

The healthcare industry has undergone remarkable expansion in recent years, driven by advancements in medical technology, demographic shifts, and rising consumer expectations. This growth has introduced numerous challenges, from optimizing limited resources to managing rising medical costs[1, 2]. The demand for healthcare services continues to escalate, driven by factors such as population aging and the prevalence of chronic diseases, further straining healthcare systems worldwide[3, 4]. Within this evolving landscape, optimizing surgical procedures is essential for both organizational efficiency and patient care[5], given that operating rooms (ORs) account for an estimated 40% of hospital income[6]. However, OR scheduling presents complex processes, involving multiple stakeholders each with their own divergent goals, including patients, surgeons, OR managers and nursing staff[7].

To address this complexity, various theoretical models have been developed, aiming to improve OR scheduling through simulation, mathematical programming, and advanced algorithms[8]. These models offer potential improvements in operational efficiency and patient care quality, marking notable progress in the field[9]. Despite a well-established and continually expanding theoretical foundation for OR scheduling[10], translating these models into practical applications remains challenging[11, 12].

These challenges arise, among others, due to theoretical models that often overlook the dynamic nature of scheduling in healthcare settings, leading to disparities between academic research and practical implementation[10]. Real-world scenarios involve continuous job influxes, resequencing issues, and intricate processing constraints, which theoretical models may not adequately capture[13]. Pinedo et al.[14] highlighted several disparities: theoretical models typically assume static conditions, such as a fixed number of jobs, while real-world environments require proactive scheduling due to continuous job influxes. They also often ignore resequencing issues and complex processing constraints, with job priorities varying over time. Additionally, real-world scheduling involves multiple objectives with shifting priorities, requiring integration with shift assignments and overtime scheduling. McKay et al.[13] and Maccarthy et al.[15] further emphasize the need for models that better reflect the complexities of real-world scheduling environments.

Other challenges include data quality, resistance to change, and organizational complexities further hinder the implementation of these models[12]. Healthcare systems often lack data collected with operational improvement in mind, and resistance from clinicians and managers, coupled with complex power structures and conflicting incentives, impedes progress. Lack of transparency and communication regarding model design and assumptions can also hinder acceptance[12]. Successful implementation requires understanding organizational culture and managing expectations. Facilitators include, among others, having a champion for operational research models, ensuring models are transparent and accessible, and emphasizing reliable patient flow data to increase awareness and support. Synergy between different elements, where success in one area supports others, is also beneficial for addressing implementation challenges[12, 16].

This gap between theoretical advancement in surgery scheduling and its limited impact in practice presents the following challenge: understanding the underlying reasons for this gap[17, 18]. To tackle this challenge, our study aims to bridge the gap between theoretical innovation and practical application in healthcare systems. We will explore the underlying reasons for Dutch hospitals' continued reliance on manual scheduling practices, identify barriers to implementing theoretical advances, and uncover facilitating factors. Our research will provide actionable insights to inform decision-making and practice, thereby empowering healthcare practitioners with evidence-based strategies to enhance scheduling processes and ultimately improve patient outcomes.

The central research question guiding our study is: "What factors contribute to the gap between theoretical literature and practical implementation in surgery scheduling, and what are the key barriers and facilitators influencing the implementation of these models?"

This study is structured as follows: Chapter 1 introduces the research problem, objectives, and research questions. Chapter 2 outlines the methodology used in this study, detailing the research design, data collection methods, and data analysis techniques. Chapter 3 presents the results, organized into three subheadings: (1) findings from the literature review, (2) findings from the semi-structured interviews, and (3) the gap between theoretical models and practical implementation. Chapter 4 discusses the relevance, strengths, and limitations of the study, providing implications and suggestions for future research and practice. Chapter 5 concludes with a summary of the findings, reinforcing the study's contributions and suggesting actionable steps for improvement.

2. Methodology

In this section, we first introduce the research design, detailing the comprehensive case study approach adopted for this study. We then outline the process of conducting a literature review to understand the current state of OR scheduling and to formulate the interview questions. Following this, we describe the semi-structured interviews conducted with relevant stakeholders to evaluate whether theoretical models align with real-world experiences in healthcare settings.

2.1. Literature review

The purpose of this literature review is twofold. First, it provides a theoretical basis for understanding the current state of OR scheduling. Second, it serves as a foundation for developing interview questions, ensuring they are aligned with established theoretical constructs. This alignment enables a thorough comparison between theoretical models and practical implementation, helping to identify gaps and areas for improvement. To achieve this, a systematic search strategy, developed by Anastasiia et al.[19], was employed. This strategy utilizes search strings and Boolean operators in the title of articles on WebScience: (”scheduling” AND (”operating rooms” OR ”operating room” OR ”operating theatre”) AND ”review”) covering publications from January 2009 to January 2024. This search is complemented by a forward and backward citation tracing method. to ensure comprehensive coverage of relevant literature.

The analysis of the found papers is grounded in hierarchical levels and key elements influencing decision-making in healthcare organizations, identified by Ackoff and Vergara[20], and Kuiper et al.[21], which provide a comprehensive framework for understanding the complexities of OR scheduling. These concepts include *available actions* for decision-makers, which encompass the set of possible actions or strategies that decision-makers can choose from when faced with a decision, constrained by available resources and other limiting factors. *Uncertainties*, are environmental or external variables that impact decision-making but are beyond the control of the organization. Outcomes expressed in *performance measures*, are the possible results or consequences of decisions, typically evaluated based on how well they achieve the desired objectives or goals. *Values* assigned to potential outcomes refer to the importance or preference that decision-makers assign to different outcomes, influenced by organizational goals, stakeholder interests, and ethical considerations. *Constraints* are the limitations or restrictions impacting the decision-making process, including resource limitations, time constraints, organizational policies etc. These elements have been chosen for their significant influence on decision-making in healthcare organizations. By grounding our interview domains in these theoretical concepts, we aim to cover all relevant areas comprehensively.

By assessing how these elements are mentioned and included in the literature, we can compare them with the findings from the interviews, highlighting discrepancies and potential areas for improvement in practical applications. The comparative analysis of literature and interview findings will be presented in Chapter 5.

2.2. Semi-structured interviews

The qualitative approach of semi-structured interviews enables an in-depth exploration of stakeholders' experiences and perspectives on OR scheduling while ensuring consistency across interviews.

2.2.1. Interview schedule

The interview schedule, which covers topics derived from Ackoff's model, is structured into four main domains: sources of uncertainty, constraints, performance measures, and practical implementation challenges. These domains cover OR scheduling practices at different hierarchical levels within healthcare organizations. The selection of these domains is informed by the identified theoretical elements influencing decision-making, as outlined in the literature. The selection of these domains is informed by the identified theoretical elements influencing decision-making, as outlined in the literature. These domains are widely recognized as fundamental aspects of OR scheduling, frequently discussed in relevant literature due to their impact on operational efficiency[10, 20-24]. To facilitate

the interview process, we have created two versions of the interview schedule, tailored to different hierarchical levels. This division ensures that the language and terminology used are appropriate for the interviewees' roles, making the interviews more accessible and effective in capturing relevant information. Both interview schedules begin with an introduction and informed consent, followed by confirmation of participation. The questions then explore the roles, responsibilities, and decision-making processes and authority of each respondent, along with the structure of their teams. This is followed by discussions on sources of uncertainty, where participants identify common uncertainties in OR scheduling, their frequency, impact, and the strategies employed to manage them. Next, the focus shifts to constraints in planning, examining how constraints and preferences are considered and balanced with operational requirements. This is followed by an evaluation of performance measures, where participants discuss the key performance indicators (KPIs) used to evaluate the effectiveness of OR scheduling and the ideal outcomes associated with good planning. Finally, the interview addresses the use of planning tools and information systems, including barriers to their implementation and the facilitators that support their use and a closing segment (see Appendix 1 for the complete interview schedule).

2.2.2. Study setting

A total of sixteen Dutch hospitals are approached to participate in the study through a formal invitation letter (see Appendix 3). Within each hospital, interview are conducted with healthcare professionals representing crucial functional areas in OR scheduling. These professionals will be selected from different hierarchical levels within the hospital, including positions at the strategic level (e.g., capacity manager, OR-manager), tactical level (e.g., OR managers, OR-planners) and operational level (e.g., day coordinators, assistants).

2.2.3. Data collection and analysis

Interviews are audio-recorded with participants' consent to capture detailed responses accurately. Data analysis follows a thematic analysis approach, coding and analyzing interview transcripts to identify recurring themes, patterns related to surgical scheduling practices. Themes are systematically organized and interpreted to derive meaningful conclusions and recommendations. Full transcripts are available upon request from the author and can be provided if considered necessary for further clarification or validation of findings.

Thematic analysis employs both deductive and inductive coding techniques. Deductive coding uses predefined themes from existing literature, allowing for the verification and validation of established theoretical constructs within the practical context of surgical scheduling, while inductive coding identifies new themes directly from the data, allowing for the emergence of new insights grounded in participants' experiences.

The findings from these interviews will be discussed in detail in Chapter 3.2, providing a deeper understanding of the practical challenges faced in OR scheduling.

2.3. Ethical Considerations

Ethical integrity is maintained, with informed consent, participant anonymity, and the right to withdraw upheld at all times. Access to the recordings is restricted solely to the author, and following transcription, all audio files are deleted. Data is anonymized during analysis to protect privacy. Ethical approval has been obtained from the University of Twente's BMS Domain Hunanities and Social Sciences Ethical Board (registration number 240344, 3 April 2024, see Appendix 2).

2.4. Validity and reliability

To enhance the trustworthiness of the study findings, strategies such as triangulation of data sources, member checking, peer debriefing, and reflexivity are employed. Participants are selected using purposive sampling to ensure representation from various stakeholders involved in OR scheduling. By combining deductive and inductive coding techniques, the study aims to validate existing theories and discover new insights. examination of the data, leveraging both the validation of existing theories and the discovery of new insights.

3. Results

This chapter presents the results of the study, divided into three subsections to provide a comprehensive understanding of the findings from different perspectives. The first subsection details the findings from the literature review, which establishes a theoretical framework. The second subsection presents the results from the semi-structured interviews, highlighting their experiences and perspectives on OR scheduling practices. The final subsection addresses the gap between theoretical models and practical implementation, analyzing the discrepancies.

3.1. Literature review

In this section, we will detail the results of the literature review. The literature review yielded 17 reviews, which have been categorized according to six key topics earlier from the works of Ackoff et al.[20] and Kuiper et al.[21].

Topic 1. Decision level,
Topic 2. Uncertainty,
Topic 3. Performance measures,
Topic 4. Constraints,
Topic 5. Possible decision,
Topic 6. Value of performance measures.

Table 1 provides an overview of the reviewed literature in relation to the identified topics. The following subsections introduce each of these topics in more detail. Due to overlap in key findings, Topic 1 (Decision level) and Topic 5 (Possible decision) have been combined, as well as Topic 3 (Performance measures) and Topic 6 (Value of performance measures).

	1. Decision level	**2. Uncertainty**	**3. Performance measures**	**4.Constraints**	**5. Possible decisions**	**6. Value of performance measures**
Abdelrasol et al. (2014)[25]	**X**				**X**	
Aktas et al. (2023)[26]		**X**	**X**			
Cardoen et al. (2010)[23]		**X**	**X**	**X**	**X**	**X**
Ferrand et al. (2014)[27]	**X**	**X**	**X**	**X**		
Guerriero and Guido (2011)[28]	**X**	**X**	**X**	**X**	**X**	
Hans and Vanberkel (2012)[29]	**X**	**X**		**X**		
Harris and Claudio (2022)[30]		**X**	**X**	**X**	**X**	**X**
Hof et al. (2017)[31]	**X**	**X**		**X**	**X**	
Hulshof et al. (2012)[32]	**X**		**X**	**X**	**X**	
May et al. (2011)[22]	**X**	**X**		**X**	**X**	
Pandit et al. (2022)[33]			**X**	**X**	**X**	
Rahimi and Gandomi (2020)[34]	**X**	**X**			**X**	
Samudra et al. (2013)[35]				**X**	**X**	

Samudra et al. (2016)		X	X		X	
Van Riet and Demeulemeester (2015)[36]	X	X	X	X	X	X
Wang et al. (2021)[37]		X	X		X	X
Zhu et al. (2019)[38]	X	X		X	X	X

Table 1: literature overview

3.1.1. Topic 1: Decision level & Topic 5: Possible decisions

Decision-making processes within healthcare operations management are typically structured across three hierarchical levels: strategic, tactical, and operational[39]. These levels involve various decisions related to capacity planning, resource allocation, task assignment, and prioritization, particularly in the context of the continuous arrival of new tasks into the scheduling system, which presents decision-makers with a dynamic array of options[20].

Strategic decisions are long-term, focusing on defining the organization's mission and objectives. At this level, key decisions include capacity planning, capacity allocation, and case mix planning (CMP)[25]. Capacity planning involves determining the overall number of ORs to build, the types of services to offer, and the necessary resources, such as staff and equipment, to meet future demand[31]. For instance, a hospital might decide to expand its OR capacity by constructing additional rooms and investing in specialized equipment to support high-demand surgeries like orthopedic or cardiovascular procedures. Capacity allocation refers to the distribution of these resources across different surgical specialties and departments over a long-term horizon, typically several months to a year[22]. Another strategic decision could involve setting targets for resource utilization, such as aiming for an 85% OR utilization rate to maximize efficiency[28]. CMP involves deciding the mix of surgical cases to optimize resource utilization and financial performance, ensuring a balanced and profitable portfolio of procedures[31]. These decisions are based on highly aggregated information and forecasts, with objectives like improving resource utilization and budget distribution. Solutions from researchers to support strategic decisions include, among others, stochastic programming models to optimize capacity planning and allocation, linear and integer programming to allocate resources efficiently across various specialties, and simulation models to predict demand and resource utilization[28].

Tactical planning organizes execution over a medium-term horizon, often entailing cyclic scheduling for surgeons[39]. This includes developing the Master Surgery Schedule (MSS), which allocates OR time blocks to different surgical specialties or individual surgeons on a weekly or monthly basis[10]. The MSS balances the workload across different surgical groups to optimize resource utilization and patient flow[38]. For instance, a hospital might allocate Monday and Wednesday mornings to orthopedic surgeries, while reserving Tuesday and Thursday afternoons for general surgery. Common decisions on this level include determining which days and times are allocated to specific types of surgeries (e.g., elective and emergency cases), ensuring that resources such as staff and equipment are evenly distributed to avoid bottlenecks[25]. Solution from researchers to support tactical include, among others, mixed-integer linear programming to develop MSS and allocate OR time blocks, heuristic methods to solve complex scheduling problems where exact methods are computationally infeasible (e.g., genetic algorithms and tabu search), and robust optimization to create schedules that can withstand variability in surgery durations and emergency cases[10].

Operational planning involves short-term decision-making, real-time monitoring, and reactive decision-making during execution, further distinguish between offline and online planning[39]. Offline operational planning is conducted in advance and includes creating detailed daily schedules for surgeries, staff, and equipment[32]. This involves sequencing surgeries to minimize downtime and efficiently use available resources. For example, surgeries requiring similar equipment or anesthesia can be scheduled consecutively to reduce setup times. Another offline decision might involve scheduling surgeries with the highest likelihood of overrunning early in the day to minimize the impact on subsequent procedures. Online operational planning involves real-time monitoring and reactive decision-making during execution[40].This includes making adjustments to schedules in response to unexpected delays, patient no-shows, or emergency cases[38]. For instance, if a surgery is

running longer than anticipated, the OR manager might reschedule or relocate subsequent procedures to avoid bottlenecks. Similarly, if an emergency case arrives, the manager must decide which elective surgeries to postpone and how to reallocate staff and resources promptly to handle the emergency without significantly disrupting the overall schedule. Solutions to support operational decisions include, among others, real-time scheduling algorithms to adjust schedules dynamically, such as Bayesian updating and predictive analytics, discrete event simulation to model and simulate day-to-day operations to help anticipate and respond to variability, and queuing theory to manage patient flow and reduce waiting times[41].

Incorporating the continuous arrival of new tasks, OR scheduling requires decision-makers to adapt flexibly and responsively. Dynamic strategies, such as real-time data analytics and predictive modeling, enhance scheduling adaptability. For instance, machine learning algorithms can predict surgery durations and patient recovery times, improving scheduling accuracy. Decision-support systems with real-time monitoring can alert administrators to potential bottlenecks or resource shortages, enabling proactive adjustments. Additionally, modular block scheduling allows for flexible time block allocation based on real-time needs, balancing elective and emergency surgeries and ensuring efficient resource utilization. To illustrate the hierarchy of decision levels in OR planning, Figure 1 from the work of Rahimi and Gandomi[34] provides an overview of decision levels in OR scheduling problems.

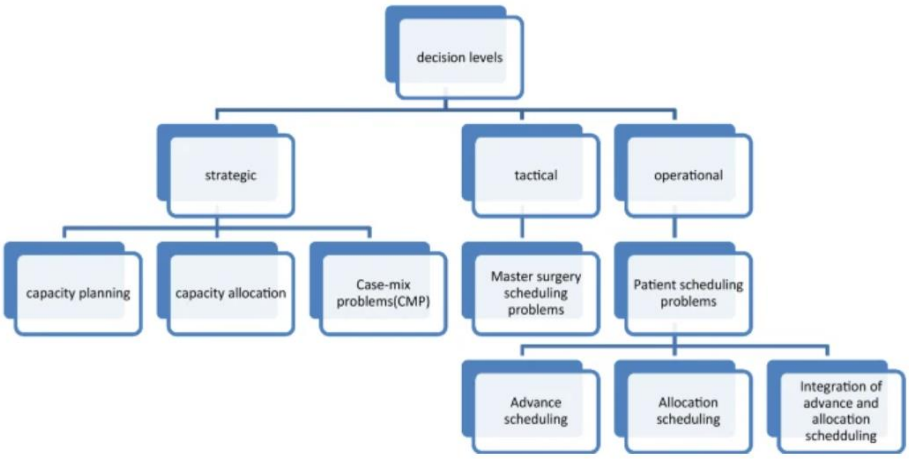

Figure 1: Decision levels in OR [34]

3.1.2. Topic 2: Uncertainty

Uncertainties in OR scheduling refer to as unpredictable factors or conditions that impact scheduling outcomes. These uncertainties may stem from variations in demand, unexpected events, or changes in resource availability. The literature on OR scheduling identifies several common types of uncertainties and suggests various methods to address them.

One of the most common types of uncertainty is surgery duration uncertainty, which refers to the variability in the actual time required to perform surgeries[38]. This variability can lead to delays, idle time, or the need for rescheduling. Patient arrival and emergency uncertainty involves the unpredictability in the arrival of emergency cases and the variability in elective patient no-shows and/or late arrivals[21]. These types of uncertainty can disrupt planned schedules and lead to the postponement of elective surgeries. Additionally, resource uncertainty, which includes variability in the availability of staff (e.g., surgeons, anesthetists, nurses), equipment, and ORs, can cause delays, cancellations, and inefficiencies in OR utilization[26]. Capacity planning is a key strategy to address this issue, ensuring adequate staffing and equipment availability through long-term planning.

Care requirement uncertainty refers to the variability in patient care needs, influencing recovery times and the scheduling of subsequent procedures[38].This uncertainty can affect the availability of postoperative recovery beds and the overall patient flow. Moreover, cancellations and complications

are also considered sources of uncertainty in OR scheduling. Cancellations can occur due to patient no-shows, medical reasons, or logistical issues, while complications during surgeries can lead to extended surgery durations and unplanned postoperative care needs[29]. In addition to these, demographic trends and regional dynamics are long-term uncertainties that few studies consider. These factors include variations in care demand due to demographic changes, such as aging populations, and regional healthcare dynamics.

Various methods have been suggested to address these uncertainties, including the use of stochastic models that account for the probabilistic nature of surgery durations. Simulation models, such as Monte Carlo simulations, are also used to estimate the impact of duration variability on scheduling, as highlighted[27].

3.1.3. Topic 3: Performance measures & Topic 6: Value of performance measures

Performance measures assess the effectiveness, efficiency, and quality OR scheduling outcomes. These metrics provide insights into how well the scheduling process achieves its objectives, serving as essential tools for continuous improvement in healthcare operations. They help evaluate resource utilization, patient care delivery, and cost management, enabling healthcare providers to make informed decisions to optimize OR management and enhance overall operational performance[37].

The most common performance measures identified in the literature include utilization rate, waiting time, cancellation rate, overtime, quality of care, and patient throughput[10]. Each metric serves specific purposes and provides valuable insights into different aspects of OR management. Utilization rate, encompassing OR, surgeon, and equipment utilization, is frequently emphasized. High utilization rates indicate efficient resource use, minimizing idle time and maximizing OR productivity. Overtime measures the additional hours worked beyond scheduled shifts, often highlighting scheduling inefficiencies and impacting both financial performance and staff well-being. Quality of care metrics, such as surgical outcomes and patient satisfaction, are crucial for monitoring and improving the standards of care provided[36]. Patient throughput evaluates the number of surgeries performed within a given time frame. Cancellation rate tracks the frequency of surgery cancellations, while waiting time measures the time patients spend waiting for surgeries, both essential for assessing the quality of service. In addition to these measures, other performance metrics found in the literature include financial metrics (e.g., revenue generated), makespan, and others[36].

The value of performance measures in OR scheduling lies in their ability to align scheduling practices with organizational goals and stakeholder preferences. Different performance measures cater to varied interests among stakeholders, emphasizing different priorities[30]. For instance, hospital administrators often prioritize metrics that reflect economic sustainability, such as revenue generation and cost-efficiency. In contrast, medical staff might prioritize measures that ensure manageable workloads and optimal patient outcomes, such as quality of care and patient satisfaction. Surgeons may focus on on-time starts and patient outcomes, while capacity managers emphasize utilization rates and financial performance. Patients, on the other hand, value their overall satisfaction and experience. This diverse prioritization underscores the importance of selecting appropriate performance measures to balance the objectives of all stakeholders, thereby improving overall OR management and patient care[32].

3.1.4. Topic 4: Constraints

Resource constraints encompass restrictions or boundaries that impact scheduling decisions. The most common constraints discussed in the literature include staff, equipment, OR availability and financial constraints[38]. Other constraints are patient preferences are medical stuff preferences. Variability in the availability of surgeons, anesthetists, nurses, and other supporting staff requires scheduling to account for shift patterns, vacations, and potential sick leave. Limited availability of essential medical equipment and OR space also poses constraints. Additionally, facility resources such as recovery beds and pre-operative areas must be managed to avoid bottlenecks and ensure smooth patient flow. Patient preferences, such as desired surgery dates and times, and medical staff preferences regarding weekends, shifts, and days, complicate scheduling[29].

3.2. Results interviews

This chapter presents a summary of the findings from the semi-structured interviews. A total of 24 respondents from nine different Dutch hospitals (cases) participated in the interviews. These respondents have different roles, as detailed in Table 2. Out of these nine cases, eight cases are complete because information was gathered at three distinct hierarchical levels, see Figure 2. Each case involved interviews with two to four professionals from each hospital. However, one case, Hospital I, is incomplete due to the lack of information from all three levels, making it insufficient and not fully representative of OR scheduling practices. The average number of ORs across these hospitals is 23, with a minimum of 12 and a maximum of 44. Hospital B was not utilizing its full complement of ORs due to staffing shortages. Additionally, five hospitals are equipped with robotic and hybrid-facilitated ORs. The results will follow the structure of the interview schedule starting with the roles, responsibilities of participants and decision-making processes, followed by the identification and management of uncertainties, constraints in planning, performance measures, and finally, the use of planning tools and implementation challenges.

Position	No. of participants
Capacity manager	7
Sector manager	2
OR Manager/unit team manager	3
OR planner	4
Operational OR planner/patient planner	3
Day coordinator	5

Table 2: Respondents overview

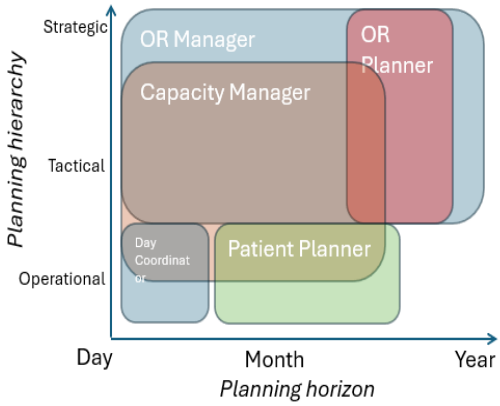

Figure 2: Hierarchical levels

3.2.1. Roles, responsibilities and decision-making processes

The planning of OR schedules in practice involves a structured process starting from high-level annual planning down to the assignment of patients to OR days. Most hospitals (5 out of 9) follow a similar procedure.

At the strategic level, capacity managers and OR managers play crucial roles. The most important decisions are for long-term capacity planning, production forecasting, and determining the annual OR plan. The annual planning, often advised by a team that focuses on capacity management, often called Integrated Capacity Management (ICM), is based on historical surgical data to estimate the required OR hours to meet the production targets set with insurers. These plans are approved by high-level boards and adjusted quarterly to align with the hospital's strategic objectives.

At the tactical level, OR planners, and unit team managers take over the responsibility of implementing the strategic plan into actionable schedules. They assign specialty blocks in a cyclical manner, manage staff rosters and make adjustment to the Master Surgical Scheduling (MSS) if needed through Regular tactical meetings (TPO) monitor the adequateness of the plans and if need make proposals to adjust these plans, usually every 3 to 8 months, typically by the OR planner considering the specialties. These meetings provide a platform for discussing and resolving scheduling conflicts, ensuring flexibility and adaptability in OR schedules. TPO also handles resource allocation, prioritizes critical surgeries, and updates schedules to reflect current needs and constraints. Respondents noted that the involvement of TPO improves inter-departmental coordination.

Operational planning involves weekly or bi-weekly reviews and adjustments, with real-time changes handled by day coordinators and facilitated by the capacity managers, e.g., to accommodate emergencies. They ensure smooth daily operations by managing emergencies, patient flow, and resource allocation. The Central Planning Bureau (CPB) typically manages the booking horizon for

assigning patients to OR days, which is generally 2-6 weeks in advance. These schedules are verified and have to be approved a week before, and a final approval is received usually a day or two before, all under the responsibility of the OR (day) coordinators.

Hospital B and Hospital E exhibit unique planning processes. Hospital B relies heavily on its Central Planning Bureau for logistical planning and daily operations, with tactical adjustments every 6 weeks. In contrast, Hospital E employs a three-tier planning system (following the logic of strategic, tactical, and operational) with frequent operational adjustments and significant involvement of sector managers in daily planning.

The interviews revealed various additional planning issues concerning the OR. Common challenges include operational planning difficulties, such as deciding patient placement and making daily adjustments for emergencies and unforeseen delays. Many hospitals also face significant staff shortages and resource management problems, necessitating coordination efforts that range from weekly to daily, requiring a lot of manual adjustments. Coordination with other departments, particularly the ICU and recovery wards, is critical to prevent bottlenecks in some hospitals.

Among the strategies employed, scheduling buffers for emergencies proved effective in hospitals like D and E, where designated ORs for emergencies minimize disruptions to elective procedures. However, Hospital R, despite having separate rooms for emergencies, still cancels elective procedures, possibly due to their inflexible annual plan and overestimation of staff capacity. Additionally, A common strategy is to schedule complex surgeries earlier in the day to manage procedural overruns and reduce cascading effects on subsequent surgeries.

There are also some unique challenges, for example, Hospital I emphasized the difficulty of aligning OR schedules with ward outflows and establishing rules for surgeon-specific procedures. The challenge lies in coordinating various factors, including surgeon availability, procedure length, recovery room availability, and the dynamic nature of emergency cases. Currently, two to three months in advance, sessions are allocated to surgeons, but the specific procedures they will perform are often only confirmed shortly before the surgery date, leading to uncertainty in the ward. To address this, rules are being established regarding what procedures surgeons can perform on specific days, known as planning quotas. For example, a group of surgeons might be required to perform hip surgeries on Mondays, knee surgeries on Tuesdays, and have flexibility on Wednesdays as long as the ward maintains a certain outflow. Hospital S pointed out the problem of distributing beds fairly among specialties, especially when some specialties plan their surgeries far in advance and through that reserve some beds, while others plan on a short-term basis.

Figure 3 summarizes the most common decisions across all nine cases, categorizing them into strategic, tactical, and operational levels, and highlighting areas of overlap.

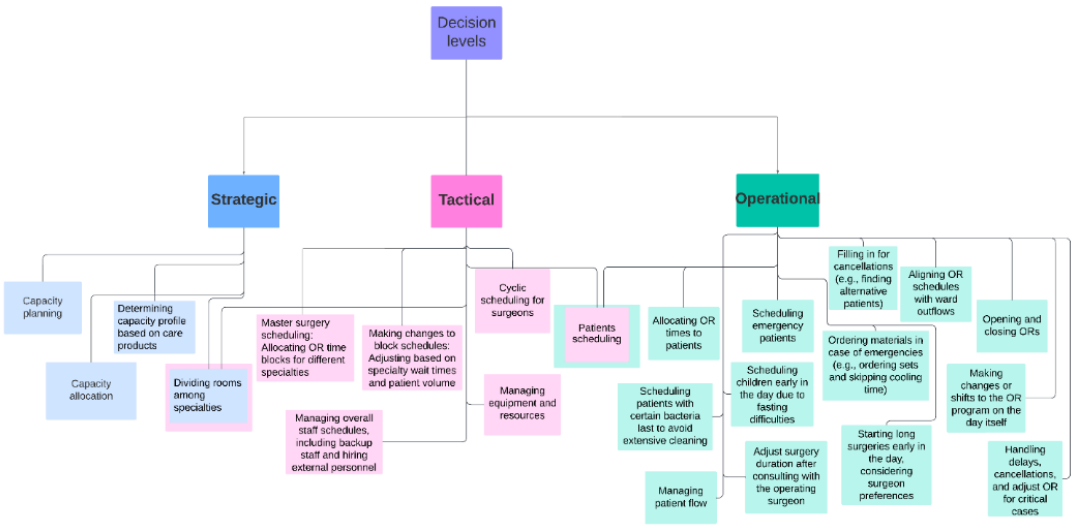

Figure 3: Decision levels practice

3.2.2. Uncertainty factors

Several sources of uncertainty in OR planning, with common and differing recognition and management practices. Variation in the number of emergency patients is a critical and universally recognized source of uncertainty, noted by all nine hospitals. This occurs daily and has a high impact, managed by maintaining dedicated emergency ORs and buffer slots real-time monitoring, and rapid response. Variation in care demand, influenced by demographic trends, is widely recognized, acknowledged by seven hospitals. It manifests as fluctuations in patient volumes and types of surgeries required, impacting long-term planning and resource allocation. Hospitals rely on historical data and adjust plans accordingly, though the effectiveness is limited. Variation in surgery duration is a significant source of uncertainty, recognized by eight out of nine hospitals, occurring daily and managed by having surgeons indicate expected durations and adjusting schedules accordingly, often with buffers (built-in slack time). Cancellations of surgeries, acknowledged by six hospitals, typically occurs weekly and is managed by reserving emergency slots, as not having to cancel them. Also, if a patient is canceled on short notice leading to a gap in the schedule, that is, unused OR time, patients are called from a short list to quickly fill these slots. All nine hospitals struggle with the availability of supporting staff and resources, rather than specialists or surgeons, which impact varies from daily to monthly and is managed manually through spreadsheets or coordinated during roster planning, with some hospitals maintaining a flexible buffer for staff and equipment. Overruns in surgery schedules are also common challenge across several hospitals, often causing significant disruptions and necessitating last-minute adjustments. three hospitals monitor these overruns, tracking the percentage of overruns and underruns on a monthly basis.

Less commonly recognized sources of uncertainty include no-shows, acknowledged by only three hospitals, which rarely happen and have a small impact. This challenge is prevented by contacting patients a day in advance. Uncertainty in patient recovery time is recognized as an issue by only two hospitals, occurring rarely but having a moderate impact; it is managed by using historical data to anticipate and plan for bed occupancy. It is important to note that a lot of respondents did not provide an answer to this question, primarily due to a lack of knowledge or because someone else in their hospital was responsible for this aspect. Therefore, assuming that this uncertainty is less recognized could be misleading, as the lack of response does not necessarily indicate a lack of awareness. Complications during surgeries, recognized by four hospitals, occur weekly and have a significant impact, they are managed by having surgeons indicate potential complications in advance and adjust schedules accordingly to reserve extra time for them and not to add a patient afterwards. Uncertainty due to regional dynamics and actions of other hospitals is recognized by five hospitals. This involves changes in referral patterns, competitive actions, and regional healthcare policies that influence patient flow. Its impact varies but can be moderate to high, managed through regional collaboration and communication, participating in regional healthcare networks, and maintaining flexibility in scheduling and resource allocation. Other uncertainties mentioned by respondents include the quality of medical staff (e.g., availability of medical knowledge and potential for misjudgment), issues with pre-operative screening, reliability of imaging equipment, advance scheduling of specialized ORs (e.g., hybrid ORs), and delays in supplier deliveries.

3.2.3. Constraints in planning

Each hospital faces unique constraints influenced by factors such as hospital size, type, and available resources. Larger hospitals with more specialized departments tend to have constraints related to coordinating complex surgical teams, while smaller hospitals often face issues related to a lack of specialized personnel or equipment. However, some larger hospitals, have enough ORs but face personnel shortages, whereas others have adequate staffing but insufficient OR capacity to meet demand. These variations indicate that constraints are not uniformly experienced across hospitals but are case-dependent. These variations indicate that constraints are not uniformly experienced across the hospitals in our study but are case-dependent.

The most common constraints across the cases are the availability of resources, including staff, equipment, and ICU beds. Staffing constraints, such as shortages of nursing and anesthesiology staff, impact scheduling flexibility. Coordinating the availability of complete surgical teams, including

surgeons, anesthetists, and nurses, is challenging because not all staff can execute the same tasks, making it a puzzle to assign the right person to the right task. This often leads to overworking the available staff and, less frequently, underutilization. Limited availability of equipment and material shortages also pose challenges. Delays in obtaining necessary surgical materials can lead to last-minute cancellations or rescheduling. Limited resources for equipment and staff necessitate prioritizing critical surgeries over others. The availability of ICU beds is also a significant constraint, as surgeries often cannot proceed without guaranteed post-operative care. When ICU beds are fully occupied, elective surgeries must be cancelled, postponed or rescheduled, disrupting the overall scheduling plan and impacting patient care and satisfaction.

All nine hospitals emphasize the need for coordination with other departments, such as ICU and recovery wards, to ensure smooth operations and prevent bottlenecks. This coordination involves regular meetings and communication between departments to align their needs and capacities. Additionally, managing the scheduling of specialized surgeries or dealing with the availability of specific equipment like hybrid ORs is also mentioned as a challenge.

Another very common constraint is surgeon preferences. Individual preferences, such as specific days for performing surgeries or the desired order of surgeries, along with the overall availability of surgeons, often create conflicts in scheduling and necessitate frequent adjustments. Respondents emphasized that accommodating these preferences is crucial because, without the surgeons' cooperation and presence, operations cannot proceed. Therefore, their preferences are considered highly important and are given significant consideration in the scheduling process.

Patient preferences are also considered, but they are generally given lower priority compared to the availability of staff, resources, and surgeon preferences. Patient preferences for surgery times and specific surgeons are taken into account but may be overridden by the need to optimize resource utilization and manage workloads effectively. Seasonal issues, such as patients' preference to schedule surgeries around holidays or vacations, particularly in the summer, can create additional challenges. These seasonal constraints are often prioritized at the top of the list by OR planners at the tactical level.

Other identified constraints include time constraints, such as shift changes for staff, especially nurses, which create strict time windows for surgeries and limit scheduling flexibility. Patient constraints, such as variations in pre-operative preparation times, add complexity to scheduling, requiring hospitals to account for these variations to ensure timely surgeries. High variability in the number of emergency surgeries also disrupts planned schedules and is a widely recognized constraint. Inadequate systems for scheduling and tracking surgeries lead to inefficiencies. Fair distribution of beds among specialties is challenging, especially when some specialties reserve beds far in advance.

Most hospitals prioritize these constraints in their planning processes, often ranking the availability of medical personnel and equipment as the most critical factors, followed by surgeon preferences and lastly patient preferences. Balancing these constraints with operational requirements involves scheduling and sometimes leaving buffer slots to accommodate emergencies and last-minute changes.

There are differences in how hospitals manage these constraints. Some hospitals, like Hospital Y, use planning tools and predictive models to enhance their planning processes, specifically for managing patient recovery times, forecasting surgery durations, and addressing uncertainties such as delays. These advanced tools help to minimize delays, optimize the use of available operating rooms, and ensure that staff and equipment are utilized more effectively. In contrast, other hospitals rely more on manual adjustments and the experience of their staff to manage these constraints.

3.2.4. Performance measures

The most commonly measured KPI is the utilization of operating rooms, monitored by all eight hospitals on a daily and/or monthly basis. Support staff and equipment utilization are also tracked, though less consistently, with some hospitals measuring these metrics daily while others do not monitor them at all. The utilization of surgeons is less frequently measured, with only a few hospitals keeping regular tabs on this indicator. Quality of care and service, particularly access and wait times,

are generally monitored monthly but often by other departments, with the OR department receiving periodic reports. Interestingly, some hospitals admitted uncertainty regarding whether certain KPIs, such as quality of care or employee workload, are formally measured. This uncertainty often comes from operational-level respondents, such as OR coordinators, who might not have direct access to or involvement with these data points. Performance is typically measured using dashboards and software tools like Power BI, HiX and Epic. Despite these tools, there is a noted desire to implement more advanced KPIs, such as detailed bed occupancy tracking and predictive models for patient recovery times. Regarding workload staff and productivity, the interviews revealed that both are infrequently measured. When workload is measured, it is typically done in two ways: automatically through tracking overtime visible in the system, or annually via questionnaires. However, many respondents were unsure if workload is formally measured, with some indicating that it is either not measured, insufficiently tracked, or only assessed informally without a specific metric. Similarly, productivity is not widely measured across the hospitals. A few respondents were unsure if productivity metrics were tracked at all, or mentioned that any available data is automatically captured by the system without regular, deliberate assessment.

When respondents were asked what constitutes good planning, the most common theme, mentioned first by almost all respondents across all levels, was high OR utilization. Only two respondents did not mention utilization in their answers: one day coordinator focused on avoiding overtime and conflicts with doctors or assistants, specifically stating *"Going home at the end of the day, all patients have been operated on, no arguments with the doctor or with the surgical assistant. From thirteen operating rooms down to three by four o'clock, and no one needs to work overtime".* The other OR planner prioritized helping as many patients as possible. Other common themes included minimal overruns and delays, and maintaining stable waiting lists. The ability to avoid patient cancellations, which often occur due to reasons such as lack of available beds, medical reasons (e.g., patients not fasting), or staff shortages, and ensure smooth patient flow. These outcomes are deemed vital for hospital operations, patient satisfaction, and provider well-being.

3.2.5. Tools and implementation challenges

Manual processes remain prevalent across all hospitals not only for real-time adjustments and operational online decisions but also for tactical and strategic processes. Activities such as counting and tracking equipment, scheduling patients, assigning surgical blocks, and adjusting plans are often done manually. For instance Hospital M utilizes manual Excel sheets for managing staff and resource availability, with significant reliance on planners' experience rather than fixed protocols. This reliance on manual processes is mainly due to system limitations but also because staff prefer to rely on their experience and intuition rather than automated systems. This is common across all hospitals, highlighting the inadequacies of current software tools, which do not fully accommodate the specific needs of OR planning or handle the variability in surgical cases and resource availability.

Common tools used include Epic, HiX, Power BI, Excel, Qlik, and SQL, which are supported by dashboards for monitoring and reporting. These tools assist in planning and data analysis, though there are significant issues reported with them. Many hospitals face problems with the limited functionalities of their electronic health record (EHR) systems.

One of the primary concerns is the inadequate support for coordinating the availability of necessary equipment and staff. This includes managing material shortages and ensuring that all team members (surgeons, anesthetists, nurses) are available for scheduled procedures. The software does not account for the specific tasks that each staff member can perform, often leading to a mismatch between staff availability and task requirements. As a result, the creation of surgical teams still requires significant manual intervention to ensure that the right personnel are assigned to the right tasks.

Moreover, respondents indicated several data accuracy issues within the current systems. The systems often provide incorrect information when assigning medical urgency and determining anesthesia types. Additionally, almost all respondents mentioned that the software does not consider patient characteristics such as obesity or whether a patient requires multidisciplinary care. This lack of consideration affects the estimation of potential complications, which surgeons need to allocate extra

time accurately. They also noted that the software fails to define gross cutting times or induction times accurately and does not facilitate effective communication and coordination between different departments, such as ICU and recovery wards.

The tools do not adequately handle the variability in surgical cases, such as differences in pre-operative preparation times and the complexity of procedures. For example, the automatic changeover time is often set to a default 10 minutes, which does not account for real-world variations such as missing sets, the need for equipment to cool down, or surgeries requiring more preparation time. This lack of consideration leads to inaccurate predictions for surgery duration and patient stay, which must be manually adjusted. Furthermore, the analysis of waiting lists is minimal, typically defaulting to selecting the first patient on the list without considering other factors. Typically, the system calculates surgery duration based on the past 6-10 surgeries. If it cannot find historical data for a particular surgeon, it uses an average from another surgeon. However, planners, through years of experience, can often predict and adjust more accurately than the system, considering individual surgeons' varying speeds and efficiencies depending on the type of procedure.

Additionally, the user interface of current software tools is often not flexible or intuitive, making it difficult for staff to use effectively. There are integration challenges with EHR systems, resulting in fragmented and inefficient processes that require frequent switching between programs. For instance, in hospital R it was noted, *"We have a scheduling tool in our EPD, there's a planning tool in there. We have a personnel scheduling tool via ORTAC. That's the second one. And in between, there's another custom-made system where all the staff information is stored and updated daily. So, there are actually three systems that need to be continuously maintained because they don't communicate with each other. It's very cumbersome."* Additionally, the systems frequently generates inaccurate warnings, leading to mistrust by staff .This lack of flexibility and usability results in a reliance on manual processes and personal experience to manage schedules.

Data analysis is utilized to some extent in most hospitals, primarily for production forecasting and tracking OR utilization. However, advanced models and algorithms are not widely implemented. Only a few hospitals are beginning to explore predictive models or optimization algorithms for better planning efficiency. For instance Hospital Y and one department in Hospital E incorporate algorithms and predictive models like the Patient Flow Forecast (PFF) to better anticipate and manage patient recovery times and other uncertainties.

Resistance to technology and improvements is another critical issue. This resistance often comes from staff who are accustomed to current practices and may distrust new systems, fear job loss, or lack the technical knowledge to use them effectively. Additionally, integrating new technology can disrupt established workflows, causing further resistance. In Hospital D, a respondent specifically mentioned that while technology could make work easier, it would also make the job less enjoyable and potentially redundant, stating, *"Makes work easier but not enjoyable; then my own work becomes boring, and eventually, I might not have a job!"* This highlights a significant barrier to adoption, driven by fear of job loss. Furthermore, multiple respondents mentioned an obstacle to implementation could be the physicians' resistance, as they currently have significant autonomy and authority, and technology introducing data-driven decisions might be unwelcome. In Hospital S, it was specifically stated, *"Here, the doctors still have a lot to say; you can want anything, but if the rest of the chain does not want to cooperate, it ends there"*. Another hospital considered a new project to calculate planning at the intervention level, taking into account all conditions for each type of surgery, specialist, and specialty. This initiative seemed promising but faced resistance, especially from specialists who currently have significant autonomy over their schedules and procedures. They are unlikely to welcome a technology that dictates when and what they must do. This underscores the challenge of gaining buy-in from key stakeholders in the healthcare process.

Moreover, capacity managers stay updated with the latest developments through literature, conferences, and networking with colleagues from other hospitals. However, at operational levels, such as with coordinators and planners, there is little to no engagement in these activities due to time constraints and lack of awareness. For example, the OR planner at Hospital S was unaware of how to stay updated, stating, *"I wouldn't know where to find that"*.

3.3. Identifying the gap

This chapter discusses the findings from our study, highlighting key discrepancies between theoretical frameworks and practical applications in OR planning and scheduling. The main gap identified is that surgery scheduling is predominantly expertise-driven and based on historical ways of working, in contrast to the structured and model-driven approaches found in the literature. Several factors contribute to this gap, which we will explore in detail.

3.3.1. Factor A: lack of structured approaches in practice

In the literature, decision-making processes in OR scheduling are structured and supported by sophisticated models. However, in practice, these processes are predominantly expertise-driven, ad-hoc, and based on historical ways of working.

In the literature, strategic decision-making processes are often supported by sophisticated models like stochastic programming, simulation, and forecasting to predict and optimize planning and resource allocation. In practice, however, the use of such advanced models is minimal. Hospitals often have a rigid annual plan based on historical data, with quarterly adjustments made by ICM teams based on available resources. Despite recognizing significant issues from the previous year's performance, such as OR shutdowns and unmet utilization targets, hospitals like Hospital A continue to use the same data without making necessary adjustments. This rigid approach contrasts sharply with the literature's emphasis on forecasting and optimization. The predominant reliance on historical data to inform decisions, coupled with the minimal use of algorithmic support or advanced modeling, further highlights a significant gap in proactive planning capabilities.

Medium-term planning and the importance of cyclic scheduling and MSS development are well-aligned in both literature and practice. However, unlike the literature, which often discusses the use of models such as mixed-integer linear programming and heuristic methods for MSS development, these supportive models are rarely employed in practice. Instead, greater emphasis is placed on regular tactical meetings and inter-departmental coordination to handle ongoing OR scheduling challenges. This approach relies heavily on addressing real-time issues as they arise and on collaborative problem-solving, rather than on pre-constructed models.

Uncertainties are frequently highlighted as crucial factors in OR scheduling literature, with structured and model-driven approaches such as stochastic models and predictive analytics recommended to handle variables such as surgery durations, patient arrivals, and resource availability. However, in practice, uncertainties are not measured or addressed in a structured manner, despite being a common challenge across all cases. Instead, uncertainties are often managed ad hoc as they arise, with solutions implemented in real-time or on short notice. There is often no formal protocol or structured approach to handle these uncertainties, relying heavily on the experience of medical staff, particularly day coordinators and operational OR planners. Additionally, in practice, there is a strong belief in the accuracy of averages, whereas one should naturally account for uncertainty in highly variable settings.

Several hospitals highlighted the issue of bed availability impacting OR scheduling. In the literature, bed availability issues are primarily addressed at the strategic and tactical levels. Solutions often involve the use of mathematical programming models and simulation techniques to optimize bed allocation and ensure that adequate bed capacity is available to meet anticipated patient needs. In practice, bed availability issues are often resolved manually at the operational (online) level, which might be too late for timely interventions, causing significant disruptions or even leading to same-day cancellations of surgeries. Addressing these concerns earlier in the planning process at higher levels could mitigate problems, ensure smoother patient flow, and reduce delays or cancellations.

3.3.2. Factor B: Limitations of current theoretic models

The theoretical models' limited applicability to the dynamic and unpredictable nature of healthcare environments is a significant gap. These models often fail to account for varying workloads and variable surgery durations, assuming static conditions and hard constraints that do not hold true in the fluid environment of actual healthcare settings.

In the literature, OR scheduling challenges, such as uncertainties and constraints, are typically addressed in isolation, each with separate models. However, in practice, these critical factors often occur simultaneously. For instance, workforce limitations, material shortages, and patient-related uncertainties can all impact the scheduling process at the same time. This segmented approach in the literature does not reflect the interconnected reality of hospital operations, where a holistic and integrated model is needed. Additionally, the assumptions of known probability distributions and static conditions in mathematical programming models do not align with the practical need for frequent adjustments due to emergencies, staff shortages, or equipment failures.

There is also a necessity for integrated models that can simultaneously consider multiple factors and apply to various types of patients and specialties. For instance, a single model should be able to handle both elective and emergency patients and be adaptable to different surgical specialties, rather than relying on separate models for each scenario.

Furthermore, theoretical models often operate under hard constraints, which overlook the importance of soft constraints in practice. In hospitals, surgeon preferences are highly valued and are considered among the most critical constraints, right after the availability of staff and resources.

The quality of data is another critical issue. Advanced models depend on high-quality data. However, in practice, many respondents reported data quality issues, making the data unreliable. Even when quality data is available, it is primarily used for retrospective analysis rather than real-time decision-making. Moreover, the literature does not adequately address the reliance on historical data for decision-making in practice, nor does it offer models based on such data.

3.3.3. Factor C: Resistance to automation in practice

The persistent reliance on manual processes in hospitals, driven by both system limitations and resistance to change. This resistance is fueled by fears of job loss, diminished control, and a lack of understanding of the benefits of automated models.

Many hospitals face problems with the limited functionalities of their EHR systems. These systems do not adequately support complex planning needs or flexible adjustments, resulting in a heavy reliance on manual processes. For example, these systems lack the capability to define gross cutting times and changeover times, making adjustments difficult due to the high variability in surgery durations and occupancy rates. Predicting operation times based on patient characteristics, such as weight, is not supported, leading to less accurate scheduling. Additionally, these systems often fail to account for nuanced decision-making criteria, such as selecting patients from waiting lists based solely on their position rather than considering other critical factors like urgency, patient condition, or resource availability. Moreover, there are integration challenges with EHR systems, resulting in fragmented and inefficient processes that require frequent switching between programs, which is cumbersome and prone to errors. The systems frequently generate inaccurate warnings, leading to mistrust and manual verification by staff.

Another significant reason for the reliance on manual processes is the lack of understanding regarding the added value of these models. Many respondents do not fully grasp the benefits of these models. When tasks are complex and require careful execution, staff tend to rely on manual processes rather than computer-generated solutions. One respondent mentioned, "*Variability in outflow toward the clinic and treatment center is a big problem, so it needs to be done manually".* This indicates a belief that manual handling is less prone to errors, even for simple tasks. Even simple tasks, such as the availability of staff and materials, are managed manually in Excel sheets, which is an outdated method.

Additionally, fear among medical staff that automated models will reduce their control and authority contributes to this resistance. Many staff members believe that these tools, which rely on objective data, might undermine their subjective judgment and diminish their hierarchical strengths. This fear extends to concerns about job loss, especially among staff whose tasks could be automated. The belief that computers could take over their roles leads to resistance to adopting new technologies.

3.3.4. Other findings

In this section, we discuss additional findings that emerged from the study, which are organized into four categories: case mix planning, the divergence in OR planner roles, performance measures, and knowledge transfer.

Case mix

The literature commonly identifies case mix planning as a critical scheduling problem at the strategic level. Surprisingly, this aspect was not identified in the interviews, indicating a discrepancy between theoretical frameworks and practical applications. This suggests that while case mix planning is theoretically significant, it may not be as prevalent or recognized as a distinct issue in hospital operations.

Divergence in OR planner roles

In the literature, operational-level activities are primarily associated with patient scheduling. However, in practice, the operational level is often closely integrated with the tactical level, with personnel performing tasks that span both levels. These tasks include opening and closing ORs, managing bed availability, and overseeing patient outflow. The decisions made at this level encompass a broader range of responsibilities that significantly impact the entire OR scheduling system and other planning objectives at different levels.

In fact, during the interviews, it became evident that the role of the OR planner did not align with initial expectations based on the literature. In practice, there are two types of OR planners. One type, responsible for patient scheduling, operates at higher levels with longer planning horizons. The other type, also called OR planner or patient planner, is active at the operational level and handles short-term tasks such as managing the order of patients and making the OR schedule for the next day, but they do not directly plan patients. This discrepancy between the two roles was not known prior to the study or evident in the literature, indicating a gap.

Performance measures

In the literature, OR utilization is frequently emphasized as a critical performance measure for achieving financial goals and operational efficiency. This metric is valued at the top management level, where high utilization rates indicate efficient resource use and productivity. However, at lower levels, metrics like overtime might be more important. In practice, OR utilization is not only valued at the top management level but also at lower operational levels, though the emphasis and perceived value can differ. Operational staff view high utilization as a means to help as many patients as possible. Other metrics, such as waiting time, cancellation rates, patient throughput and staff workload, are highlighted in the literature. However, in practice, very minimal attention is given to these metrics. It was noted that while many KPIs are automatically calculated in practice, only OR utilization is actively monitored and used for decision-making.

Knowledge transfer

Despite the extensive literature and updates on OR scheduling, these advancements seem not to reach practice effectively. Only ICM advisors or managers occasionally contribute to academic network meetings where knowledge is exchanged. At the operational level, which is crucial for implementing new methods as the resistance identified is mainly from there, this knowledge transfer is lacking.

4. Discussion

This chapter will discuss the relevance of the study, highlighting its contributions to the understanding of OR scheduling and planning in a real-world context. Following this, we will delve into the theoretical embedding of the research, aligning our findings with existing literature and suggesting future research directions. Next, we will present practical recommendations for enhancing OR scheduling and planning processes, addressing identified gaps and proposing actionable steps. Finally, we will conclude with an examination of the study's strengths and limitations, offering a balanced perspective on the research conducted.

4.1. Relevance

We have gained valuable insights into the complexities and challenges of OR scheduling and planning in a real-world context. This study identifies several gaps between theoretical models OR scheduling and the practical realities faced by healthcare institutions, highlights discrepancies between theoretical assumptions and real-world implementation. Unlike previous studies that often focus on isolated aspects of OR scheduling, this research offers a holistic view that includes technological, organizational, and cultural dimensions. This study contributes to the scientific literature by providing empirical evidence of the challenges healthcare professionals face, thereby informing future developments in healthcare operations management. Moreover, it emphasizes the importance of integrating practical insights with theoretical advancements, ultimately aiming to enhance scheduling efficiency, resource utilization, and patient care in hospitals.

4.2. Theoretical embedding of this research and future research design

The findings of this study are consistent with other research in the field[12, 42]. For instance, the resistance to adopting new technologies was a common theme. This resistance often stems from a fear of job redundancy and a preference for manual adjustments. This finding is consistent with the literature, such as the study by Lapointe and Rivard[43], which found that healthcare professionals often resist technology due to concerns over job security and the monotony of automated tasks. Additionally, Cresswell and Sheikh[44] discuss the barriers to adopting new IT systems in hospitals, noting that staff often prefer familiar practices and are wary of the disruptions caused by implementing new technologies. They also recommend involving end-users in the design and implementation process to ease the transition. Also on the challenges of implementing theoretical models in practical healthcare settings. The importance of high-quality data and cross-departmental coordination is emphasized in the research by Brailsford[45] supporting the need for integrated data systems and regular interdisciplinary meetings.

Future research should adopt a longitudinal approach to examine how OR scheduling practices and challenges evolve over time, providing deeper insights into the long-term impact of different strategies. Moreover, including interviews with all five identified key will ensure comprehensive case studies and make the findings more robust. As well as expanding the study to include more hospitals can always enhance the generalizability of the findings. Researchers can also consider mixed-methods approaches that combine quantitative data with qualitative interviews to understand the underlying reasons behind observed patterns and outcomes. For example, incorporating quantitative data on performance metrics and outcomes can strengthen the findings and provide a more comprehensive assessment of the effectiveness of different scheduling strategies.

4.3. Recommendations

The results of this study underscore several key areas that require enhancements in OR scheduling and planning to improve efficiency and effectiveness in hospital settings. These can be addressed through both practical interventions and focused research efforts.

Researchers should develop more adaptable and dynamic scheduling models that account for the complexities and unpredictability of healthcare environments, such as focusing on integrating downstream resources and improving alignment between planning levels, such as integrating tactical and operational levels. Additionally, models should simultaneously consider uncertainties, constraints,

and other limitations, as these often occur together in practice. To enhance current systems, robust, user-friendly software solutions are needed to manage complex scheduling requirements, integrate seamlessly with existing systems, and address user needs and challenges. Engaging hospital staff to understand their challenges and incorporating their insights into model development can ensure that theoretical advancements are grounded in practical realities. Collaborative research projects and pilot studies in clinical settings can facilitate this knowledge exchange, change their perspective and reduce resistance to adopting new tools. Additionally, simplifying research language and terms can make theoretical work more accessible, thereby minimizing the knowledge gap among staff.

Hospitals should identify areas where automation can be introduced, such as scheduling adjustments, resource allocation, and performance monitoring, to streamline operations and reduce administrative burdens on staff. Establishing comprehensive protocols and structured approaches to proactively handle uncertainties and repeated constraints is crucial. This proactive approach allows staff to focus on managing emergencies rather than dealing with multiple issues that could have been anticipated and resolved in advance, thus reducing the day-of-surgery workload and ensuring smoother operations. We believe that capacity managers, knowing the OR planning problem at different levels, such as bed management, and integrate these considerations into their strategic and tactical planning processes, can play a crucial role in facilitating the planning process and preventing last-minute disruptions. Enhancing cross-departmental coordination will ensure better alignment between bed availability and OR scheduling, further contributing to efficient and effective hospital operations. Moreover, establishing a regular interdisciplinary meetings, similar to the TPO structure, but inclusive of key stakeholders from different levels, especially from operational level, hospitals can foster collaborative problem-solving and timely discussions. These meetings should also be used to regularly review performance data, not just OR utilization, to inform planning decisions. This approach can help identify areas for improvement and track progress over time. Establishing a more balanced approach to performance measurement by incorporating additional metrics into regular reporting and decision-making processes, coupled with regular audits and feedback loops, can ensure these metrics are actively monitored and used to drive improvements.

Furthermore, to address resistance to new technologies, hospitals need to create supportive environment that encourage innovation and continuous learning. This includes comprehensive change management strategies, training programs, demonstration of new technology benefits, and involving staff in the selection and implementation process. Training programs and workshops could be organized to familiarize hospital staff with these models and their practical applications. Collaboration with academic institutions to develop customized training modules or regular events, such as scientific evenings, can present new methods and insights. It is crucial to involve staff members from various functions and levels within the hospital, especially at the operational level, to address the knowledge gap among medical staff. ICM teams and OR managers, generally more familiar with technology, are open to adopting new methods due to their higher knowledge levels. However, we believe that day coordinators are more suitable to lead initiatives to integrate theoretical models into real-world settings, as they play a crucial role in managing daily operations and are closely connected to both the operational team and higher-level management.

By addressing these recommendations, both practitioners and the scientific community work towards of a holistic approach bridging the gap between theoretical models and practical implementation in OR scheduling. Through collaborative efforts, innovative technologies, and a commitment to continuous improvement, it is possible to enhance the efficiency and effectiveness of OR planning.

4.4. Strength and weaknesses

While this study provides valuable insights, it also has several limitations. Initially, it was assumed that three key roles (capacity manager, OR manager, and OR planner) would be sufficient to understand the scheduling process. However, the study revealed that there are five crucial roles directly involved in this process: capacity manager, high-level OR manager, tactical OR planner, operational OR coordinator, and the day-to-day OR scheduler. Due to time constraints, we were unable to complete the case in all hospitals, potentially missing important perspectives.

The identified discrepancies regarding the roles of OR planners could suggest that some important perspectives from the patient planners may have been missed, potentially impacting the comprehensiveness of our findings. However, the core insights regarding OR planning and scheduling practices remain robust, as the operational tasks performed by the OR planners we interviewed are critical components of the overall scheduling process. To confirm this further, we interviewed two OR planner from two different hospitals, responsible for patient scheduling to assess the potential impact on our results, their responsibilities and knowledge did not significantly address our research questions, indicating minimal impact on the study's outcomes. Their responsibilities and knowledge did not significantly address our research questions, indicating minimal impact on the study's outcomes.

The use of self-reported data from interviews may introduce biases such as social desirability or recall bias. Respondents might provide answers they believe are expected or may not accurately recall details of their scheduling practices. Additionally, the study primarily focuses on current practices and immediate challenges, lacking a longitudinal perspective that could provide insights into how these practices and challenges evolve over time.

Despite these limitations, the study has several strengths; the inclusion of respondents from various hierarchical levels provides valuable diversity of perspectives within the hospital. Participants were selected based on purposive sampling, a non-probability sampling technique, to ensure they were chosen based on their knowledge, experience, and involvement in the OR scheduling process. Triangulation of data sources was employed to incorporate multiple perspectives, and member checking was implemented to ensure the accuracy and credibility of the findings. Additionally, peer debriefing involved seeking feedback from colleagues and experts in the field, validating the research process and findings.

The hospitals in this study were located in various regions across the Netherlands, encompassing both academic and non-academic institutions, which provided a broad understanding of OR scheduling practice. Reflexivity was also emphasized to acknowledge and mitigate potential biases introduced by the researchers. The transcription and coding process was conducted by two independent researchers, minimizing subjectivity and enhancing data reliability. Additionally, the dual approach of combining deductive and inductive coding techniques further enhances methodological rigor, leveraging both the validation of existing theories and the discovery of participants' unique perspectives and experiences.

Conclusion

This research aimed to explore the factors contributing to the gap between theoretical literature and practical implementation in surgery scheduling, and to identify the key barriers and facilitators influencing the adoption of these models in Dutch hospitals. Our comprehensive case study across nine hospitals revealed that surgery scheduling is predominantly expertise driven and based on historical ways-of-working, contrasting sharply with the structured and model-driven approaches found in the literature. This indicates a significant gap between theory and practice. This research goes beyond merely stating that implementation fails by delving into the reasons why theoretical models are not adopted in practice.

Several key factors contributing to this gap have been identified:

- **Resistance to automation:** one major factor is the persistent reliance on manual processes in hospitals. Many hospitals face problems with the limited functionalities of their EHR systems, leading to distrust in these systems and a heavy reliance on manual processes. This reliance is due to system limitations but also but also resistance to change, driven by fears of job loss, diminished control, and a lack of understanding of the benefits of automated models.
- **Model limitations**: another significant factor is the limited applicability of theoretical models to the dynamic and unpredictable nature of healthcare environments. These models often fail to account for varying workloads and variable surgery durations. In the literature, such factors are often addressed in isolation, without considering other critical constraints such as workforce or material limitations. Additionally, there is often a lack of focus on integrating downstream resources and improving alignment between planning levels. In practice, multiple factors, such as the type of patients and uncertainties, must be considered simultaneously and depend heavily on the decision-maker. Theoretical models often operate under static conditions and assume known probability distribution. These assumptions do not hold true in practice, where frequent readjustments due to emergencies, staff shortages, or equipment failures are necessary. Furthermore, most models are based on hard constraints, whereas actual healthcare settings often involve soft constraints, such as surgeon preferences.
- **Data quality:** accurate and integrated data is essential for model-driven approaches in scheduling. However, many hospitals struggle with data issues like missing anesthesia times, which hampers the application of sophisticated scheduling models or tools. Even when data is available, it is often used for retrospective analysis rather than real-time decision-making, highlighting a gap in proactive planning capabilities.

Several barriers to implementing theoretical advances in OR scheduling were identified. Although there is potential for automation, staff prefer the flexibility and familiarity of manual control, leading them to rely more heavily on their own experience and intuition. Staffing and resource constraints, particularly staff shortages, create significant scheduling challenges as models often assume optimal conditions that do not reflect real-world limitations. Effective OR scheduling requires coordination across multiple departments, a factor frequently overlooked in theoretical models. Practical implementation is hindered by communication gaps and misaligned priorities between departments such as the ICU and surgical teams. Many hospitals also lack the necessary know-how of more advanced tools and software to utilize theoretical models. There is a strong belief in the accuracy of averages, whereas one should naturally account for uncertainty in highly variable settings.

Despite these barriers, the study identifies several facilitators that can support the successful implementation of theoretical scheduling models. Ensuring that scheduling models are transparent and easy to understand can help gain buy-in from staff and reduce resistance, particularly among employees without advanced planning and scheduling training where complexity might be a barrier. Leveraging predictive analytics and advanced data integration can enhance scheduling accuracy and operational efficiency. Additionally, interdisciplinary meetings and improved communication channels, especially with other departments, can facilitate better coordination and resource allocation.

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Appendix 1: Interview-schedule

Introduction
Hello and thank you for your participation in this interview. My name is ..., and I am conducting this interview as part of a research study focused on OR scheduling and planning in Dutch hospitals.

Informed consent
Before we begin, I want to make it clear that your participation in this interview is entirely voluntary. You can withdraw at any time without consequences. Your answers will be treated confidentially and anonymized in the final analysis. If you have any questions or concerns, feel free to ask. Do you consent to participating in this interview? Additionally, this interview will be recorded to ensure an accurate representation and analysis of our conversation. Your recorded responses will be treated with the same confidentiality and anonymity standards as mentioned earlier, they will be immediately deleted after the interview is transcribed. Do you consent to the recording?

Confirmation of participation
Great! Thank you for your willingness to participate. The purpose of this interview is to gain insights into the challenges and complexities of surgical scheduling practices within Dutch hospitals. We aim to understand the decision-making processes, resource constraints, and operational limitations involved in scheduling surgeries effectively. Your insights will be valuable for our research. We will cover a total of four domains using a questionnaire: sources of uncertainty, structure and constraints in planning, performance indicators, and challenges. The interview will last about one hour.

Interview question
Alle eerst willen we graag wat algemene vragen stellen om een goed beeld te krijgen van uw rol, ervaring, en de operationele procedures binnen de planning van operatiekamers

1. What is your current position in the hospital and what are your responsibilities?
2. How many colleagues do you have with approximately the same responsibilities?
3. How many operating rooms (ORs) are there and how are they shared?
4. How is the annual plan for the OR determined?
    a. How are historical surgical data and statistics used in the strategic planning process?
    b. How is this plan monitored throughout the year and how are adjustments made if necessary?
5. What is the planning horizon for assigning specialty blocks?
    a. Is it cyclical or non-cyclical and what is the time period (month) involved?
    b. Who has the mandate for this?
    c. How is this plan monitored throughout the year? How often? How are adjustments made if necessary?
6. Is there tactical-level consultation (e.g., TPO)? If so, how often and who is involved?
    a. What is discussed and what decisions are made during these consultations?
    b. Who has the mandate in the consultation and who makes the final decision?
7. What is the booking horizon for assigning patients to OR days?
    a. Are patients scheduled individually (e.g., when they call) or in groups?
    b. Who has the mandate for this?
8. During the day, is the realization of the planning monitored on the same day? If so, how?
    a. How are adjustments made if necessary?
    b. Who has the mandate? Based on what information are adjustments made?
    c. Are there fixed protocols? If so, what do they look like?
9. What other planning issues concerning the OR have we not yet mentioned?

Domain 1: Sources of uncertainty
Now we will focus on unforeseen challenges in OR planning, known as sources of uncertainty. We would like to know if you recognize these and how often they occur, and how they are dealt with. Can

you indicate for each item if and how often this happens (on a scale from never, once per ..., to always)?

SOURCE OF UNCERTAINTY	RECOGNIZABLE? (YES/NO)	FREQUENCY (NEVER, ONCE PER YEAR, RARELY - ONCE PER MONTH, SOMETIMES - ONCE PER WEEK, OFTEN - DAILY, ALWAYS - EVERY PATIENT)	IMPACT (NONE - NEGLIGIBLE EFFECT, SMALL - MODERATE EFFECT, LARGE - SIGNIFICANT EFFECT)	HOW IS IT ADDRESSED?
VARIATION IN CARE DEMAND (DEMOGRAPHIC TRENDS)				
REGIONAL DYNAMICS (WHAT OTHER HOSPITALS DO)				
VARIATION IN NUMBER OF EMERGENCY PATIENTS				
CANCELLATIONS OF SURGERIES				
VARIATION IN SURGERY DURATION (SHORTER/LONGER)				
RECOVERY TIME OF THE PATIENT (OUTFLOW)				
AVAILABILITY OF STAFF OR RESOURCES				
OTHER, NAMELY …				

Domain 2: Structure and constraints in planning

Now that we have discussed sources of uncertainty, we focus on the structure and constraints in planning.

1. How is consideration given to other departments when planning, such as the ICU, recovery wards, and waiting areas? If so, which ones?
2. What constraints or preferences are considered in planning?

    a. How do you balance these preferences with operational requirements?

3. Can you rank the following constraints or preferences in importance? Which are the most important and which are secondary? Preferences of patients, surgeons, availability of medical staff, availability of resources/materials, financial or budget constraints.

Domain 3: Performance indicators
Now we will look at when the planning is good and when it could have been better according to you.

1. When is the planning good according to you?

    a. Can you describe the associated ideal outcomes? (Multiple, hopefully there are more. This can be related to quality/efficiency/effectiveness).
    b. Why are these outcomes important for the hospital or patient? (Relative, the underlying reason why something is measured).

PERFORMANCE INDICATOR	MEASURED? (YES/NO)	FREQUENCY (DAILY/WEEKLY/... + DETAILS)
UTILIZATION OF OPERATING ROOMS		
UTILIZATION OF SUPPORT STAFF		
UTILIZATION OF EQUIPMENT		
UTILIZATION OF SURGEON-SPECIALISTS		
QUALITY OF CARE		
QUALITY OF SERVICE (ACCESS TIME, WAIT TIME)		
WORKLOAD OF STAFF		
PRODUCTIVITY		
OTHER?		

2. How is the performance of the current planning measured (e.g., dashboards)?
3. Are there specific challenges you encounter in monitoring or improving these performance indicators? How do you deal with them?
4. What other performance indicators are you considering implementing? Why would these be useful/important?

Domain 4: Challenges

Finally, we consider the gap between practice and theory, looking at practical challenges in potentially improving planning.

1. How are priorities set when there are conflicting needs and constraints (e.g., urgency of surgeries vs. availability of resources)?

    a. Can you give examples?
    b. What criteria do you use to make a decision here? c. How can you achieve this in the planning? Where can you intervene?

2. Are there manual processes involved in planning? If so, which aspects are still managed manually and why?
3. What planning systems or tools are currently used for planning and managing ORs? If not, why are these tools not used?

    a. What role do you play in the selection and implementation of these tools? (HIX/Epic or self-chosen)
    b. How do these tools help improve planning processes?
    c. Is data analysis used to discover patterns? If so, which ones? In case of historical data, how many surgeries are used for predicting surgery duration?
    d. Are simulation models or mathematical algorithms used to analyze scenarios? If so, which ones?

4. Are there specific improvements or technologies you would like to implement in your planning process? If so, which ones?

    a. What obstacles could stand in the way of implementing, for example, planning software?
    b. What resistances or barriers still need to be overcome?

5. How do you stay updated with the latest developments around planning (e.g., literature, attending conferences, or networking with colleagues from other hospitals)?

Closing

This was my last question, thank you again so much for your time and valuable insights. Your participation is greatly appreciated, and your input will contribute significantly to our research. If you are interested in the results of this study, we would be happy to keep you informed. If so, could you please share your email address with us?

EMAIL: _____

Appendix 2: Ethical approval

UNIVERSITY OF TWENTE.

FACULTY BMS

240344 REQUEST FOR ETHICAL REVIEW

Request nr:	240344
Researcher:	Moussally, N.
Supervisor:	Leeftink, A.G.
Reviewer:	Bruinsma, G.W.J.
Status:	Approved by commission
Version:	2

Appendix 3: Participants invitation letter

UNIVERSITEIT VAN AMSTERDAM

CHOIR

UNIVERSITY OF TWENTE.

Dear Reader,

A significant amount of scientific knowledge has been developed regarding the planning and scheduling of operating rooms. However, we have the impression that little of this knowledge actually reaches the workplace. To test and analyze the factors influencing this, we are conducting a study. Therefore, we would like to interview two employees within your organization: an OR planner and an OR manager and/or capacity manager involved in the management of the operating rooms (e.g., the setup of the MSS).

Purpose of the study
The purpose of the interviews is to gain insight into how the planning and management of operating rooms are carried out in practice. We want to discover which methods and tools are used, the experiences gained with them, and whether there is familiarity with existing theoretical methods. Additionally, we aim to explore the challenges associated with the implementation of these methods and tools. Through this study, we hope to obtain a better understanding of current practices and provide recommendations for further knowledge development to enhance the relevance and value of scientific research for practical application.

Background information
This research project is a collaboration between two universities: the University of Amsterdam (UvA), led by Prof. Dr. Jeroen de Mast, and the CHOIR (Center for Healthcare Operations Improvement and Research) research group at the University of Twente (UT), led by Prof. Dr. Ir. Erwin Hans. The interviews will be conducted by Anastasiia Shcherbina, a PhD student at UvA, and Naya Moussally, a master's student in health sciences at UT.

What we ask of you
We kindly invite you to participate in our study through a semi-structured interview, which is a questionnaire with structure. This interview will take a maximum of one hour, and we are happy to visit you at your location for this purpose. Depending on your availability, we will schedule your interview sometime in April or May 2024.

Your experience will help us bridge the gap between science and practice. Therefore, we sincerely hope you can contribute to our study and look forward to your participation. It is important to note that our research is conducted in accordance with ethical standards, and we have obtained approval from the ethical committee of the University of Twente. Of course, we will keep you informed of our findings through our reports and presentations at well-known forums such as the CHOIR symposium. https://www.utwente.nl/en/choir/

Kind regards,

Jeroen de Mast (UvA)
Erwin Hans (UT-CHOIR)
Alex Kuiper (UvA)
Gréanne Leeftink (UT-CHOIR)
Anastasiia Shcherbina (UvA)
Naya Moussally (UT-CHOIR)