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RESEARCH ARTICLE

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Using implementation science to anticipate adoption challenges for an operations research solution in a children's hospital

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ABSTRACT

Introduction: Mathematical and optimisation models are frequently used to improve hospital planning and capacity management. However, the resulting model-derived solutions are rarely evaluated for their adoption within the real-world context of a hospital.
Objectives: In this study, we share our experience of an interdisciplinary collaboration between operations research/management science and implementation science, as one way of bridging the gap between technically sound solutions and their practical, sustainable use in healthcare.
Methodology: We applied implementation science prospectively to anticipate adoption implications at the design stage of a scheduling tool. Specifically, we used the Consolidated Framework for Implementation Research (CFIR) to identify anticipated barriers and facilitators for adopting a mathematically optimised surgery blueprint schedule within a children's hospital.
Results: Identified anticipated facilitators included strong staff motivation to improve schedules, as well as positive perceptions of an objectively designed mathematical scheduling tool. Barriers included resistance to change among some staff and the demand for more evidence of the schedule's benefits prior to implementation. We identified a strong culture of retaining autonomy in scheduling decisions, as well as operational adjustments made to current scheduling tools.
Practical implications: Applying CFIR prospectively demonstrated how implementation science frameworks could provide a structured way to anticipate adoption challenges and align technical solutions with organisational realities.

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Operations research; hospital scheduling; operating theatre; implementation science; capacity management; logistics

1. Introduction

Planning and capacity management for hospitals is particularly important in the operating theatre (OT) setting, where surgeries need to be scheduled, beds prepared, surgical tools ready, and, importantly, the workforce be made available. Despite accounting for a large proportion of hospital admissions and cost (around 70% according to (Denton et al., 2007)), the daily operations of OT departments worldwide are not always optimised. At worst, there are cancellations that impair patient's health, the pressurised environment can lead to medical errors, and inefficiencies are created due to suboptimal planning. Many of these inefficiency challenges have been modelled mathematically and/or via simulation studies in operations research and management sciences (OR/MS). However, these models rarely make it from theory to practice in a real-life hospital setting. For example, in a recent publication within *Health Systems*, Lame et al. highlighted the need to bring evidence and empirical evaluations of operations research interventions into real-world healthcare settings (Lamé et al., 2022). Other recent scholars in this journal have also explored the adoption of technical applications within real health settings, such as the deployment of AI (Esmaeilzadeh & Maddah, 2026), embedding OR modelling as decision support in healthcare planning (Brailsford et al., 2023), and the roll-out of patient-held health information technologies (McCarthy et al., 2022). This leaves an opportunity for a scientific approach to understand how adoption of models works in practice, thereby creating an empirical evidence base to understand how adoption and implementation of these planning and scheduling models can be successful in other organisations.

In this study, we directly address this theory-to-practice gap for OR/MS solutions for the healthcare domain. Specifically, our study's aim was to identify

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the barriers and facilitators for implementing and/or adopting a mathematically optimised surgery blueprint schedule within a children's hospital. Before proceeding, it is important to clarify how we use the terms adoption and implementation. In a review by Brailsford et al., OR/MS models are classified into three categories according to the extent of implementation: suggested to client (i.e., developed without interaction with a client organisation), conceptualised (i.e., developed through interaction with a client organisation) or implemented (i.e., used by a client organisation) (Brailsford et al., 2016). We adopt a similar definition to the third category of implementation: actual adoption and/or use by a client organisation. Within the health domain, a growing discipline for examining the implementation of interventions is *implementation science*, described as "the scientific study of methods to promote the systematic uptake of research findings and other evidence-based practice into routine practice and, hence, to improve the quality and effectiveness of health services" (Eccles & Mittman, 2006). In this paper, we use the term implementation in the sense defined by implementation science – that is, the adoption, integration, and sustained use of interventions in real-world settings (Eccles & Mittman, 2006), rather than the common usage in operations research, where implementation often refers to the computational deployment or execution of a model to produce solutions.

The field of implementation science formally coalesced in the mid-2000s, yet its theoretical roots reach much further. As Nilsen (2015) summarises, implementation science builds upon decades of work in organisational change, behavioural science, and knowledge-translation research. It shares with the change-management tradition a concern for how innovations are adopted and sustained, but differs in its systematic study of the determinants, processes, and outcomes of implementation in complex service environments such as healthcare. Recognising these shared foundations, our study applies an implementation science framework to assess the anticipated adoption challenges for an operations-research solution within a hospital context. Rather than evaluating a live implementation, or providing a narrative account of implementation challenges *ex ante*, we prospectively explored anticipated facilitators and barriers to adoption, as perceived by hospital staff, to anticipate factors that may shape future implementation efforts. By doing so, we contribute to the wider discourse (Carter & Busby, 2023; Royston, 2013) on how to bring mathematical operations research outputs closer to real-world adoption and practice, and propose that, for health applications, frameworks from implementation science could be one useful approach for doing so.

The remainder of this paper is structured as follows: Section 2 compares the implementation science framework used in this study with the existing literature in operations research and management studies that also tries to address adoption and uptake of models. Section 3 details the study's context and setting, and the methods used in the study. Section 4 presents the main findings from our study, categorised by the emergent themes inspired by the adopted implementation science framework. We discuss the implications and key learning from our findings for interdisciplinary collaboration in Section 5, and how these could be used for wider studies of adoption for operations research and management studies outputs. Finally, we give concluding remarks in Section 6.

2. Background literature

A recurring debate in operations research and management science concerns why technically sound models often fail to achieve sustained adoption in real healthcare environments (Carter & Busby, 2023; Royston, 2013; Scheinker & Brandeau, 2020). Following an extensive literature review on studies specifically on OT planning and scheduling (the focus of our study), Cardoen et al. note how very little is known about the process of implementation (in their sense, adoption), or factors that enhance implementation (Cardoen et al., 2010).

There may be various reasons for this scarcity of evidence in the academic literature for adoption and/or implementation of such studies. It may simply be that many studies are not yet intended to be adopted and are at an early, conceptual phase; therefore, the focus of the publication strategy is to describe the technical solution itself. Limited stakeholders involvement, poor organisational fit, and model complexity have also been cited as barriers to implementation (Eldabi, 2009; Visintin et al., 2017). However, the absence of academic evidence on the adoption of OR/MS outputs does not imply that they are never adopted. It has been argued that part of the real-life implementation of operations research work happens outside of academia (see, for example, (van Lent et al., 2012), and (Brailsford et al., 2016)), partly since uptake may be left to industrial partners rather than modelling researchers themselves (Brailsford et al., 2016), which is why it is not captured in academic publications.

Where adoption has been studied, a range of methodological traditions have been used. A number of studies have sought to describe and reflect on implementation activities, often retrospectively, through narrative or pragmatic reflections written by the project or research team (see, for example, (Bikker et al., 2025; Scheinker & Brandeau, 2020; Smalley et al., 2015)). These are extremely valuable accounts but are limited in providing scientific learning in the adoption and implementation processes. In a systematic review of studies targeted at finding implementation activities from OR/MS studies, Lame et al. found 24 studies in which implementation (in this sense, adoption of the resulting solution) was a key focus on the study (Lamé et al., 2024). On close analysis of these studies, the authors found that the reporting of implementation activities varied, and only a selection of them reported on how sustained implementation was achieved in their targeted setting. Table 1 summarises a selection of these studies, to illustrate the diversity of approaches and the level of sustained adoption achieved.

Collectively, these studies show that while adoption and implementation activities do occur, their documentation remains fragmented and inconsistent across the literature. Some have used soft systems methodology or other qualitative research designs by increasing the involvement of stakeholders (those who will either benefit or use the resulting outputs from the research) either during model development or post-development. These engagement strategies are valuable for fostering shared understanding, building trust, and aligning model design with local needs and constraints. For example, some studies drew on "improvement science" principles (Vindrola-Padros et al., 2017) and were more emphatically targeted towards sustained adoption efforts. Pagel et al. (2017) describe a project enabled by a "researcher-in-residence" model (Marshall et al., 2014), whereby operations research academics were partly seconded to a hospital to translate insights into practice. Recent work in *Health Systems* (Harper & Mustafee, 2023; Lamé et al., 2023) similarly underscore the potential of participatory and co-design methods to enhance the relevance and usability of modelling outputs.

The diversity of approaches represented in these studies, ranging from improvement science to theory of constraints, participatory design, and soft systems, suggests that operations research and management scholars are already experimenting with different ways to bridge the gap between model development and real-world application. However, these efforts remain uneven and highly context-specific. As observed by (Lamé et al., 2024), few studies offer structured analyses of why adoption succeeds or fails, and reporting practices vary widely. Bacelar-Silva et al. (2024), for example, note how implementation efforts could not be sustained after the key "champion" left the organisation. In many cases, these engagement approaches support the development process but fall short of structurally exploring what happens after a model or tool is completed, offering little insight into the organisational, behavioural, or contextual factors that determine long-term use.

Taken together, these examples illustrate that adoption is often pursued in practice but poorly theorised in research, scattered across methodological traditions and seldom connected to a broader conceptual understanding of implementation processes. The fragmented and largely descriptive nature of existing adoption studies suggests a need for frameworks that can connect the technical, organisational, and behavioural dimensions of change. The literature thus reveals an opportunity for interdisciplinary exchange. Fields such as behavioural science, organisational change, and implementation science (introduced earlier) have developed systematic approaches to analyse how innovations are adopted, adapted, and sustained in complex service environments.

Table 1. Selected studies that include description of adoption/implementation activities as a core part of research study.

Study reference (author-date)	Goal of modelling or OR/MS approach	Methodological approach intended to study or enable adoption of modelling outputs	Extent of adoption achieved as reported in article (if any)
(Crowe et al., 2024)	To identify drivers of Emergency department performance, using queuing model	Improvement science; where OR researcher is embedded into hospital setting	Scaled-up change achieved in setting
(Pagel et al., 2017)	To forecast short term demand for beds in an intensive care unit	Improvement science; research in residence approach	Tool in use in hospital setting (at time of study publication) for five years
(Mabin et al., 2018)	To resolve long-standing resource and service constraint challenges in a hospital	Theory of constraints	Proposed interventions were piloted and evaluated
(Lamé et al., 2020).	To support the improvement of patient flows in cancer care	Combination of soft systems methodology, ethnographic observation and discrete event simulation	Long-term implementation/adoption not achieved [discussed in the articles]
(Bacelar-Silva et al., 2024)	To improve the throughput (quantity of patients treated) of and ophthalmology imaging practice	Theory of constraints	Implementation not sustained after 'key champion' left the organisation [potential reasons discussed in study]
(Visintin et al., 2017)	To develop and implement an operating room scheduler at a children's hospital	Action research	Implementation achieved and reflected upon in study
(Harper & Mustafee, 2023)	To support short-term decision-making in an emergency department	Design (participatory) research	Adoption challenges addressed in the study, but no actual sustained adoption reported

Our study takes a step towards this interdisciplinary exchange by drawing on implementation science principles to prospectively explore the adoption potential of an OR/MS solution in healthcare. Rather than evaluating a live implementation, we use these principles to anticipate barriers and facilitators for adoption during the design stage. This anticipatory use of implementation science enables us to examine adoption potential before deployment, providing structured input into design and stakeholder engagement. In doing so, we contribute to the growing conversation in Health Systems and related journals on how OR/MS can evolve from producing technically optimal models to producing solutions that are organisationally and behaviourally adoptable (Harper & Mustafee, 2023; Lamé et al., 2023).

3. Methods

3.1. Overarching approach: CFIR framework

Several frameworks used in implementation science provide valuable perspectives on adoption processes, though they differ in focus, scope, and intended application (Nilsen, 2015). Broadly, these frameworks aim to guide the process of translating research into practice (process models), explain factors that influence implementation outcomes (determinant frameworks, classic theories, implementation theories), and evaluate implementation efforts (evaluation frameworks) (Nilsen, 2015). We also acknowledge that business-oriented or transformation change models, such as those proposed by Kotter (Kotter, 1996), and Hiatt (Hiatt, 2006), offer useful perspectives on leadership and organisational readiness for change. However, these models were developed to guide transformation processes (similar to process models) rather than to provide a diagnostic tool to analyse implementation determinants in complex healthcare systems.

Given our study's diagnostic focus on anticipating adoption factors for a specific intervention, we focussed on determinant frameworks which specifically help understand the factors (determinants) that influence adoption in real-world settings. For example, the Promoting Action on Research Implementation in Health Services (PARIHS) framework (Kitson et al., 1998; Rycroft-Malone et al., 2011) emphasises the interaction between evidence, context, and facilitation as determinants of implementation success (Kitson et al., 1998; Rycroft-Malone, 2011); the Theoretical Domains Framework (TDF) focusses on behavioural determinants such as knowledge, skills, beliefs, and social influences that shape individual adoption (Cane et al., 2012).

In our study, we used the updated Consolidated Framework for Implementation Research (CFIR), which is specifically used to investigate the governance, behavioural, and technical factors for introducing interventions and/or innovations in complex settings (Damschroder, Reardon, Widerquist, et al., 2022). CFIR is a deterministic framework among the range of implementation science tools for studying implementation processes; that is, it is among frameworks that "delineate determinants (i.e., barriers or facilitators) that influence the outcome of implementation efforts" (Damschroder, Reardon, Widerquist, et al., 2022). CFIR was selected for this study because, while encompassing many of the elements in the other frameworks, it provides a multi-domain, determinant-based structure, encompassing individual, organisational, process, and contextual factors to assess the adoption potential of a specific innovation within one organisational setting. This breadth and flexibility make it particularly suitable for OR/MS innovations such as the surgical blueprint schedule examined here. Furthermore, although CFIR tends to be used for studying innovations during or post-implementation (Kirk et al., 2015), it can be used to prospectively study barriers and facilitators to implementing a new innovation, which was the explicit purpose of our study. CFIR organises these determinants into five domains ((i) characteristics of the innovation, (ii) outer setting, (iii) inner setting, (iv) individuals involved, and (v) implementation processes), providing a comprehensive structure for analysing the multilevel influences on adoption. In our case, the studied intervention or innovation was a surgery blueprint schedule which had previously been developed through a mathematical model (see details in Section 3.2), and the "complex setting" in which the innovation was to be introduced was an academic children's hospital.

3.2. The studied technical solution (or innovation)

We used the CFIR framework to explore the anticipated implementation effects of introducing a new blueprint schedule ("the innovation" in CFIR terminology) within a children's hospital ("the setting"). This new proposed schedule had been previously developed[1] at the request of a children's hospital to provide patients and their parents with more detailed information on when a specified patient (child) would have their surgery, to inform their planning as a family. At this children's hospital, 18 different surgical specialties use the same shared resources such as the OT and wards. In current practice, it is difficult to provide this surgery date, and often surgeries need to be cancelled because of bed unavailability. This new schedule provides a blueprint of when groups of different surgery types can be scheduled (thereby it is more detailed than a "master surgery schedule" (18), since actual surgery groups are scheduled). The surgery group are then scheduled in such a way that the

OT utilisation is maximised and the bed occupancy at the ward satisfies the available capacity. The innovative part of this prior research is therefore that the scheduled surgery groups are sequenced over the day to also deal with the bed availability at the day care wards as patients need to be discharged at the end of the day. The blueprint can then be used by the surgeons or planners to assign specific surgeries to each scheduled surgery group. As a result, the resulting schedule operates at the tactical level of hospital planning, where the allocation of capacity is determined for defined groups of patients rather than individual cases. This aligns with the framework for healthcare planning and control described by Hans et al. (2012), which classifies tactical decisions as those that translate strategic objectives into medium-term capacity and resource allocations (Hans et al., 2012). While our model increases the granularity of the surgery blueprint schedule, from specialty-based to patient-group-based planning, it remains within the tactical domain. Furthermore, we use centralised scheduling to refer to decision-making led by a designated hospital-wide planning body, specifically, the Tactical Planning Committee, that coordinates operating-theatre and ward capacity across specialities. In contrast, decentralised scheduling denotes adjustments made at the level of wards or individual clinicians in response to day-to-day contingencies, reflecting the distributed decision-making realities in clinical environments.

A simple conceptualisation to show how patient groups are categorised according to surgery duration and length of stay is illustrated in Figure 1.

3.3. Setting and participant selection

The setting for our study is the operating theatre and ward departments of a large (245 beds) academic children's hospital in The Netherlands. For the purposes of our study, the planning department, operating theatres and wards in the children's hospital were considered the "inner setting" for the to-be adopted schedule (in accordance with CFIR guidelines). The wider hospital, and any further regulatory or policy drivers beyond the hospital were considered the "outer setting".

Because the proposed surgery blueprint schedule was developed for implementation within a single children's hospital, we deliberately adopted an in-depth single-case design. While CFIR is often applied across multiple sites to enable comparison, it is also well suited to context-sensitive diagnostic analysis within one organisational setting.

In accordance with the CFIR guidelines, we collected data from individuals who were seen to have power and/or influence over the implementation outcomes (Damschroder, Reardon, Opra Widerquist, et al., 2022). We initially used purposive sampling to identify participants. Participants were chosen for their involvement in scheduling and planning for beds, staff and/or materials in the operating theatres or wards at the children's hospital. This included a variety of roles within the hospital with either exclusive capacity management responsibilities (e.g., planning coordinators, integral capacity management, admissions coordinators), as well as staff with clinical responsibilities who are also involved in planning (e.g., ward managers, nurses, surgeons and anaesthesiologists). These initial

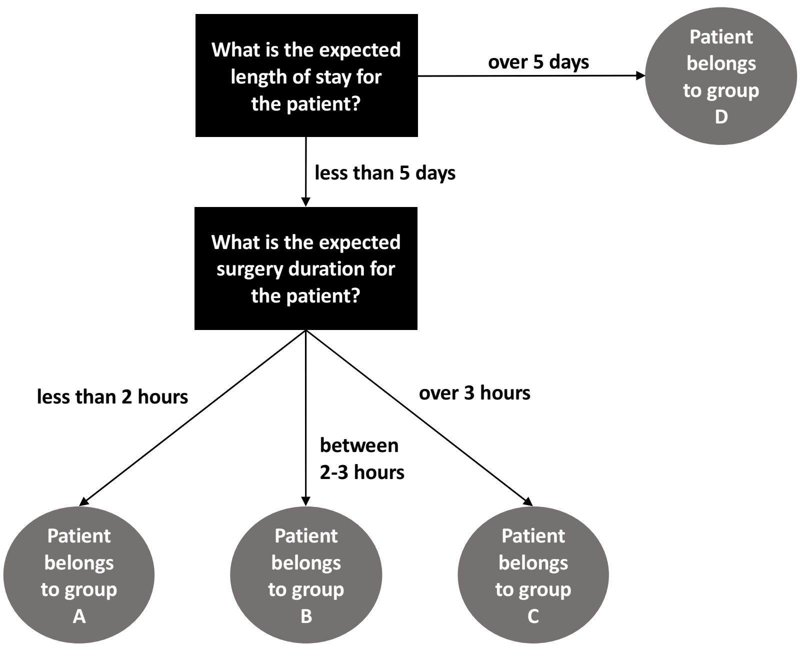

Figure 1. Sample of surgery blueprint schedule conceptualisation shown to show how patient groups are categorised according to surgery duration and length of stay.

participants were identified by a discussion with representatives from the children's hospital (one clinician and one capacity planning staff member); and subsequent participants were identified by referral from initial participants recruited for the study.

Staff were invited to participate in the study via email, as well as during a meeting for the planners in which the aims of the study were briefly presented. We estimate that a total of 25–30 staff were invited, given the number of people emailed, those attending the meeting, and those that would have been invited via word of mouth through staff who heard about the study. We continued to recruit participants from a range of functions in the hospital until saturation across the CFIR constructs was reached, resulting in 19 participants included in the study. Consistent with guidance from Saunders et al., (2018), we operationalised saturation in relation to our research aim and analytic framework (Saunders et al., 2018). We identified saturation as the point at which no new barriers or facilitators emerged within any CFIR domain (described in 3.4). Interviews were conducted face-to-face on site within hospital office spaces. Some interviews were held in groups, with only the interviewees and interviewer present.

3.4. Applying the CFIR to our study design

The complete updated CFIR contains 48 constructs across five domains: (i) the innovation (in this case, the optimised surgery blueprint schedule), (ii) outer setting, (iii) inner setting, (iv) individuals, and (v) implementation processes. We studied the templates for questionnaires available on the CFIR guide, and identified the most relevant constructs (and related questions) for our study. Given that the study was exploratory and intended to study potential implementation determinants prospectively, we chose a qualitative approach for our study in the form of semi-structured interviews. An interview topic guide (Appendix A: interview guide) was designed by adapting the (updated) CFIR framework.

To operationalise CFIR, three researchers (KV, EI, SHK) reviewed the complete updated framework (48 constructs across five domains). Construct selection was conducted a priori and by consensus, guided by (i) the characteristics of the proposed surgery blueprint schedule, (ii) the prospective and anticipatory focus of the study, and (iii) feasibility within semi-structured interviews. Not all CFIR constructs were applicable. For example, implementation process constructs such as "reflecting and evaluating", and formal implementation outcomes were excluded because the intervention had not yet been implemented. Similarly, constructs related to physical or IT infrastructure were outside the scope of the conceptual scheduling blueprint. CFIR was therefore used as a flexible determinant framework, adapted to the specific context and research question of this study. A summary of excluded constructs and rationale is provided in Appendix B.

3.5. Data collection

We conducted semi-structured interviews with the 19 participants. Interviews lasted circa 60 min and were conducted in Dutch as that was the language in which the participants and interviewee (KV) spoke most fluently and comfortably. In addition to the interview guide, participants were previously sent a flyer providing information about the surgery blueprint schedule about which they would be interviewed, shown in Figure 3. To make the proposed new way of patient group scheduling understandable, we created a sketch to demonstrate how it differed from the current master surgery schedule (Figures 1 and 2), thereby communicating the intent of the proposed innovation.

3.6. Data analysis

All interviews were audio-recorded and transcribed verbatim in Dutch. Transcripts were translated into English for internal analysis purposes, initially by one author (KV) and fully checked by another author (TvE).

Data analysis followed a hybrid deductive – inductive approach. We began with selected constructs from the updated CFIR as parent codes, reflecting our interest in identifying anticipated implementation determinants (selection of these described in 3.4). Initial coding was conducted by KV using ATLAS.ti. Approximately 10% of transcripts were independently reviewed by a second researcher (SHK) to examine coding consistency and interpretation. Differences in interpretation were discussed within the research team

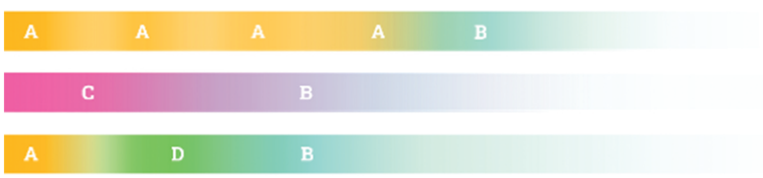

Figure 2. Surgery blueprint schedule conceptualisation (as presented to the interviewees). Each bar represents an operating room. Letters represent the scheduled surgery groups. Fading colours represent the uncertain surgery duration.

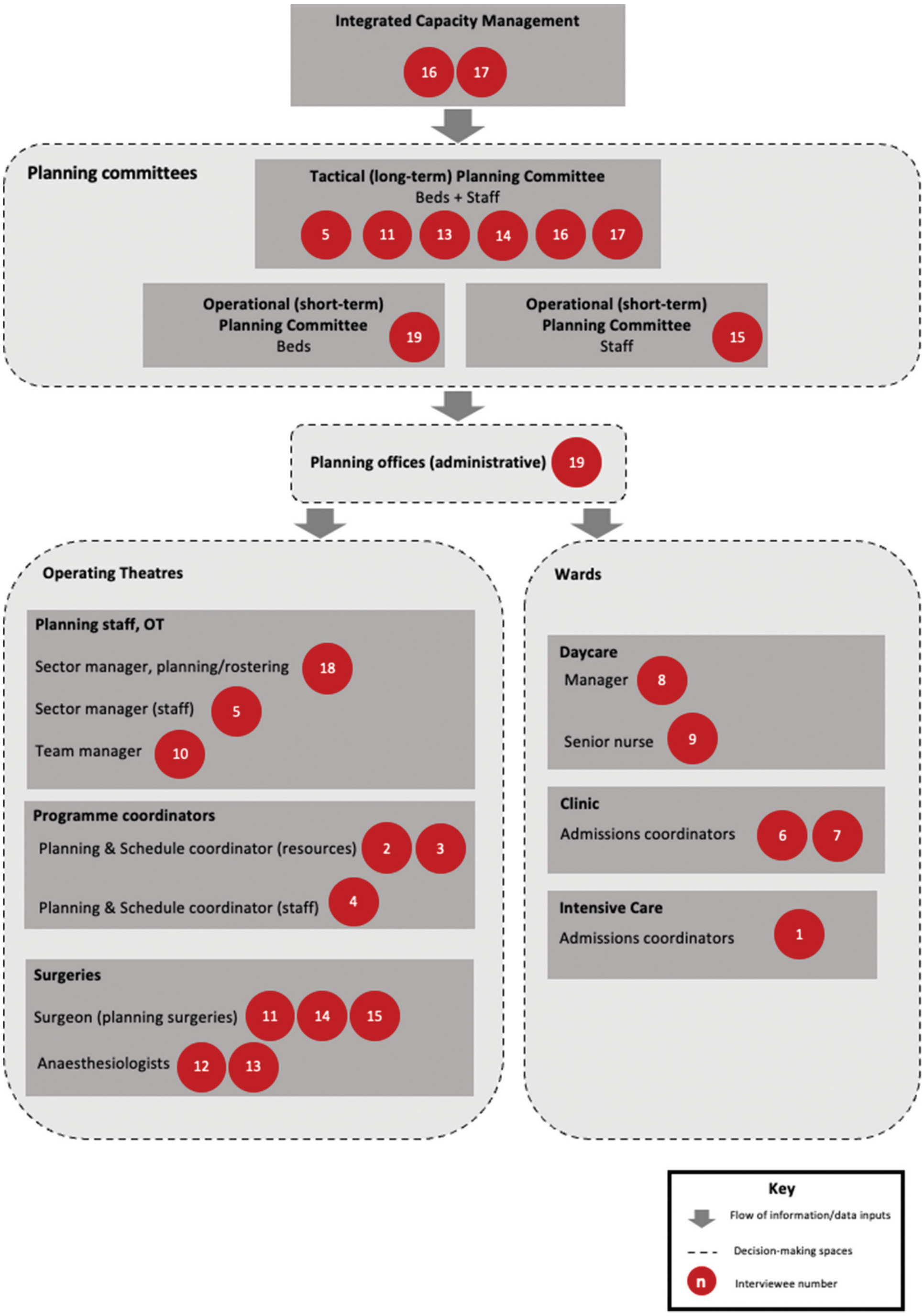

Figure 3. Overview of staff interviewed, and their role within respective planning functions (numbers correspond to interviewed participants in Table 1).

until consensus was reached. Throughout the coding process, new subcodes were allowed to emerge inductively from the data. These emergent codes were discussed iteratively among the research team and, where conceptually aligned, mapped back to relevant CFIR domains. Weekly analytical meetings were held during data collection and analysis to discuss emerging patterns and assess whether additional interviews continued to generate substantively new insights. Saturation was determined pragmatically when successive interviews no longer resulted in new codes or altered the interpretation of existing themes (see also 3.3).

3.7. Ethics statement

This study was approved by the Human Research Ethics Committee of the TU Delft ((http://hrec.tudelft.nl), considered a low-risk study (file number 3112). Informed consent forms were signed by all participants in the study.

4. Data sharing statement

Original audio recordings, transcripts, and signed informed consent forms are kept on secure password protected servers (SURFDRIVE) available to the research team only, due to the inability to fully anonymise participants in the files. All other data are available in this manuscript: interview protocol (Appendix A), selection of direct anonymised quotes from participants, and list of roles of participants (Table 1).

5. Results

5.1. Overview of interview participants and planning processes

A total of 19 staff participated in the interviews (see Table 2 for their characteristics and roles in relation to planning and scheduling). Given that some interviewees opted to participate an interview together with their colleague, 13 interviews were held.

These individuals play different roles within the planning process. An overview of these broad ranges of individuals involved in surgical planning, with varying responsibilities, is illustrated in Figure 3.

Through our interviews, we elicited how decision-making processes and information decision flows take place for the purposes of planning, as described briefly below (in part referring to Figure 3):

- **Strategic planning**: Master surgery schedules (blueprints) are originally created at this level, mostly on an annual basis. They provide a general structure for the total number of surgeries and number of beds needed, but these are annual estimates of total hours of use for the operating room per specialty (not included in Figure 3).
- **Integrated capacity management**: This team has the oversight of the bed occupancy levels and staff numbers. This data is used as input for different planning committees (next bullet point).
- **Planning committees**: These committees plan how to fill beds and ensure there are available beds for the incoming patients. Tactical level planning (by the Tactical Planning Committee) is where ward schedules are planned. Master surgery schedules can be adapted slightly at this level by the committee. Operational level planning (by the Operational Planning committee) is where weekly schedules are created.
- **Surgery blueprint schedule**: This is the "innovation" introduced in our study: it provides a blueprint of when groups of different surgery types can be scheduled (thereby it is more detailed than a "master surgery schedule" created in the Strategic and Tactical planning phases, since actual surgery groups are scheduled). The blueprint can then be used by the surgeons or planners to assign specific patients to each scheduled surgery group.
- **Operational planning/Planning offices**: The daily filling of the blueprint schedule is completed at this level, by allocating actual patients (including contacting patients/families to see if they are available). In principle, this would be considered the final schedule.
- **Daily adjustments**: These are daily adjustments made to the allocation of patients, depending on staff and bed availability, and possible cancellations. This is done by the programme coordinators both in the operating theatres and in the wards.

We refer to these processes in the rest of our results. Of particular importance is to note that the proposed new blueprint schedule is designed to schedule "groups" of patients only, according

Table 2. List of interview participants included in the study.

Interviewee number*	Role in hospital	Role in planning and scheduling
1	Admissions coordinator, Ward PICU	bed capacity PICU
2a	Planning & Schedule coordinator (resources), OT	OT room, OT schedule, materials
3a	Planning & Schedule coordinator (resources), OT	OT room, OT schedule, materials
4a	Planning & Schedule coordinator (staff), OT	daily coordination OT
5	Sector manager (staff), OT	staff capacity OT/member TPC
6b	Admissions coordinator, Ward	bed capacity wards
7b	Admissions coordinator, Ward	bed capacity wards
8c	Manager, Daycare Ward	staff & bed capacity daycare ward
9c	Senior nurse, Ward	bed capacity wards
10	Personnel/Team manager (staff), OT	staff capacity OT
11	Surgeon, Children (Planning Specialty Surgery only)	specialty specific patient planning/member TPC
12d	Anaesthesiologist, manager	daily coordination OT
13d	Anaesthesiologist	member TPC/daily coordination OT
14	Surgeon, Children (Planning Specialty Surgery only)	specialty specific patient planning/member TPC
15	Surgeon, Children (Planning Specialty Surgery only)	specialty specific patient planning/member OPC
16e	Consultant integral capacity management	integral capacity management/TPC
17e	Consultant integral capacity management	integral capacity management/TPC
18	Sector manager (resources), OT	OT room, OT schedule, materials
19	Planner (Planning specialty surgery only)	specialty specific patient planning/member OPC

Abbreviations: Paediatric intensive care unit (PICU), Operating theatre (OT), Operational Planning Committee (OPC), Tactical Planning Committee (TPC) .
* All interviewees designated with a letter participated in a joint interview with another interviewee with the same letter.

to their surgery type (including length of stay and expected surgery duration, see Figure 1). It does not allocate specific individual patients, as this is done further down (see Figure 3, under "planning offices"). We therefore refer to the new schedule in our results as a schedule for patient groups, and not a schedule for patients. We divide our results according to the constructs identified in the CFIR framework, as this guided both the interview protocol and the clustering of the initial themes in the analysis. We also report on additional insights on implementation which emerged during the analysis, beyond the constructs sought from our analytical framework.

5.2. Overview of anticipated facilitators and barriers to adoption

Using the Consolidated Framework for Implementation Research (CFIR) as a guiding structure, we identified a series of anticipated facilitators and barriers that could influence the adoption of the proposed optimised surgery blueprint schedule within the children's hospital. These insights represent participants' expectations and perceptions of what might support or hinder future implementation, rather than reflections on an intervention already in use.

To provide a concise overview, Table 3 summarises the anticipated facilitators and barriers according to CFIR domains, together with illustrative examples drawn from the interview data. To construct Table 3, identified barriers and facilitators were synthesised by CFIR domain and construct, and emerging constructs/themes. The column "extent observed" reflects qualitative prominence rather than a statistical measurement. This assessment was based on recurrence across interviews, depth and emphasis within discussions, and code application counts.

Across interviews, the most prominent facilitators included the perceived objectivity and fairness of a mathematically optimised schedule, strong motivation to improve current planning inefficiencies, and the openness of staff to participate in the tool's design. The main barriers related to concerns about loss of professional autonomy, the perceived rigidity of the model, and the deeply embedded culture of informal coordination and local negotiation. Several factors, such as existing communication networks, were recognised as both potential enablers and risks, depending on how they would be managed during implementation.

The following sections elaborate on these anticipated facilitators and barriers in more detail, structured by the five CFIR domains.

5.3. Detailed findings by CFIR domain

The following subsections expand on the overview presented in Table 3 by describing in greater depth the themes emerging within each CFIR domain and sub-construct. Each subsection integrates illustrative quotations to show how participants articulated their expectations, concerns, and perceived conditions for

Table 3. Overview of anticipated facilitators and barriers identified in study, grouped by CFIR domains.

Construct/Concept identified in this study	Illustrative insight/example	Extent observed*
CFIR domain (i): Innovation characteristics		
Perceived relative advantage (facilitator)	Mathematics and objectivity viewed as fair and "refreshing"; model seen as a way to create more balanced bed use.	Strong
Complexity and adaptability (barrier)	Concerns that children's surgeries and staff variability require flexibility not captured in the model.	Moderate
CFIR domain (ii): Outer setting		
External pressures and incentives (facilitator)	Hospital leadership and staff recognise urgent need to improve efficiency and relieve workforce pressure.	Strong
Patient needs and resources (facilitator)	Recognition that better scheduling could reduce cancellations and improve patient experience.	Moderate
CFIR domain (iii): Inner setting		
Networks and communication (mixed)	Informal communication supports coordination but may undermine centralised scheduling.	Strong
Culture and readiness for change (barrier)	Embedded habits of local negotiation and "fiddling until it fits" may conflict with a centralised blueprint, as perceived by respondents.	Strong
CFIR domain (iv): Characteristics of individuals		
Knowledge and beliefs about the solution (facilitator)	Staff understood and valued the innovation, but still proposed further design inputs	Strong
Perceived threat to autonomy (barrier)	Clinicians may resist loss of control in scheduling decisions.	Moderate
Capability/self-efficacy (barrier)	Concern about lacking technical expertise to maintain or adapt the model.	Limited
CFIR domain (v): Process		
Engagement and co-design (facilitator)	Participants appreciated involvement and encouraged co-developing the solution.	Strong

* Extent observed refers to an indicative assessment of how widely a theme was mentioned across interviews, combining frequency and distribution across professional groups: Strong = widely and repeatedly discussed in the interviews (mentioned by nearly all participants); Moderate = raised by several (between 4–11) participants and across professional groups); Limited = raised infrequently (by three participants or less). These categories do not capture all possible variations (e.g., differences between frequency and professional groups). Constructs were only classified as barriers or facilitators where there was consistent interpretation across participants; mixed or context-dependent views are described in the qualitative findings.

success. Together, these findings illustrate how behavioural, cultural, and organisational factors intersect with the technical characteristics of the proposed scheduling solution.

The results are organised under the five CFIR domains: Innovation characteristics, Outer setting, Inner setting, Characteristics of individuals, and Implementation process (see Appendix B for full details per domain), to highlight both cross-cutting patterns and domain-specific nuances. Following the CFIR guide (Appendix B) we use the term organisational culture to describe shared norms, values, and expectations within the hospital that influence staff behaviour. This forms part of the inner setting, whereas the outer setting refers to contextual factors external to the organisation, such as regulatory, economic, and workforce pressures, that shape the conditions for change.

5.3.1. Innovation characteristics

5.3.1.1. General positive reactions to a mathematically derived schedule. Following their view of the sketch of the new idea of the proposed schedule (Figures 1 and 2), all interviewed participants could explain it back to the interviewer in their own words, suggesting they understood it.

All interviewed participants positively reacted to the proposed innovation source, which in this case was a mathematically derived schedule, developed by researchers with expertise in operations research specifically in healthcare, by describing it as "refreshing" [Interviewees 5 and 12], that it "makes a lot of sense" and is "good". Participants also commented on how the model provides objectivity to planning.

> . . . taking the intuition out of it and doing it more on the numbers and say with evidence I think that's better. [Interviewee 11]

> The maths is fair. Mathematics does not distinguish between my opinion and anyone else's. [Interviewee 14]

> I think it's really good to look at numbers, because otherwise I think you're emotionally favoured there, that you think, "Well in that OT, only that is possible". and that surgeon only wants to be there. [Interviewee 10]

Most participants pointed out the relative advantage of the new group scheduling compared to current practice. They acknowledged that such new group schedules are indeed needed, even if this proposed model was "not perfect" nor taking into account the dynamic changes within the hospital environment.

> The biggest selling point is that it will make bed capacity more 'even' across the week (rather than peaks on Tuesday etc). [Interviewee 7]

> Yes, because [for example] you have to cancel four children on Thursday and Friday, but on Monday and Tuesday there were eight places together. [Interviewee 6]

However, given that this was not a fully validated model/schedule, a few participants pointed out limitations of the schedule itself, for example that the duration of surgeries are not sufficiently taken into account. This was to be expected, given that this was not a fully validated and trialled innovation, but rather a proposed new schedule. Even for participants who were positive about the new schedule, they commented on the need for more "medical knowledge" for it to be implementable, but they saw the potential in a more objective way of scheduling:

> I'm really glad it's being looked at this way because I think there's really room for improvement [in current practice] [Interviewee 11]

Another pointed out how much of the current practice involves adjustments made while filling in patients within the current schedules. The new mathematical scheduling approach allows these rearrangements to happen earlier:

> We do this already, in terms of puzzling with the variables . . . but the difference with such a model is that it can do it for you, saves time in that puzzling. [Interviewee 14]

5.3.1.2. The required balance between centrally optimised group schedules and on-the-floor needs. Given that this was a proposed first version of a new patient grouping schedule, one of the main discussion points in the interviews was its ability to consider the complexity and dynamic behaviour of the operating theatre environment. Unprompted, a handful of respondents focused on the exceptional cases when paediatric patients need more time for comforting before a surgery, therefore stating that these schedules would not work in practice. They emphasised that children are unpredictable and indicate that they are therefore afraid that theory and practice are different. The schedule itself was therefore not deemed to take into account the level of adaption and complexity in the system by some of the participants.

A few participants were happy to think along with the design of the schedule and commented on how such adaptability can be achieved by specific parameters that could be incorporated into the mathematical model, including factors that are already considered such as the surgery duration, length of stay of different patients, and new factors, such as the "difficulty" of the patient (such as the presence of multi-morbidities for the patients, whether the child needs extra psychological or emotional support before/after surgery) and the variable amount of time needed by each surgeon or anaesthesiologist to perform their tasks (*"you need to take the human diversity in the workforce into account" [Interviewee 5])*. These latter factors are more difficult to assess and can affect the surgery groups assigned, or indeed affect the daily allocation of individual patients. Although these factors were mentioned across the interviews, they were not quantified or specified in detail, indicating a degree of tacit knowledge about how patients (and surgeon working styles) are expected to be different. This adds to their perceived need of always needing to make changes on the floor, no matter what a new novel way of group scheduling may bring.

> . . . sometimes you just have to think in advance "we have to have some extra time with this one", so maybe there has to be some kind of way that you can put an extra block in of "needs more time [in the model] [Interviewee 12]

The interviewer explained that such factors could be considered by creating ranges and parameters within the model that can be adjusted, and this resonated well with the participants.

Finally, participants were keen to ensure that the schedule considers the whole chain of events in the hospital *("It's a chain and a domino" [Interviewee 3])*. Surgery changes affect ward occupancy, and not every department will have the same needs (reflected, partly, also on the staff working there).

> The most important thing is just that when it comes to it, it's not just about us, it's going to affect the whole hospital. [Interviewee 2]

Again, this is exactly what the proposed group schedule intends to do in a future fully developed version. But the emphasising of these adaptability points demonstrated that, despite understanding the intent of the new blueprint schedule (see Section 5.3.2), there were still concerns that group scheduling, while promising as an approach, would not sufficiently balance individual patient and family needs with hospital benefits.

5.3.2. Outer setting domain

5.3.2.1. External pressures support innovation. What stood out as an external driver for adopting this new schedule, in the context of their current experiences, was the relatively urgent need to release pressure from staff (e.g., *"the nurses are reaching their breaking point"* [Interviewee 8]). Dissatisfaction with current scheduling arrangements was voiced by all participants, and therefore a more objective form of scheduling was generally welcome. Furthermore, it had been noted that the hospital board has also made explicit the requirements to create efficiencies, as pressures on the workforce and shortages of staff contribute to existing challenges.

> Yes, the need is mainly that we are again confronted today that there is a continuous shortage of staff, so there is a shortage of admission beds. So everyone really feels the urgency to get the most out of the availabilities, we all do our best for that, but actually we are all just kind of yes well-meaning volunteers, say amateurs, actually and there is as much as possible open in the field of algorithms or systems that can really help us. That people really do see that something must be better everything that makes it better, just have to grab it with both hands, yes. [Interviewee 12]

From the participants' perspective, there are no regulations, laws or policies prohibiting the potential introduction of the proposed schedule innovation as a barrier to the adoption of such an innovation.

5.3.3. Inner setting domain

5.3.3.1. Informal communications as enabler for operational planning. Generally, the participants acknowledged ongoing communication between the different planners and planning departments, especially during the week when cancellations occur or when more beds are needed somewhere.

> In that respect, we try to think along with each other, because we all want the best for the patient. [Interviewee 1]

> If they need something, they just ask, so to speak. They don't hesitate to ask. At the [Operational Planning Committee], it is also said if a bed becomes available, then I want it and then I also write it down . . . like if there is space then it takes precedence first. [Interviewee 9]

As described in Section 3.1, general blueprint schedules are formed centrally, but allocation of patients are created in consultation between clinical staff and coordinators.

> Every morning we [the PICU admissions coordinators, three nurses actually] walk around the beds and see who's lying there, so then we see if we have empty beds and for the kids that are there, what's the plan with them? Some just stay put and some can go to another hospital or to another ward and some can go home. [Interviewee 1]

A few participants who have clinical and/or surgical roles (e.g., interviewees 11–15) refer to one-on-one conversations they have with planners and coordinators to influence their changes in how patients are allocated. For example, they discuss with their planners the waiting lists, which types of surgeries on it involve more complex planning (cooperation with other departments, or needing an ICU bed) and should be given priority and filling the gaps with more elective cases, which can be rescheduled more easily if needed.

While these informal relational connections between staff are helpful in adopting such a new solution as the proposed schedule, those who design any new proposed group schedule would have to bear in mind that such informal meetings may result in compromising the intention of a centralised blueprint schedule if it were to be too rigid. Currently, our proposed innovation creates a general blueprint but with some restrictions (i.e., by patient groups, as seen in Figure 1), but the actual patient allocation is up to ground-level decision-making, which would work well in our studied context where these informal communication lines exist. So, while there is flexibility to some extent on actual patient allocation, the adjustments on how these patient groups are scheduled centrally may be a reason for resistance (as described in the next section). Therefore, while such open communication enables adoption of any new solution, in this case it might create a barrier to renewed planning approaches, because of the on-the-ground changes that are so embedded in the working culture. A few participants went as far as stating that these small conversations between surgeons and planners are the "real planning", and planners "fiddle with [the schedule] until it fits" [Interviewee 12]. If a new centralised blueprint would be too rigid at the operational level, these habits and working practices could work against the adoption of a centralised scheduling of patient groups.

5.3.3.2. The potential for resistance to change in existing working cultures. As alluded to above, there was a general perception by the interviewed staff that there could be resistance to change because of (clinician) individual preferences on their scheduling choices. That is to say, that even the way the patient group schedules are optimised (to take into account more efficient practices across the whole hospital) may be a reason for resistance for some clinical staff who have individual preferences on where their surgery groups should be scheduled. Indeed, such resistance to change was an often-mentioned topic in the interviews. Taking away this autonomy and "freedom" (Interviewee 16) may create more resistance to any new scheduling approach.

To be able to bring stakeholders/planners along, participants mentioned that it would be important to emphasise what this grouped schedule is trying to do: in other words, describe the intention to more efficiently level bed occupancy for the whole hospital (including wards), rather than only creating optimised schedules for the operating theatre. There were also suggestions of how to create change, by taking people along as the intervention is being introduced, and recognise that changes take time.

> I first let it sink in, because I had already thought of that or that seemed smart to me, but then it is useful if I inquire "What do you think?" ... the people who were actually going to change places, agreed, and two did not, but they indicated "In the long run, we would like that, but not now. [Interviewee 10]

> To make sure it's done well, you have to take everyone with you, because otherwise you'll all get people saying, yes, it's decided but I'm not doing it anyway. I think there are a lot of captains on the ship, who set their own course, so the chance of success is only if you try to get everyone on board. [Interviewee 1]

However, it should be noted that despite many participants mentioning they expect resistance to change from "others", this sentiment did not appear among those we interviewed, which represented a range of roles and responsibilities within the operating theatres and wards.

5.3.4. Individuals domain

5.3.4.1. A range of individuals have influence over scheduling. As is shown in Figure 3, we observed that the same individuals are involved in centralised planning committees (named Operational Planning Committee and Tactical Planning Committee in Figure 3), as on the ward. Further, those involved in planning, either in a centralised capacity or within the operating theatres or wards, have different degrees of influence in creating changes in schedules. Despite the seemingly top-down setup in the figure and above description, as was noted in the previous sections, many changes are made lower down daily, when actual patients are allocated.

Throughout the interviews, we identified individuals who would ultimately have to be involved in leading and facilitating the new schedule; these included the Tactical Planning Committee, the operating theatre managers, ward managers, as well as the "user council" which includes representation from all the medical specialities and wards. However, the innovation recipients in this case are clinicians who "receive" the new OT schedule which changes both the schedule itself and the form of scheduling, and they are both affected by centralised decisions and display power to change these decisions (schedules), due to their preferences.

> Surgeon X always sits down with Y, the planner. And then finally determine the order who goes where. I don't know if all planners do that, but to that extent the surgeon will have a finger in the pie there too. [Interviewee 2]

According to some participants, this can be problematic – despite benefits to the end-user (the clinician ultimately planning and benefitting from the revised schedule), decisions on schedules (for surgery groups) made at one ward create knock-on effects at other wards and their respective schedules, which may not be optimal, creating further inefficiencies. This was exactly what the new planning tool is trying to resolve through its optimised surgery blueprint schedule. However, when prompted to respond on who would be the leaders and facilitators of a new scheduling intervention, many mentioned "planners", referring to the more administrative centralised planning (i.e., those further up in Figure 3), rather than the end-user clinicians who may, in some instances, actually have more influence over individual patient schedules.

Finally, we learned about the importance of acknowledging the diversity in skills within capacity management in general, which can have an influence over how new innovations are taken up. Some new innovations may come across as too technically challenging, and require in-house expertise for future adoption and implementation, and such expertise may not always be present in current practice (although this can vary across hospitals).

> . . . so that it is then made from certain mathematical backgrounds or technical business administration certain models and then at least for me and I think for most of them are abracadabra. The outcome is clear, but how do I get to where we can build that up? Who is going to pick this up? Who's going to keep up? For that you actually need that expertise that I think may be lacking or at least not sufficiently present. (Interviewee 16)

6. Discussion

As with any other innovation for clinical practice, a change in management or organisation comes with adoption and implementation challenges. Using the CFIR framework, we identified specific barriers and facilitators to adopting a proposed surgery blueprint schedule in a children's hospital. Importantly, this application was prospective: rather than analysing a past or ongoing implementation, we used implementation-science principles to anticipate adoption challenges in advance of any implementation. We divide our discussion into what we learned about the implementation challenges of the schedule (innovation) itself, what we learned regarding design inputs for the innovation in the future, and what we learned about the use of CFIR for exploring implementation challenges in this context. Finally, we look ahead to the potential of further interdisciplinary engagement to enable the systematic study of adoption of technical solutions.

6.1. What we learned about the challenges for adoption of the surgery blueprint schedule ("the innovation")

Overall, we observed general positive reactions to the mathematically derived schedule, reflecting a perceived relative advantage of the solution. In principle, it was acknowledged that a centralised surgery blueprint group scheduling tool would be able to balance the needs of the operating theatres and wards, creating overarching efficiencies for the hospital. Participants also expressed a clear sense of urgency and external pressure for improvement, stemming from workforce shortages and hospital efficiency demands – which together form an important outer-setting facilitator for adoption. This attitude will be a key facilitator for new centralised planning tools. There are informal networks between centralised tactical planners and those further in the operational planning process.

Although resistance to change in the organisation can be expected, it was acknowledged that genuine engagement in the design of the tool and introducing changes incrementally could facilitate the adoption of a new scheduling approach. A desire was expressed for specific stakeholders to be brought along while the innovation [the new schedule] is being developed and ensure they feel part of the process, a pattern common to many organisations trying to implement change (van Bruggen et al., 2019). When positioned within the wider literature on implementing scheduling tools in healthcare, our findings resonate closely with studies that emphasise participatory and iterative development processes. For example, Visintin et al. (2017) developed and implemented an operating-room scheduling tool using an action-research approach, underscoring that success depended on early stakeholder engagement, credible preliminary results, and gradual introduction of changes. They emphasise the need for leadership support, stakeholder involvement, iterative feedback, gradual change, and tool flexibility as essential factors for implementing a scheduling tool. Our findings also propose that the advantages of the scheduling tool should be clearly communicated, specifically its ability to bring efficiency improvements to the whole organisation, rather than an individual ward, unit, or operating theatre. Similarly, Smalley et al. (2015) and Scheinker and Brandeau (2020) highlighted that clear communication, transparency, and perceived fairness are central to sustaining adoption efforts.

These previous studies filled an important gap by documenting the link between model features and organisational realities, offering practical guidance for introducing scheduling tools in complex settings. Our study confirms these recurrent themes but extends them in important ways. First, while Visintin and colleagues examined a model implemented primarily within the surgical department, our proposed surgery blueprint schedule explicitly links operating theatres and ward capacity, operating across multiple planning levels. This cross-unit scope introduces additional coordination and governance challenges, including blurred decision boundaries between tactical and operational planning (Hans et al., 2012) and the need to reconcile priorities across specialities and wards. Second, because the blueprint embodies a centralised optimisation model, it surfaces sharper tensions around professional autonomy and accountability, illustrating how adoption dynamics evolve when decision-making becomes system-wide rather than locally negotiated.

Beyond the above facilitators, our analysis identified that despite the intention to adopt centralised schedules, there are cultural and work practice barriers to overcome. The identified open lines of communications are both enablers and barriers to implementing a centralised schedule. Surgeons and other senior clinicians often hold implicit authority to override or reshape schedules, even when planning responsibilities are formally centralised. This influence is reinforced by role ambiguity, where "planners" may include both administrative staff and clinical leads, and by the absence of clearly defined decision rights across tactical and operational levels. Similar patterns have been described in other studies of hospital capacity management (e.g., van der Ham et al., 2020), where informal power networks sustain flexibility but can also hinder collective optimisation. Clarifying decision ownership and accountability between tactical and operational planners may therefore be a prerequisite for effective adoption.

Schedules created at the tactical level are adapted and adjusted to suit individual's needs – which might benefit the specific surgery speciality, for example, but have negative consequences in other wards. This behaviour is common in other capacity management instances and relates to examples of local adaptation and decentralised adjustments, explaining changes made on the ground from a centralised plan. Given that the proposed surgery blueprint schedule is situated within tactical planning, some degree of tactical flexibility and operational adjustments are necessary to make it function. Similar patterns of workaround behaviour have been identified in other parts of the healthcare system in previous work. Such studies highlight the potential threats to patient safety and quality of care, for example, in the context of workarounds in medical systems (Koppel et al., 2008), while in other studies such practices are deemed necessary for healthcare practitioners to flourish and excel in a sociotechnical environment (see, for example, workarounds in nursing (Lalley & Malloch, 2010) or clinicians in general (Braithwaite et al., 2009)). While our study did not address these trade-offs specifically in the context of capacity planning, understanding the potential trade-offs between centralised and decentralised planning in future studies would help identify any existing threats to care quality and efficiency. What our study does strongly highlight, however, is expressions of wishing to retain some degree of autonomy and control in decisions at both the tactical and operational planning level.

Finally, we reflect on the diverse skill base and organisational positions of "planners" in our studied hospital setting. A planner could mean anything from someone whose sole responsibility is to plan and schedule in an administrative function, to the surgical specialists. This means that the background, skillsets and experiences vary, but also the position of influence within the hospital. As shown in other studies, responsibilities for capacity planning are not uniform even in the same country (van der Ham et al., 2020). This can cause frustrations and uncertainties within the job position itself, especially among those with more administrative functions. One of our main challenges in our application of the CFIR framework was to identify differences between intervention beneficiaries/end-users, leaders, and facilitators, as these roles are not clearly defined. Any future implementation of scheduling interventions would have to be mindful of these differences and the exact responsibilities of those who would adopt and champion the new intervention.

Taken together, these insights situate our findings within, and extend, the existing body of implementation evidence on scheduling innovations. They demonstrate that many well-documented behavioural determinants, such as communication, trust, and autonomy, persist in new forms when planning becomes more integrated across the hospital. In this way, the study not only corroborates earlier accounts but reframes them for a multi-level, organisation-wide coordination environment, as summarised in Table 3.

6.2. What we learned regarding design inputs for the innovation (the proposed surgery blueprint schedule)

Our anticipatory use of implementation science thus serves not only to diagnose potential barriers and facilitators to adoption but also to shape the design space of the innovation itself. By systematically identifying where organisational culture and model logic may misalign, implementation-oriented insights can be fed directly into model development, bridging the typical divide between technical optimisation and practical usability. Given the identified networks and informal communication leading to schedule adjustments, the learning point for designing a new schedule is that it needs to work within such a culture and expect these necessary adjustments. The system would have to be adaptable or flexible to allow for extreme cases, whether this is designed centrally or allowed to be designed further on in the process (and some of this uncertainty is already considered in the proposed model). This would also mean accounting for differences such as: in surgeon's time for completing their tasks, the difference in children, patients, and carers needing more comforting, comorbidities that affect anaesthesia and the impact of the surgery. These would be in addition to the existing considerations in the proposed model which already include different surgeries requiring different lengths of stay in the ward.

We also learned that any new schedule should clearly demonstrate its advantages, for example, that it reduces the time they need to execute a task or increases the capacity instead of taking a lot of time and the result being relatively small. It is important that such benefits are made visible early, for example, through pilot, simulation, or demonstration exercises, to engage stakeholders in reflecting on potential gains and trade-offs (also as echoed in the study by Visintin et al., 2017).

6.3. What we learned about the use of CFIR for a proposed (not trialled) OR/MS innovation

To our knowledge, the explicit use of implementation science frameworks is not extensively used in OR/MS for healthcare settings, despite this field's clear intended purpose of supporting the sustained adoption of any intervention in healthcare (Lamé et al., 2024). As summarised in the Background section (Table 2), there are scattered examples of either reflecting on implementation challenges in narrative accounts, and studies that engage in participatory approaches to engage stakeholders early, with the intent to support adoption efforts afterwards. A study closely related to ours is that by (Visintin et al., 2017), whose aim was to identify the features that would make a master surgery schedule optimisation model effective and easy to implement, thereby identifying actions that would facilitate their introduction and use during the study. They used an action research approach alongside their schedule design process. In our case, by applying the CFIR prospectively, our study moves beyond reflection on past implementations to the anticipatory identification of organisational, behavioural, and contextual determinants that could shape adoption. This approach demonstrates how implementation-science frameworks can be used not only to evaluate but also to inform innovation design before deployment. Some critical reactions to the innovation arose from the fact that it is not a fully developed, trialled, evidence-based innovation but bringing this draft schedule along allowed participants to "think along" the need for improving capacity management.

Our approach also differs from the pragmatic, experience-based reflections that characterise much of the applied operations research/management science literature in which implementation challenges are discussed, even extensively, as is the case for (Bikker et al., 2025; Scheinker & Brandeau, 2020; Smalley et al., 2015). While such studies have provided important accounts of how interventions are introduced in practice, their insights are typically organised around practical lessons or project-specific narratives rather than through a shared theoretical structure. By using CFIR, we were able to systematically classify determinants of adoption across multiple levels – individual, organisational, and technical. This comparison highlights how implementation-science frameworks can complement and strengthen the operations research/management tradition by augmenting practice-based or experiential findings with a more cumulative and transferable evidence base.

Reflecting on the specific use of CFIR, we found it to be a helpful framework to explore different implementation challenges across the various constructs. While as researchers we could have left interviews entirely open, the framework's structure guided our questions and analysis, helping us shift from "what did we learn?" to an *a priori* "what should we ask about implementation?" It provided a structured way to anticipate barriers and facilitators that might otherwise only surface post hoc. Importantly, however, our prospective application required adaptation of the framework. Not all CFIR constructs were equally relevant at a pre-implementation stage; constructs relating to observed effectiveness, sustainability outcomes, or post-implementation reflection were necessarily excluded. Instead, emphasis shifted towards constructs concerning perceived relative advantage, adaptability, communication structures, role clarity, and organisational readiness. This selective and context-sensitive use aligns with guidance from the CFIR community itself, which explicitly encourages adaptation to setting and purpose. From this perspective, we argue that CFIR, as one of the many tools available from implementation science, provides a useful and practical framework that can readily be used (and adapted for use, as we did) to operations researchers wishing to explore adoption challenges and roadmaps for their research outputs. For OR/MS scholars, this highlights that determinant frameworks can be used both prospectively and retrospectively, provided construct selection is transparently justified.

A further methodological reflection concerns whether OR/MS innovations differ in meaningful ways from the types of interventions for which CFIR was originally developed. CFIR emerged largely within the study of clinical, behavioural, and organisational interventions, such as care protocols, service redesigns, or implementation of evidence-based practices. OR/MS innovations, by contrast, often take the form of analytical models, optimisation routines, simulation tools, or scheduling blueprints. At first glance, such innovations may appear more technical and less socially embedded than traditional healthcare interventions. However, our findings suggest that, once introduced into organisational settings, OR/MS outputs are enacted in ways similar to other complex healthcare innovations. We observed issues of professional autonomy, role clarity, governance structures, communication patterns, and organisational culture. In that sense, the adoption dynamics of a mathematically derived blueprint schedule did not fundamentally differ from those reported for other complex service innovations. At the same time, OR/MS innovations may introduce distinctive considerations. For example, they may depend on data infrastructure, integration with IT systems, or alignment with existing planning hierarchies. These we did not capture since our tool was in a prototype phase and not something ready to implement. Yet, rather than requiring an entirely different implementation framework, our experience suggests that CFIR is sufficiently flexible to accommodate these characteristics through context-sensitive adaptation. Thus, the key implication and learning is not that CFIR must be redesigned for OR/MS, but that its constructs must be interpreted with attention to the socio-technical nature of analytical innovations. OR/MS outputs may be technically sophisticated, but their uptake ultimately depends on how they intersect with existing work practices, cultures, and governance arrangements, a pattern consistent with broader implementation science insights.

In our case, the CFIR approach helped translate our interdisciplinary reflections into a systematic language of determinants, bridging the qualitative, participatory traditions of applied OR/MS with the structured, theory-informed diagnostics of implementation science. In doing so, this study contributes to the broader conversation within Health Systems on how analytical and organisational perspectives can be combined to understand not only how innovations are designed but how they become embedded and sustained in practice (Harper & Mustafee, 2023; Lamé et al., 2023). This bridging role points directly to the broader opportunities for interdisciplinary collaboration discussed in the Section 6.5.

6.4. Limitations

While the CFIR framework was valuable for identifying barriers and facilitators to implementing the proposed surgery blueprint schedule, its application in this study was prospective, as the schedule itself remained in its conceptual stage. As such, the barriers and facilitators identified are based on staff perceptions of the concept rather than experiences with a fully implemented innovation. This anticipatory orientation was intentional, allowing us to surface design-relevant insights before implementation, but it also means that findings represent expected rather than observed determinants. Studying expected rather than observed implementation means that some determinants may differ from those that would surface during an actual rollout. Future work could triangulate such expectations with evidence from pilot or implementation studies. This pre-implementation goal aligns with our aim of gathering insights to inform future design iterations, as supported by the CFIR framework. However, the responses regarding broader organisational and technical implications for adoption may be less reliable compared to findings from studies involving a trialled or implemented version of the schedule. This aligns with our aim of gathering insights to inform future design iterations, but the findings should be interpreted as indicative rather than conclusive. Future research should focus on pilot testing the blueprint schedule and incorporating feedback from such trials to refine both the model and its implementation strategy. This also raises a question about timing: whether anticipatory-oriented implementation inquiry should ideally precede model development. In our case, a preliminary version of the blueprint schedule was intentionally developed to provide a concrete basis for discussion, mirroring qualitative research practices that use graphic elicitation, as visual diagrams or models presented in interviews to stimulate participant insights that may not emerge through verbal questioning alone (Crilly et al., 2006). This allowed participants to engage with a tangible representation of the schedule and provide more concrete reflections than would have been possible with otherwise abstract prompts. Our approach therefore represents an intermediate step: early enough to inform design, yet sufficiently developed to enable meaningful stakeholder input.

This study was conducted in a single academic children's hospital in the Netherlands, which limits transferability from this single case (although, as argued earlier, the use of a standardised CFIR coding framework helped structure these adoption challenges for future comparability across settings). Differences in hospital size, resource availability, and organisational culture across different settings may produce distinct implementation challenges. Because CFIR is also used in multi-site studies to enable comparative analysis, our single-site application limits the ability to contrast determinants across organisational contexts. Future research could replicate this prospective, implementation-science-informed approach across multiple hospitals to assess the transferability and variability of anticipated adoption challenges. Although our interview sample included participants from various roles within the hospital's planning and scheduling processes, the perspectives of patients and their carers were underrepresented. Incorporating these voices in future studies would help provide a more holistic understanding of the innovation's potential impact and acceptability.

Finally, in reflecting on how we conducted this study, several methodological considerations warrant mention. Conducting both group and individual interviews enriched the data but may have shaped how certain themes emerged; for example, group discussions tended to highlight shared assumptions and norms, whereas individual interviews revealed more personal concerns and sensitivities. The combination enriched the dataset but may have influenced which CFIR constructs were emphasised. Applying the framework within an operations-research project also required careful interdisciplinary interpretation. Our team included one implementation-science specialist, two operations-research modellers, a clinician, and a researcher trained in soft-systems and problem-structuring methods. This diversity strengthened the analytical rigour and interpretive depth of our findings, though it may have foregrounded organisational and behavioural aspects more than technical ones.

6.5. Looking ahead: interdisciplinary and field-level reflections

We recognise that for some OR/MS scholars, questions of adoption or implementation may sit outside their immediate research interests or disciplinary incentives. Nevertheless, considerable effort is already devoted to stakeholder engagement during modelling processes, often to ensure that the assumptions and parameters accurately reflect real-world contexts. Such engagement can have a two-fold purpose: it improves the validity and relevance of the model or tool itself, while also laying groundwork for potential acceptance and uptake in practice (Lamé et al., 2023; Mingers & Rosenhead, 2004).

For OR/MS scholars, our implication is not that they must become implementation scientists, but that collaboration with disciplines already dedicated to studying adoption processes may strengthen translational impact. For OR/MS communities in which model development is prioritised, integrating implementation science expertise, whether through collaboration or methodological exchange, can add analytical depth without detracting from modelling contributions. Our experience suggests that a staged, interdisciplinary pathway may be particularly promising for OR/MS innovations: early stakeholder engagement or soft-systems exploration to structure the problem; analytical model development; prospective identification of adoption determinants using implementation-science frameworks; iterative redesign; and, where feasible, formal evaluation using complementary implementation frameworks that focus on the processes of implementation (Nilsen, 2015).

We approached this study with the intention of sharing our own (positive) interdisciplinary experience, combining expertise from operations research and optimisation, implementation science, clinical practice, and soft-systems methods to connect technical model design with the behavioural and organisational factors that influence adoption. Building on this experience, we encourage those interested in adoption and implementation processes to engage more systematically with implementation science and related social-science approaches to understand how analytical innovations become (or fail to become) embedded within organisations. Doing so will strengthen the cumulative learning within the field and ensure that the analytical contributions of operations research and management science continue to deliver tangible, sustained value to health systems.

7. Conclusion

In this study, we used an implementation science framework (CFIR) to prospectively identify barriers and facilitators for adopting a mathematically optimised surgery blueprint schedule within a children's hospital. By applying this framework early, before implementation, we were able to anticipate organisational and behavioural factors likely to influence future adoption and feed these insights back into the model's design.

Our study resulted in three sets of findings with implications for future work. First, we identified the adoption barriers and facilitators for introducing a new scheduling approach in our study's setting. Adoption facilitators included strong motivations among staff to optimise schedules (especially given resource constraints and work burdens), as well as positive reactions to an objectively designed mathematical scheduling tool. Barriers included a resistance to change among some staff, and the need for more evidence about the new schedule's benefits before implementation. A particularly striking finding was the deeply embedded culture of operational adjustment and informal negotiation that characterises current planning practices – an enduring challenge for any centralised or optimised scheduling solution. Furthermore, we identified that the diversity in skills and influence of different staff who have the role of a "planner" in a hospital setting can lead to frustrations and uncertainties about who could adopt and champion a new scheduling innovation.

Second, by examining these dynamics prospectively, we were able to identify design implications for future model iterations. These include the required adaptability to different surgeon's needs and those of the patients/families, as well as the need to strongly communicate the benefits of the new schedule versus current practice. These findings highlight the practical value of exploring adoption determinants in advance, when adaptations to both the model and its implementation plan are still possible.

Finally, we found that our use of the CFIR demonstrated the value of implementation-science frameworks for studying operations research and management science innovations at the design stage. The framework's structured domains helped classify determinants across individual, organisational, and contextual levels, creating a systematic language for interpreting adoption dynamics. Rather than replacing existing participatory or reflective traditions within OR/MS, this approach complements them by offering a transferable structure through which implementation insights can accumulate across studies. This moves beyond pragmatic or anecdotal reflections often found in the literature towards a more theory-informed, cumulative evidence base of adoption challenges.

We note that many efforts are underway to enable adoption of model outputs, such as the use of soft systems methodologies, action research, and improvement science in various studies across OR/MS. By involving stakeholders before, during or after model development, such studies encourage the adoption of results from the modelling efforts. We propose that the use of implementation science approaches, such as CFIR in our case, can complement these traditions by providing explicit and adaptable frameworks for analysing adoption determinants, whether prospectively or retrospectively. By combining analytical, behavioural, and organisational perspectives, future interdisciplinary work can not only optimise systems in theory but also ensure that these innovations become workable, adoptable, and durable in health systems practice.

Note

1. This schedule was developed as part of an educational exercise for an MSc thesis. For details of its development, see: http://resolver.tudelft.nl/uuid:a808976d-31a5-40a1-bd14-e978f6e414ff

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Author contributions

CRediT: **Kelly Vos:** Data curation, Formal analysis, Investigation, Project administration, Writing – original draft, Writing – review & editing; **J. Theresia van Essen:** Conceptualization, Formal analysis, Funding acquisition, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing; **Erwin Ista:** Conceptualization, Methodology, Writing – review & editing; **Lonneke M. Staals:** Conceptualization, Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing; **Saba Hinrichs-Krapels:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing.

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Data availability statement

All original interview audio recordings, transcripts and informed consent forms from the interviews are stored under the university's secure SURFDRIVE system for a limited period. Due to these containing personal and sensitive information, they are not made available publicly in accordance with the ethical approval for this study.

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