# ORAHS 2026

Program

July 8, 2026

# TECHNICAL PROGRAM

## Monday, 9:00-10:00

### ■ MA-01

*Monday, 9:00-10:00 - Room: Emeleus Lecture Theatre*

#### Opening

Stream: Plenary sessions
*Invited session*
Chair: *Adele H Marshall*
Chair: *Laura Boyle*
Chair: *Roberto Aringhieri*
Chair: *Melanie Reuter-Oppermann*

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## Monday, 10:00-11:00

### ■ MB-01

*Monday, 10:00-11:00 - Room: Emeleus Lecture Theatre*

#### Plenary Professor Sally McClean

Stream: Plenary sessions
*Invited session*
Chair: *Adele H Marshall*

**1 - Markov and semi-Markov Processes for Healthcare Modelling and Mining**
*Sally McClean*

Models, such as Markov chains or Petri nets, have often been used to describe processes where mathematical approaches can facilitate diagnosis, prognosis and optimisation, while simulation approaches can use such models to imitate important behaviours without having to disrupt the real-life set-up. Also, with the ever-increasing capability of computer systems to collect detailed information about all aspects of such processes, such as different tasks, events, alarms, intrusions or failures, as well as interoperability, has come increased ability to analyse process behaviours and outcomes leading to better understanding and improved efficiency.

In this talk we will explore more expressive models of healthcare dynamics, generalising Markov to semi-Markov models, where state durations can have more expressive representations. As such, we will present a number of process modelling and mining problems, such as detecting anomalous sequences of tasks, predicting faults, non-compliance, or timely completion of processes, as well as analysing and forecasting likely occurrence of absorption and associated costs, through death, or discharge to possible locations. Examples from healthcare, digital innovation for smart homes, and health economics will illustrate how stochastic models can be combined with data analysis for better use of such complex processes.

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# Monday, 11:30-12:30

## ■ MC-01

*Monday, 11:30-12:30 - Room: Emeleus Lecture Theatre*

### Integrated planning (1)

Stream: Presentations
*Contributed session*
Chair: *Christina Büsing*

**1 - Facility Location Planning for nurse-led centers in home healthcare**
*Yasamin Babaei, Gréanne Leeftink, Derya Demirtas, Erwin W. Hans*

Home healthcare providers face rising demand, staff shortages, and high nurse travel times, creating a need for new care delivery configurations. This study examines a hybrid model that combines home-based and center-based care, where some patients receive specific services, such as wound care, at nearby nurse-led centers (NLCs), while others continue to be treated at home. Although this configuration will be implemented by our partner home healthcare organization, it raises the question of where and when to open, maintain, or close NLCs under uncertain and changing demand over time. We propose a multistage stochastic dynamic facility location model and solve it using Monte Carlo sampling and a multistage scenario-tree approximation within a sample average approximation framework. Demand uncertainty is modeled through both location-specific uncertainty from historical data and stage-specific uncertainty that grows over time. Simulated demand paths are compressed into a scenario tree using forward stage-wise construction with greedy k-median reduction. The model minimizes system costs subject to budget limits, accessibility requirements, and stage-specific service-level constraints. Results indicate that the hybrid model achieves about 34% cost savings compared with a home-only benchmark.

**2 - Towards Balanced Hospital Operations: An ALNS Approach for Integrated Assignment Decisions**
*Emily Lex, Fabian Schäfer, Alexander Hübner*

Optimizing patient-to-room and nurse-to-patient assignments is crucial for efficient hospital workflows, high-quality care, and patient and staff satisfaction. By integrating both assignment problems into a unified decision framework, joint objectives depending on room and nurse allocations can be optimized simultaneously. These include minimizing nurse walking distances, balancing workload distribution, and limiting the number of nurses assigned to patients sharing the same room to reduce negative externalities such as cross-room infection risks and unnecessary patient disturbance. For this integrated problem, we develop an Adaptive Large Neighborhood Search metaheuristic. The method is designed to flexibly adapt to diverse hospital settings, operational constraints, and objective priorities, enhancing its applicability in real-world healthcare environments. Extensive computational experiments are conducted on both real-world and artificially generated datasets of varying size and complexity. To assess solution quality, the proposed approach is evaluated against current best-known results, demonstrating its efficacy and competitiveness. The framework is designed to generate managerial insights by revealing structural patterns in staffing and room allocation decisions. These insights can help hospital administrators understand trade-offs between efficiency, workload balancing, and patient-centered care, thereby improving both strategic and operational decision-making.

**3 - Modelling different stakeholder interests in integrated healthcare timetabling**
*Felix Engelhardt, Christina Büsing*

The Integrated Healthcare Timetabling Competition 2024 (IHTC) brings together three critical problems in healthcare: surgical case planning, patient admission scheduling and nurse-to-room assignment. For the IHTC, a model with hard and soft constraints was given, and solving meant minimising the aggregated penalties for soft constraint violations.

In this talk, we interpret the IHTC instances as multi-objective optimisation problems, where instead of total utility, we optimise different and potentially conflicting objectives with respect to patient preferences, medical treatment quality, staff workload and costs. Thus, we ask ourselves: 1) To what extent can different stakeholder objectives be traded against each other? 2) Are there different (near-)optimal solutions that meet different preferences, and if yes, how can we compute those? 3) How sensitive are the optimal solutions and solution values to variations in weights for soft constraints? 4) What if some soft constraints become hard and vice-versa? 5) How do we present this information in an understandable manner?

All of the above are subject of ongoing research. We will give a quick overview about the computational methods used, i.e. modelling-to-generate-alternatives and its links to diversity optimisation and sensitivity analysis. Then, we provide computational results with a focus on using different types of visualisations to present results. Code can be made available upon request.

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## ■ MC-02

*Monday, 11:30-12:30 - Room: Bell Lecture Theatre*

### Healthcare management

Stream: Presentations
*Contributed session*
Chair: *Houra Mahmoudzadeh*

**1 - Managing Operating Room Capacity under Uncertainty: Evidence from Robust, Regret, and Data-Driven Approaches**
*Amin Ahmadi Digehsara, Amir Ardestani-Jaafari*

Operating room (OR) planning is a critical task in hospital operations, where decisions on the number of rooms to open and surgery assignments must be made in advance despite uncertainty in surgery durations. Poor planning may result in idle capacity, excessive overtime, and delays in patient care.

This study develops and compares three optimization approaches for OR planning under uncertainty: robust optimization (RO), regret minimization (RM), and a data driven distributionally robust framework referred to as mean robust optimization (MRO). RO protects against worst case realizations but can be overly conservative. RM limits performance loss relative to an ideal ex post solution, offering a less conservative alternative. MRO incorporates historical data through clustering based ambiguity sets, balancing robustness and data adaptivity.

We reformulate the RO and RM models into tractable problems and solve them using efficient column and constraint generation algorithms. Computational experiments under varying uncertainty levels and cost structures reveal clear trade offs: RO ensures reliability at higher cost, RM reduces conservatism but may increase variability, while MRO achieves a balanced performance.

**2 - Improving Access to Maternal Care Through Remote Monitoring**
*Salar Ghamat, Parang Zadtootaghaj*

High-risk pregnancies often require frequent assessment of symptoms such as decreased fetal movement, but many reported alarms do not reflect true complications. Remote maternal-fetal monitoring can expand access by allowing surveillance at home and reserving clinic visits for concerning cases. However, it also creates new reimbursement and capacity-allocation challenges. We develop an analytical model with three stakeholders: a payer, a provider, and patients. The payer designs reimbursement for virtual visits, the provider allocates patients between remote and in-clinic monitoring under visit-capacity constraints, and patients differ in risk and in how they value the two care modes. We show that targeted reimbursement for remote monitoring can better

align provider decisions with patient needs and welfare goals, improving patient surplus, provider payoff, and total welfare. Incentives that align care more closely with patient preferences generate the largest welfare gains, but once payment costs are considered, incentives designed around the payer's welfare objective create greater net value. We also show that when providers can flexibly adjust the frequency of virtual visits, remote monitoring acts as a capacity buffer that absorbs false-alarm workload and allows more patients to be safely managed remotely. These findings suggest that reimbursement policies for maternal telemonitoring should account for both operational capacity and expected alarm intensity.

**3 - Including class-wise preferences for vacation periods: A model to assign periods of vacation and practical- as well as theoretical education for general nurse trainees**
*Corinna Oppitz, Jens Brunner*

We address a planning problem within the dual vocational education for general nurses. In each year of their apprenticeship, all trainees receive theoretical education at a vocational school and practical education at care institutions. Usually, all trainees in a class are scheduled collectively to theoretical or practical education, resulting in class-wise plans. Here, class-wise vacation periods must be included if vacation is planned centrally. To make the most of the involved institutions' resources, it is beneficial to balance the number of trainees scheduled for practical education over time. We extend a model that develops schedules assigning classes to practical and theoretical education, taking class-wise vacations as inputs. In our model, vacation periods are no longer inputs and vacation preferences of both the school and the classes are integrated. The resulting model is a multi-period multi-criteria assignment problem with block and coverage constraints. We investigate the effects of variable vacation periods on the objective of balancing the trainees in practical education and on preference maximization. Therefore, we formulate our model as lexicographic optimization problem, where balancing the trainees in practical education is the most important objective, followed by preference maximization for vacation periods. We solve our model sequentially using a solver. For our computational study, we use artificial data. We discuss and present our results.

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# ■ MC-03

*Monday, 11:30-12:30 - Room: MAPTC OG/017*

## Healthcare modelling

Stream: Presentations
*Contributed session*
Chair: *Sally Brailsford*

**1 - The impact of infrastructure failure on healthcare delivery within the NHS**
*David Jones, Sally Brailsford*

This talk discusses the impact on patient care of backlog maintenance of hospital infrastructure. Defined as the total volume of tasks such as inspections, repairs, and preventive maintenance deemed necessary but not completed, backlog reached '15.9bn in 2025 in NHS England. The research is a triangulation of four studies which examined the extent to which patients are being harmed by backlog maintenance and whether current levels pose a risk to the wider delivery of healthcare. The first two studies, generative AI analysis of 4.6m patient incidents and a case study of maintenance incidents, examined the impact of infrastructure failure on patients. The third study used causal loop diagrams to explore the implications of backlog maintenance. The final study, a workshop of estates experts, considered the changes needed to make improvements.

The research highlighted significant discrepancies in the quality and level of reporting across national systems, marring the potential interpretation of the data. However, it was clear that patients are being harmed and treatment delayed, and that the NHS is being put under greater pressure due to failing infrastructure. The findings highlight the challenges facing decision makers and the need for a better flow of information on the impact of infrastructure failure. The research also showed that all NHS managers need to understand the potential impact of infrastructure failure on the whole system as well as on individual patients.

**2 - Competition and Performance-Based Reimbursement in Drug Markets**
*Soodabeh Asadi Dezaki, Salar Ghamat, Greg Zaric*

Access to high-cost therapies is increasingly shaped not only by pricing but also by how reimbursement rules interact with market competition. This study examines how the entry of competing drugs affects reimbursement design and patient access when treatment outcomes are uncertain. We develop a game-theoretic framework in which an incumbent firm responds to a new entrant by choosing among alternative reimbursement approaches, while a healthcare payer determines coverage based on expected value across heterogeneous patients. The model captures key trade-offs among pricing, uncertainty in treatment effectiveness, and the cost of verifying outcomes. Our results show that competition fundamentally alters the structure of reimbursement decisions. Strong competitive pressure can expand access and reduce prices, but it also shifts incentives towards adopting performance-contingent reimbursement mechanisms. In contrast, weaker competition leads to higher prices and more restrictive coverage. We further show that the presence of alternative reimbursement options can influence market behaviour even when they are not actively used. The analysis highlights that reimbursement policies cannot be designed in isolation from market structure and provides insights into how competition shapes access, pricing, and welfare in pharmaceutical markets.

**3 - Domain-Informed Feature Engineering for Modelling in Epidemiology and Public Health**
*Jessica Stockdale*

Machine learning methods are increasingly applied to problems across epidemiology and public health, yet challenges remain in model transparency and explainability. In many scientific applications, we are not only interested in model performance, but also in understanding the mechanisms by which our data are informative. In this talk, we will explore how domain-informed feature engineering can support the development of interpretable models. By transforming raw epidemiological, clinical and/or administrative data into designed features, we can incorporate subject expertise - whether of the researcher or of research partners - producing outputs that decision-makers can understand and act on. We will explore two very different case studies: COVID-19 forecasting from population-level genomic surveillance data and cohort identification of people experiencing homelessness from individual-level electronic health records. In both, feature engineering enabled simple models such as random forests to perform well even when data were limited or noisy. We argue that successful modelling in public health contexts can lie as much in knowing what to measure as in knowing which model to use.

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# Monday, 13:30-15:00

## ■ MD-01

*Monday, 13:30-15:00 - Room: Emeleus Lecture Theatre*

### Emergency Departments

Stream: Presentations
*Contributed session*
Chair: *Steffen Zschaler*

**1 - On the Effects of Boarding Congestion on Treatment Time in Emergency Departments**
*Beste Kucukazici*

We conduct multimethod research to examine how boarding congestion affects patient treatment times in emergency departments (EDs) and evaluate two operational strategies aimed at reducing its negative effects. First, we perform an empirical analysis using ED visit data from eight Canadian hospitals, revealing an inverted-U-shaped relationship between congestion and treatment time, with moderate congestion worsening delays. Mechanism testing shows that ED resource use by boarding patients mediates this non-linear relationship, with hospitalist visits—by inpatient service physicians—moderating the link between congestion and resource usage. Second, based on our empirical findings, we develop a simulation model to assess the two strategies within the complexities of real-world EDs. Simulation results demonstrate that these strategies can jointly decrease the negative impact of boarding congestion on treatment times by 44% in a typical ED. Our study offers new insights into how boarding patients influence ED performance and underscores the importance of considering congestion in operational decisions.

**2 - The Impact of Appointment-Based Services for Non-Urgent Patients in Emergency Departments**
*Chiara Morlotti*

Emergency departments (EDs) face persistent challenges related to urgency, timely service delivery, and overcrowding. The growing number of non-urgent patient visits significantly contributes to overcrowding, thereby reducing the efficiency and quality of care for patients requiring immediate attention. Several strategies have been proposed to address inappropriate ED utilization, ranging from strengthening primary care systems to optimizing ED triage processes. This study investigates the potential of an appointment-based service for non-urgent patients. To evaluate the impact of this approach, we first developed a stated-preference survey considering attributes such as waiting time, time to visit, and visit duration. Respondents are presented with alternatives including an appointment-based service—where patients' conditions are remotely assessed to determine whether an immediate ED visit is required or a scheduled appointment can be offered—and the traditional on-site triage. Second, discrete choice models are applied to estimate users' willingness to adopt the proposed service compared to traditional triage. Finally, the estimated preferences are incorporated into a simulation model, calibrated using real data, to assess the effects of the service on ED performance. The results indicate significant improvements in ED performance, with outcomes varying depending on the availability of dedicated resources to manage appointment scheduling.

**3 - A Discrete-Event Simulation Tool for Tactical Decision-Support in Emergency Departments**
*Irene Dominguez-Galan, Victor Fernandez-Viagas, Jose M. Molina-Pariente, Sandra Leal Gonzalez*

This study presents a tactical Emergency Department (ED) decision-support tool based on a discrete-event simulation model. Historical data are used to estimate model inputs, including hourly inter-arrival time distributions; probabilities of patient symptoms, urgency levels and care pathways; processes that define each pathway and their service time distributions. The tool enables users to design and evaluate scenarios through three modules. First, users define the ED resource configuration such as resourcing levels, schedules and care teams (groups of resources that operate together). Second, they can set restrictions on patient use of resources, including limiting access to specific resources and defining care continuity policies so patients are attended always by the same professional. Third, arrival patterns can be modified by adjusting inter-arrival times or patient volumes by symptom or urgency level. After a specific scenario is defined, the simulation can be executed to analyse different variants of the base scenario and estimate different key performance indicators (KPIs), including length of stay, waiting times and resource utilization. Thereby, the tool supports what-if analysis for tactical planning, enabling ED professionals to assess the impact of changes in resources, demand and resource use policies. The tool has been validated using real data from two Spanish hospitals to ensure that it accurately reflects the operation of EDs.

**4 - Towards a Modelling Workbench for Reusable Emergency Department Simulation**
*BoFan Zhang, Steffen Zschaler, Matthew Edwards*

Discrete-event simulation has been extensively studied for modelling Emergency Department (ED) operations. However, simulation remains confined to academia rather than routine use in ED settings. A key barrier is that existing approaches come in 2 extremes: (i) generic black-box models assume a fixed structure fits all EDs, allowing parameter tweaks but failing when a hospital's operations differ; (ii) building a simulation from scratch provides great flexibility but requires programming expertise and significant time, limiting accessibility for clinical managers and harming economic feasibility. Neither extreme exploits the structure ED operations share: ED flow is driven not by diagnosis but by the work the system has to do for each patient, so the same representational decisions and flow patterns recur across EDs. We propose a modelling workbench that exploits this recurrence, making it easier to build a simulation structured around how a specific ED actually works, without writing code from scratch. To develop our workbench, we capture knowledge in two ways: (i) a structured catalogue of recurrent design decisions, such as resource granularity and pathway logic, including their interdependencies; and (ii) a library of partial models capturing common patient-flow patterns enabling reuse instead of from-scratch model creation. We will present an early prototype workbench showing how a modeller is guided by the catalogue to configure and run a simulation model.

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## ■ MD-02

*Monday, 13:30-15:00 - Room: Bell Lecture Theatre*

### Appointments

Stream: Presentations
*Contributed session*
Chair: *Jedidja Lok - Visser*

**1 - General model and batch scheduling approach for inter- and intraday scheduling of outpatient chemotherapy appointments**
*Jonathan Faasse, Theresia van Essen, Uxia Corredoira Y Teijeiro, Mark Mulder, Steven Petit*

Cancer care in the Netherlands is facing major challenges, due to high expected increases in cancer incidence and personnel shortages, which increases the need for efficient scheduling processes. This work focuses on scheduling outpatient chemotherapy appointments and provides a general model that includes all steps of blood collection, blood analysis, consultation, drug preparation, and infusion. The scheduling problem is formulated as a Mixed-Integer Linear Program for inter- and intraday multi-appointment scheduling and resource assignments. We solve the problem using Gurobi. A batch scheduling approach is introduced to study the effect of the number of patients that is scheduled simultaneously, reflecting different options for integration in clinical workflows. A case study is performed based on the chemotherapy outpatient clinic of a Dutch Academic Medical Center.

**2 - Bridging the OR Implementation Gap: Implementation Strategies for Optimized Patient Appointment Scheduling**
*Uxia Corredoira Y Teijeiro, Jonathan Faasse, Mark Mulder, Theresia van Essen, Steven Petit*

Cancer care in Europe is under growing pressure due to rising cancer incidence and staff shortages. Therefore resource optimization is becoming more important in hospital care. Operations research is used in many industries for resource optimization. In healthcare however there exists an implementation gap between developed OR models and their actual use in clinical care. The goal of this study was to identify barriers and facilitators for the implementation of OR for cancer care optimized appointment planning in the outpatient clinic and treatment center of Erasmus MC Cancer Institute, match suitable implementation strategies, and assess patient preferences. A literature review guided by the Consolidated Framework for Implementation Research identified relevant barriers and facilitators, which were validated through focus groups with nurses, planners, physicians, and a quality assurance officer. Barriers and facilitators were matched to implementation strategies using the Expert Recommendations for Implementing Change tool. Ninety studies were included. Key barriers and facilitators related to stakeholder engagement, model evidence base, and its complexity. Recommended strategies include preparing champions, consensus meetings, and creating an implementation blueprint. Patient preferences were assessed in a single center prospective survey. Patients indicate preferring same-day appointments, but currently one in three patients does not receive them.

**3 - Does the patient really want to come to the hospital? Quantifying and optimizing time savings from patient preference-informed pre-assessment**
*Jan-Willem de Jong, Jedidja Lok - Visser, Joan Doornebal, Joris van Dijk, Gréanne Leeftink*

Outpatient clinics (OCs) face increasing patient demand and provider shortages. Remote patient monitoring strategies, including pre-assessment based on patient health data, is increasingly used to improve care delivery. However, patient preferences are rarely incorporated.

Our goal is to quantify and optimize the potential time savings from pre-assessment and estimate the added value of incorporating patient preference into this framework. Using retrospective Dutch nephrology OC data, we compare a dynamic pre-assessment scheduling approach incorporating uncertainty in patient preferences with a static scheduling policy. We estimate annual appointment time per patient under both approaches and use these as input for a stochastic programming model.

To derive an optimal capacity allocation policy under patient appointment request uncertainty from pre-assessment outcomes, we develop a stochastic programming model solved with Sample Average Approximation. We evaluate scheduling performance with and without patient preference information, as well as a baseline scenario without pre-assessment, thereby quantifying the added value of incorporating patient preferences in both demand estimation and scheduling.

Our results show that value-driven scheduling reduces the annual appointment time per patient by at least 18%. Incorporating patient preferences better aligns care delivery with actual patient needs and enhances patient-centeredness in outpatient scheduling.

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# ■ MD-03

*Monday, 13:30-15:00 - Room: MAPTC OG/017*

## Care pathways and patient flow

Stream: Presentations
*Contributed session*
Chair: *Davide Duma*

**1 - Combining Segmentation and Process Mining to Identify Inequities in Clinical Pathways**
*Luca Murazzano, Catherine Paquet*

Combining patient segmentation from routinely collected sociodemographic and clinical data with process mining of care event logs offers a pragmatic approach to explore heterogeneity in clinical pathways within learning health systems. We propose a reproducible pipeline that prepares secondary data into an event log enriched with patient attributes, derives interpretable patient segments using simple rule-based and clustering strategies, and applies process mining discovery and variant analysis to each segment to compare pathway structure, frequencies and time-based indicators. The emphasis is on accessibility for non-specialists through clear rules for variable selection, basic data quality checks, and straightforward validation criteria. We discuss how segment-specific process insights can generate hypotheses for targeted pilots, the governance and bias considerations relevant to secondary data use, and a reporting checklist to support replication and dissemination.

**2 - Modelling the Cancer Diagnostic Pathway - A Generic Approach**
*Martin Pitt*

Early cancer diagnosis is key to improving patient outcomes and preventing avoidable deaths. It is a major priority for the UK NHS. Computer modelling to support cancer pathway management has been shown to be effective, but most applications are limited to specific clinical contexts and cancer types. Given the dynamic and diverse landscape of cancer diagnostic care (new technologies, changing demographics, service reorganisation etc.) there is clear benefit in developing modelling approaches that can address a wider range of scenarios, maintain flexibility, and support reuse. This presentation outlines a generic modelling framework blueprint for the cancer diagnostic pathway. The framework combines Markov state-transition modelling with discrete event simulation overlaid with an interactive graphical interface. This flexible toolset allows users to visualise and explore 'what-if' scenarios and investigate key relationships between parameters and outputs including cost-effectiveness. Prototype frameworks will be shown for both lung and bladder cancer which demonstrate the potential for exploring the impact of primary care referral rates on downstream demand for diagnostic scanning services. At all stages input from professional cancer service staff, both managerial and clinical, was pivotal in the development of the framework and early feedback suggests that there is strong potential for these tools to provide invaluable support for service managers in cancer care.

**3 - Modelling and Optimization of ECG Patient Flow Using a Conceptual Digital Twin**
*Rym M'Hallah, Mei Tuson*

In healthcare, managers/policymakers are often called to find innovative and cost-effective ways to plan and improve hospital efficiency and productivity, ensure the continuous delivery of comprehensive quality services, and promote the well-being of their staff. Digital Twins (DT), which are a digital representation of a real-world system with a bi-directional exchange of data connecting the physical real-world system and its representation, could help decision makers gain insight into their services (e.g., how increased demand, limited resources, staff shortage) and assess patient outcomes, satisfaction, and waiting time of potential solutions before implementing them. This research integrates systems engineering and systems thinking to construct a template DT Hospital Information Flow Framework (DTHIFF) that guides the structure and the building of a conceptual DT. The research showcases the utility of DTHIFF by applying a simulation-based optimisation to the DTHIFF of a use case of ambulatory ECG. It illustrates how the unified framework enables clinicians, managers, and policy makers to visualize process flows, determine bottlenecks, conduct 'what -if' scenarios, thus, redesign processes. For example, it informs when to use two alternative ECG technologies and their impact on waiting times and resource utilization of a hospital.

**4 - How to model a regional healthcare system leveraging healthcare big data**
*Roberto Aringhieri, Davide Duma, Alberto Guastalla*

Healthcare Big Data (HBD) is generated from a plurality of sources and offers possibilities for new insights, for understanding human systems at the systemic level to develop personalised medicine, prevent diseases and support healthy life. From a management perspective, HBD is a key enabling technology for analysing the healthcare system at the individual patient level.

We propose a general framework in which the HBD can power a detailed health system analysis using Discrete Event Simulation (DES) methodology: indeed, one can replicate the behaviour of the health system modelling how each single patient flows within their care pathway exploiting the HBD. Unlike other more traditional analytical approaches for the health system analysis, our framework allows to (i) better represent the variety of the patients accessing the health system, (ii) better capture the actual capacities of each wards over time, and (iii) replicate the day-to-day admissions process.

We illustrate this approach by modelling the regional healthcare system in Piedmont using three years' worth of hospital discharge records (more than 1.5 million records) in order to analyse the flows of patients asking for a specialist treatment as a result. We detail the various steps that lead to the development of the complete quantitative model. We also outline the various analyses that can be carried out using the resulting model.

# Monday, 15:30-17:00

## ■ ME-01

*Monday, 15:30-17:00 - Room: Emeleus Lecture Theatre*

## Staffing and rostering (1)

Stream: Presentations
*Contributed session*
Chair: *Nadia Lahrichi*

**1 - Scheduling for Stability: Evaluating Proactive Strategies in Nurse Scheduling**
*Henriette Thier, Christina Büsing, Gréanne Leeftink, Johanna Leweke*

Understaffing in hospitals leads to overwhelmed nurses and inadequate patient care. Demand for patient care is expected to increase due to population aging, yet the number of nurses is not expected to increase accordingly. To avoid understaffing by increasing the workforce is therefore becoming an increasingly unrealistic solution. Thus, other solutions need to be assessed. Currently hospitals apply strategies to prevent understaffing based on experience. We aim to equip hospitals with a guideline based on empirical evidence helping them decide which strategy of buffer, intermediate shift, and reserve shift fits them best and how to incorporate them.

We present a framework to evaluate proactive staffing strategies, comprising three components: simulation, scheduling, and reassignment. Explaining this framework, we address demand modeling, schedule objectives, strategy integration, and nurse reassignment. We report the results of applying the framework to the buffer, intermediate, and reserve shifts.

**2 - A mathematical formulation of equity and fairness in Physician Scheduling**
*Begoña Álvarez Tena, Marta Cildoz, Fermin Mallor, Pedro Mateo*

Fairness and equity are often considered in physician shift scheduling, yet most approaches rely on ad hoc balancing rules within integrated optimization models. This work presents a formal framework that models both concepts as explicit workload calibration principles. We propose a Fairness-Equity Calibration model that defines target workload distributions across physician groups, separating structural balance from shift assignment. The model accounts for heterogeneous contracts, eligibility constraints, and priority levels, while controlling global imbalance, inter-group differences, and individual deviations.

Based on this framework, we study two scheduling approaches: a two-phase exact method and a constructive heuristic guided by calibrated targets. Experiments on synthetic and real instances show that the decomposition improves tractability over monolithic models. In large-scale problems, the heuristic produces high-quality schedules in short times while preserving fairness and equity, clarifying workload distribution and enabling more scalable scheduling methods.

**3 - Generation of equal and flexible cyclical nurse schedules**
*Loic Flament, Christelle Guéret, Odile Bellenguez, David Rivreau*

Designing work schedules for hospital staff is a complex and time-consuming task, due to numerous legal and institutional constraints, which may generate tensions within teams. This work proposes a method for generating cyclical schedules. A common cycle is shared among agents with identical contractual working hours, while distinct cycles are built for each contract type.

The first step enforces proportional equity by distributing shift types according to each agent's contracted working time and spreading the resulting overstaffing across the planning horizon, in full compliance with legal, contractual, and organizational rules.

Since multiple solutions of comparable quality remain, a flexibility criterion is introduced to discriminate among them. In practice, agents frequently swap shifts and days off once the annual schedule is published, and managers may also perform swaps when someone is absent. Maximising the number of legally feasible swaps facilitates adjustments while maintaining compliance. Two types are considered: same-day swaps, a direct exchange between two agents working on the same day, and cross-day swaps, involving a working agent and an off-duty agent with the latter receiving a compensatory day off through an additional exchange.

Two integer linear programming models are proposed, one based on individual shifts, and the other on three-day patterns. Their performance is evaluated and compared using real instances from partner hospitals.

**4 - Improving Emergency Department Physician Rostering through Flexible Shift Design**
*Nohaila Ahssinou*, *Nadia Lahrichi*

Emergency departments (EDs) increasingly face congestion due to rising demand and constrained physician availability. As capacity expansion is often infeasible, effective physician rostering is essential to improve responsiveness and mitigate overcrowding. This work addresses the physician rostering problem by integrating time-varying physician productivity, patient demand and flexible shift design. In particular, the model jointly optimizes shift start times and shift lengths, rather than relying on fixed assignments. Productivity is estimated using clustering methods that identify distinct patterns, which are subsequently adjusted based on assignment type, shift length and individual physician characteristics, thereby capturing dependencies across consecutive shifts. Using real-world data from an emergency department, we examine clinical outcomes around shift transitions to assess potential fatigue effects. Computational and real-world experiments have shown improved demand coverage and the generation of realistic schedules.

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# ■ ME-02

*Monday, 15:30-17:00 - Room: Bell Lecture Theatre*

## Machine learning and AI in heathcare

Stream: Presentations
*Contributed session*
Chair: *Alison Harper*

**1 - Predicting Clinical Pregnancy Outcomes in IVF Using Electro-Physiological Stress Indicators**
*Vedat Verter*, *Morteza Nikoonejad*, *Alice Domar*

Predicting clinical pregnancy outcomes prior to embryo transfer in in vitro fertilization (IVF) remains challenging due to biological variability and uncertainty in routinely collected clinical data. This study investigates the predictive value of electro-physiological stress indicators, alongside traditional clinical metrics, using machine learning models applied to an observational cohort. The dataset was obtained from women undergoing their first IVF cycle at a fertility clinic in the United States, with wearable devices recording 35 electrophysiological markers daily during treatment. After preprocessing, data from 109 of the 240 participants were retained for analysis. Logistic regression and random forest models were evaluated under repeated random resampling. Logistic regression achieved the strongest performance, predicting clinical pregnancy outcomes with an accuracy of 75.3% prior to frozen embryo transfer. The results demonstrate that electro-physiological stress indicators contain meaningful predictive signal and provide a basis for transparent, and reproducible pregnancy prediction in clinical IVF settings.

**2 - Predicting call abandonment in a mental health helpline: A calibrated machine-learning approach**
*Salman Ahmad*, *Raymond Bond*, *Zeeshan Tariq*, *Gillian Cameron*, *Maurice Mulvenna*, *Edel Ennis*, *Kristel Miller*

Mental health helplines regularly lose callers before they reach a counsellor, and these abandoned calls represent unmet demand. Real-time methods to predict abandonment remain scarce. As part of a KTP project developing a digital analytics platform for mental health and wellbeing services, we built a machine-learning model that estimates abandonment risk while callers are in queue and flags high-risk calls to support real-time operational decisions. The study used 141,952 calls from 2023 to 2025, with an abandonment prevalence of 1.72%. We used a strict temporal design: training on 2023 data with tuning and threshold selection on 2024 data, and held-out evaluation on 2025 data. Outlier caps, aggregate features, and preprocessing were fitted on training data only to prevent leakage. A set of 15 features captured call routing, wait time, and automated menu engagement. Gradient boosting was selected on PR-AUC, with a feature-group ablation confirming the chosen features. Probabilities were calibrated with isotonic regression using time-aware cross-validation folds. The calibrated model achieved a test PR-AUC of 0.21 and ROC-AUC of 0.93. An operational threshold of 0.85, selected from the 0.80 to 0.85 range with priority on recall, flagged 2,383 calls with an abandonment rate of 24.3% (around 14 times the base rate). Operationally, this supports resource allocation during periods of elevated risk, while the ethics of any caller-level response require separate consideration.

**3 - Generative artificial intelligence for converting images of queuing networks into simulation models: an LLM workflow approach**
*Thomas Monks*, *Alison Harper*, *Navonil Mustafee*

This talk presents a novel workflow for converting computer-aided and hand-drawn process flow diagrams of open queuing networks with reneging into discrete-event simulation models. The approach uses open-weight large language models (LLMs) running on private local hardware and combines two LLM-based stages with a final rule-based conversion step. Using a set of eight diagrams, we demonstrate the feasibility of automatically generating simulation models in the Python package Ciw from diagram images. We evaluate the workflow's performance and show high accuracy and reliability across the diagrams included in this pilot study. We also reflect on potential failure modes of the approach and outline priorities for future development.

**4 - Geometry-Informed Machine Learning for Predictive Treatment Planning of Prostate Cancer**
*Sean Rose*, *Rana Shiravi*, *Houra Mahmoudzadeh*, *Johnson Darko*, *Ernest Osei*

Radiation therapy (RT) is a critical component of modern cancer treatment, yet developing a personalized treatment plan for each patient remains a complex, time-consuming process. Despite advances in treatment planning systems, generating high-quality, individualized plans remains labour-intensive and highly dependent on planner experience. Treatment planners must account for anatomical geometry, tumour characteristics, and comorbidities that are unique to each patient while sparing organs at risk and ensuring adequate target coverage.

This talk covers some applications of machine learning techniques to historical prostate RT cases and explores how anatomical geometry can be used to predict key elements of a treatment plan. Methodology and results are presented for a descriptive analysis, a predictive analysis, and K-means clustering of 13 geometric features across 430 patients from a local cancer centre. Dosimetric metrics are used to provide clinical relevance and interpretability for unsupervised models.

This work demonstrates that geometric features alone capture meaningful patterns that are relevant to early-stage treatment planning. These insights motivate future development of geometry-informed, knowledge-based planning tools designed to provide oncologists data-driven starting points while enhancing both plan quality and workflow efficiency.

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# ■ ME-03

*Monday, 15:30-17:00 - Room: MAPTC OG/017*

## Healthcare logistics

Stream: Presentations
*Contributed session*
Chair: *Sebastian Kraul*

**1 - Multistage Stochastic Mobile Healthcare Facility Location under Facility Disruption Uncertainty**
*Bonn Kleiford Seranilla*

Motivated by the need for resilient healthcare delivery, this paper studies a multi-stage stochastic mobile healthcare facility location problem under facility disruptions. Disruptive events such as natural disasters can severely affect service availability. We develop a multi-period model that determines the number and locations of temporary mobile field hospitals, as well as the allocation of patients. The resulting formulation is a multistage stochastic mixed-integer program, which we solve using the state-of-the-art algorithms stochastic dual dynamic integer programming (SDDiP) and shadow price approximation (SPA). Through numerical investigations, we aim to demonstrate the effectiveness of SDDiP and SPA for this class of problems.

**2 - Hospital-at-Home Systems: Applications of Operations Research in Logistics and Planning**
*Mathias de Bang, Allan Larsen*

Hospital-at-Home (HaH) systems deliver hospital-level care within patients' homes as an alternative to inpatient hospitalisation. Driven by ageing populations, chronic disease prevalence, and increasing pressure on hospital capacity, HaH is gaining more traction. Studies suggest that home hospitalization can lead to lower costs, comparable medical outcomes to inpatient care, while patients report higher satisfaction from being treated at home. However, as treatments move outside hospital walls, new operational and logistical challenges emerge. HaH systems must coordinate care across dispersed locations, requiring complex planning of transport, staff, and equipment. The more acute nature of treatments demands reliable and responsive operations to ensure patient safety. This talk presents an overview of key operational challenges in HaH systems and discusses how methods from operations research and operations management can be applied to address these. A particular focus is given to patient transportation problems although broader problem classes from network design and scheduling are also introduced to outline promising directions for future research.

**3 - Optimizing Population Allocation in Healthcare Districts: A Metaheuristic Approach with Contiguity and Specialty Guarantees**
*Damián Pérez-Asensio, Victor Sanchez-Anguix, Fulgencia Villa, Yulia Karpova*

The healthcare sector is a relevant field of study due to its impact on population well-being. In hierarchically organised healthcare systems, health districts are responsible for organising and planning healthcare resources, providing care to their assigned population through healthcare centres. In this sense, health districts can be understood as fictitious territorial divisions within a larger territory, designed to facilitate the efficient management of available resources. The boundaries of health districts tend to remain unchanged over time, despite demographic and social changes that may alter the distribution of healthcare demand. This lack of updating can lead to imbalances in workload across centres, suggesting that a territorial reorganisation may be warranted. This work proposes a new allocation of the population to health districts, redefining their boundaries to balance the care burden across existing health centres. To this end, a metaheuristic algorithm equitably redistributes population while ensuring territorial continuity and minimising patient travel distances. The main contribution of this study is to ensure that each health district has a minimum set of medical specialties, thereby improving the efficiency of the health service without the need to build new infrastructure. In this regard, when establishing new districts, it is necessary to consider the specialties available at each health centre.

**4 - Robust batch scheduling for hospital sterilization under decision-dependent uncertainty**
*Sebastian Kraul*

Central sterile service departments are a recurring bottleneck in surgical workflow management. Steam sterilization cycles vary substantially due to equipment heterogeneity, load composition, and mandatory safety holds, yet existing scheduling models treat durations as deterministic. Schedules that look optimal in theory can therefore degrade severely in practice and compromise instrument availability. We formulate the sterilization stage as a parallel batch processing machine problem with incompatible job families and propose the first tractable robust model under decision-dependent uncertainty: scheduling decisions themselves shape exposure to disruption, because every additional batch adds a potential processing time extension. The bilevel arc flow model is solved to certified optimality via an exact LP dual embedding that exploits the knapsack structure of the adversarial subproblem. A case study on a large German hospital shows that moderate protection delivers substantial robustness at a 9 to 14 percent makespan cost, while 99.5 percent of robust schedules preserve the deterministic batch count. Protection is obtained by reallocating batches across autoclaves rather than by adding cycles, and a single unreliable autoclave is accommodated at under 2 percent makespan penalty. The analysis yields concrete guidance on parameter choice and on when replacing aging autoclaves is warranted.

# Tuesday, 9:00-10:30

## ■ TA-01

*Tuesday, 9:00-10:30 - Room: Emeleus Lecture Theatre*

### Emergency medical services

Stream: Presentations
*Contributed session*
Chair: *Geert-Jan Kommer*

**1 - Dynamic Ambulance Allocation During System Overload: Efficiency-Fairness Trade-offs**
*Brian Overbeek, Roberto Aringhieri, Pieter van den Berg, Caroline Jagtenberg, Rob van der Mei*

Ambulance management plays a crucial role in ensuring timely first aid during emergencies. Although ambulance management has been widely studied, almost all studies focus on regular operating conditions. Little is known about managing ambulances during system overload. However, several EMS systems face structural overload due to rising demand and resource constraints. Additionally, temporary periods of extreme demand can result in any EMS system being unable to handle incoming requests promptly.

We consider real-time ambulance planning under system overload, where demand exceeds fleet capacity and a queue of waiting patients accumulates. We address the joint problem of dispatching newly available ambulances and allocating incoming calls. We explicitly include the possibility of diverting ambulances already en route to patients.

We formulate the problem as a Markov Decision Process to maximize the number of patients served. Since the uncountably large state space precludes an exact solution, we develop heuristic policies and establish bounds to analyze their performance. However, maximizing throughput leads to geographic inequity, with service probabilities varying significantly across regions. We therefore analyze the efficiency-fairness trade-off, defining fairness as the uniformity of service probabilities across areas. This provides insights into sustaining performance while ensuring equitable service during system overload.

**2 - Information Design for Volunteer Emergency Response**
*Giulia Montagna, Pieter van den Berg, Caroline Jagtenberg, Rob van der Mei*

Community first responder systems expand the traditional emergency services with trained volunteers that can be dispatched through an app. Volunteers can accept or decline alerts to provide first aid at an emergency until professional services arrive. The decision whether to accept an incoming request depends on the expected impact that a volunteer has on the patient's health outcome and on their current activity. Usually, volunteers are only informed about their distance to the incident. This research investigates how providing more information to the volunteers could lead to improved patient outcomes given that sharing certain information increases or decreases the probability of acceptance. With this work we aim to show that the performance of a CFR system can be improved by redesigning the information contained in the notification sent to the volunteers. What information is shared in the notification the volunteers receive is decided beforehand by the system. We use computer simulations to compare the performance of different information sharing policies. This will give an indication if sharing more, or less, information can lead to the most valuable volunteer accepting, and as such improve patient outcomes.

**3 - Reducing Emergency Medical Helicopter Cancellations: A Data-Driven Survival Modelling Approach**
*Nina Baumgartner, Derya Demirtas, Richard Boucherie*

Helicopter Emergency Medical Services (HEMS) can improve medical outcomes for the most critically injured patients. However, time-sensitive triage leads to high cancellation rates, where dispatched helicopters provide no patient assistance. These cancellations strain highly scarce resources and reduce availability for patients who truly need HEMS.

We present a data-driven framework to balance cancellation risk with patient outcomes by strategically postponing helicopter departure based on dispatch characteristics. We model cancellation probability over time using a proportional hazards model and assess how short take-off delays can reduce this risk. Additionally, we provide a method for estimating the impact of delayed departure on patient outcomes.

In a case study, we applied our framework to dispatch data from a Dutch HEMS. We evaluated postponing take-off for a specific patient group, using expert estimates of morbidity risk as a function of response time, developed with HEMS physicians. We identified postponement durations that yield Pareto-optimal trade-offs between cancellation risk and patient morbidity. The approach also revealed dispatch characteristics in Dutch HEMS operations, where short postponements sharply reduce cancellations with minimal impact on morbidity.

Applicable across various HEMS systems, this framework lays the groundwork for more intelligent, data-driven HEMS operations, enhancing operational efficiency while conserving scarce resources.

**4 - Modelling the demand for EMS workforce in the Netherlands**
*Geert-Jan Kommer*

This study quantifies current and future demand for professionals in emergency medical services (EMS) including ambulance services, out-of-hours GP services, and hospital ED's by patient age, sex, and disease. The model enables projections based on demographic and epidemiological trends and allows scenario analysis of policy impacts on workforce demand. Data of the demand for EMS covered the period 2019-2023. Treatment time, the number of professionals, and nature of the medical emergency were estimated from registrations and surveys. Using these data, we estimated required labor hours by patients age, sex, and disease group and projected future workforce demand using population forecasts and cost trends. In 2026, we estimate 1.3 million EMS services in the Netherlands, requiring 1.9 million service hours and 10,600 eight-hour ambulance shifts. Ambulance teams consist of 3,100 drivers and 3,190 nurses. Of all services, 13% were accident-related, 12% involved heart diseases, and nearly 8% were related to stroke. Updated workforce demand estimates for EMS will be available before summer 2026. The workforce model offers a tool to assess future healthcare professional demand and explore the effects of various policy scenarios such as lifestyle interventions, new technologies, or alternative care pathways on EMS and GP workforce needs. This approach supports planning for policy impacts on disease-specific workforce demand in the Dutch healthcare system.

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## ■ TA-02

*Tuesday, 9:00-10:30 - Room: Bell Lecture Theatre*

### Operating room planning

Stream: Presentations
*Contributed session*
Chair: *Roberto Aringhieri*

**1 - Operating room scheduling with fairness over time and proper training**
*Alice Daldossi, Alessandro Druetto, Roberto Aringhieri*

Surgical departments must coordinate patient priorities, operating room (OR) capacity, and staff availability. In academic hospitals, this complexity increases due to the need to ensure equitable resident training while maintaining timely patient care. Residents follow structured multi-year training pathways, making balanced exposure to procedures essential. Achieving this balance is critical for effective OR management.

We address a surgical scheduling problem that explicitly integrates trainee assignment into OR timetabling, with the dual objective of promoting fairness in training opportunities and improving resource utilization. Starting from a baseline Mixed-Integer Linear Programming (MILP) formulation capturing the core scheduling constraints, we progressively refine the model by incorporating increasingly rich fairness criteria to better represent training requirements.

To cope with the computational burden of solving these enhanced models on sequences of real-world instances, we develop a matheuristic algorithm.

The approach is validated using data from the Vascular Surgery Unit of the Città della Salute e della Scienza Hospital (Molinette), Turin, collected between 2018 and 2025.

**2 - Demand-Side Flexibility Design for Operating Room Efficiency**
*Chao Pan*

Operating room (OR) capacity planning must balance timely access for emergency surgeries with efficient use of limited surgical capacity. In practice, this is difficult because emergency demand is highly uncertain, while elective patients differ in how much scheduling flexibility they can accept. We address this challenge by proposing a patient-centered OR planning approach that introduces a flexible elective category: eligible patients can choose between a fixed surgery date and a flexible date window. This creates a buffer that helps hospitals respond to emergency demand while making better use of otherwise idle OR time. Using a design science research approach, we combine interviews, workshops, surgical-log data, modelling, simulation, and practitioner evaluation across two hospital settings. The results show that even modest levels of elective flexibility can improve OR performance. In the studied settings, allowing about 10-20% of elective surgeries to be scheduled flexibly increased OR utilization and reduced overtime risk, while maintaining responsiveness to emergency cases. For operations management, the findings show how limited demand-side flexibility can be designed as a practical buffer to improve capacity utilization under uncertainty in healthcare services.

**3 - Collaborative Surgery; A Promising Approach for Complex Procedures?**
*Navid Izady*

Collaborative surgery, in which two or more senior surgeons jointly perform complex, lengthy procedures, is becoming increasingly prevalent. Although medical studies report reductions in operative duration, operating costs, and re-operation rates, the effect on patient waiting times remains largely unexplored. We address this gap by modelling the joint cost of patient waiting and operative delivery. We compare non-collaborative un-pooled provision with configurations that combine queue pooling and collaborative teams of different sizes under individual and batch referrals. The analysis incorporates less-than-additive speed gains, collaboration-induced changes in re-operation rates, and arrival and service-time variability. We derive analytical cost comparisons and approximations, and identify conditions under which different pooling-collaboration designs are preferred. We also study stable-team preservation, showing that small preservation frequencies can be locally suboptimal when matching delay enters at first order, while heavier traffic can justify greater preservation. Calibrated breast-microsurgery and spine examples show that full collaboration is attractive mainly at moderate loads, low arrival variability, or low waiting costs; in larger portfolios, queue pooling with paired teams can dominate separation. The results support decisions on whether, and how far, to combine queue pooling with collaborative surgery.

**4 - Robust Operating Room Scheduling with Cancellations**
*Amir Ardestani-Jaafari, Amin Ahmadi Digehsara, Vahid Roshanaei, Bahman Naderi*

Canceling or delaying time-sensitive elective surgeries often necessitates subsequent costly interventions. In this talk, we first discuss key clinical considerations underlying elective surgery cancellation decisions, including uncertainty in surgical durations, the use of overtime, surgery sequencing, and the modeling of uncertainty. Within the context of operating room (OR) block scheduling, we demonstrate that (i) sequencing surgeries within an OR is an indispensable component of optimal cancellation decisions, and neglecting it leads to a systematic underestimation of cancellation costs; (ii) uncertainty in surgical durations can be modeled using robust optimization techniques; and (iii) there exists a critical trade-off between the costs of surgery cancellations and overtime. Finally, we develop an exact solution approach and apply it to a real-world case study.

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# ■ TA-03

*Tuesday, 9:00-10:30 - Room: MAPTC OG/017*

## Forecasting and statistical modelling in healthcare

Stream: Presentations
*Contributed session*
Chair: *Thomas Philip Runarsson*

**1 - Forecasting Demand for Hospital at Home Services Using Probabilistic Modelling Approaches**
*Holly Merelie, Bárbara Morais, Inês Marques, Daniel Santos, Ana Barbosa-Povoa*

Hospital at Home (HaH) services are increasingly adopted as an alternative to inpatient care, delivering hospital-level care in patients' homes. While evidence highlights significant benefits, their implementation introduces important challenges for long-term planning, particularly due to demand uncertainty and the complexity of service delivery. Despite the growing relevance of HaH, existing Operations Research literature focuses on tactical and operational problems, with limited attention given to strategic-level decisions. This research focuses on the development of probabilistic models to forecast demand for HaH services under uncertainty. Given the limited availability of structured data and the complexity of patient pathways, state-transition approaches such as Markov models are explored to represent the progression of patients through different stages and estimate HaH admission probabilities. The model incorporates key demand drivers, including demographic characteristics, eligibility criteria and healthcare system factors, including referral pathways. Monte Carlo simulation is used to account for parameter uncertainty and generate demand projections under different assumptions. The proposed approach aims to provide a structured basis for anticipating future demand and supporting strategic planning decisions. The research is being developed in the context of the Portuguese healthcare system and intends to support future integration with capacity planning models.

**2 - The association of functional capability and mental state with cancer screening participation among older adults in England**
*Ka Keat Lim, Rishi Hazarika*

Objective: To examine whether baseline and recent change in functional capability and depressive symptoms were independently associated with participation in bowel, breast and prostate screening in England.

Methods: We used data from English Longitudinal Study of Ageing Waves 9-11. Functional capability was measured with Instrumental Activities of Daily Living (IADL) and Activities of Daily Living (ADL) and depressive symptoms with the Centre for Epidemiologic Studies Depression Scale (CESD), using values at W9 as "baseline" and the difference between W9-10 as "recent change". Participation in bowel, breast and prostate screening at W11 was self-reported. We ran three logistic regressions: (1a) IADL and ADL only (1b) CES-D only; (2a) IADL and ADL with baseline covariates and (2b) CES-D with baseline covariates; and (3) IADL, ADL and CES-D with baseline covariates.

Results: In regression model (3), greater baseline IADL limitation (OR 0.65, 95%CI 0.46-0.91) and worsening IADL (OR 0.73, 95%CI 0.58-0.93) were associated with lower bowel screening participation among those aged 50-75, but not when the samples were limited to those aged

60-75. IADL had no association with breast or prostate screening participation. ADL and CESD had no association with all screening.

Conclusion: IADL limitations may hinder participation in bowel screening which relies on self-collection of stool sample. Interventions aiming to reduce task burden may improve screening participation.

**3 - Embedding survival-based length-of-stay prediction within hybrid discrete-event simulation: application to hip fracture pathways**
*Alison Harper, Thomas Monks, Navonil Mustafee*

This study presents a hybrid modelling framework that embeds survival-based length-of-stay (LoS) prediction within a discrete-event simulation (DES) of hip fracture pathways. Hip fracture services place pressure on hospital bed capacity, with outcomes and resource use strongly influenced by time-to-surgery and patient heterogeneity. Traditionally, DES represents LoS as independent, static distributions, overlooking dependencies between pathway stages, patient characteristics, and outcomes. In hip fracture care, delays accumulate and interact: post-operative LoS depends on time-to-surgery, requiring a pathway-aware modelling approach that integrates survival models directly within simulation. Using a retrospective cohort of 526 patients, discharge destination is modelled via a two-stage logistic regression, while pathway-specific parametric accelerated failure time models estimate post-operative LoS. These models are embedded within a DES representing trauma theatre scheduling and ward flow, where surgical delay is generated endogenously and passed to the survival models, allowing dynamics to propagate into LoS. Generative validation demonstrates close agreement between simulated and observed LoS distributions, while sensitivity analysis highlights how variation in patient characteristics and delays impacts bed occupancy. The framework provides a pragmatic, interpretable approach for improving representational fidelity in DES and supporting decision-making in healthcare.

**4 - Planned vs Actual Length of Stay: Understanding Bias in Hospital Discharge Forecasts**
*Thomas Philip Runarsson*

Hospitals routinely record planned discharge dates for patients, or equivalently their expected length of stay (LOS). These values are often used as inputs for operational planning. Despite their widespread use, the reliability and bias of these planned values remain poorly understood.

In this study, we analyse planned versus actual LOS using event data from the National Hospital of Iceland. Rather than focusing on improving prediction accuracy, we study the properties of planning error. Our findings show that planned LOS contains substantial predictive signal and consistently outperforms models based on routinely available variables such as age, admission urgency, and surgery type. This suggests that clinicians incorporate additional, partially unobserved information when forming expectations, which is not fully captured in hospital data.

However, planning errors exhibit systematic patterns and are influenced by update frequency and patient characteristics. We quantify how planned LOS deviates from actual LOS, investigate bias across patient groups and admission urgency, and examine how accuracy evolves over the course of a patient stay.

These results highlight that planned discharge dates should be interpreted as dynamic and imperfect forecasts. Understanding their bias and variability enables the construction of more realistic LOS distributions for simulation models, supporting improved patient flow management and more robust operational decision-support systems.

# Tuesday, 11:00-12:30

## ■ TB-01

*Tuesday, 11:00-12:30 - Room: Emeleus Lecture Theatre*

## Integrated planning (2)

Stream: Presentations
*Contributed session*
Chair: *Joe Viana*

**1 - Integrated Scheduling and Perishable Inventory for Chemotherapy Drug Preparation under Cancellation Uncertainty**
*Camille Pinçon, Nadia Lahrichi, Antoine Legrain*

The preparation of chemotherapy drugs in hospital pharmacies involves complex operational decisions due to patient-specific prescriptions, perishable materials, and frequent last-minute cancellations. Pharmacy managers must balance early preparation to avoid treatment delays against the risk of drug waste. Despite its importance, this problem has received limited attention, and existing approaches typically consider scheduling and inventory decisions separately.

We model the chemotherapy drug preparation problem as a two-stage stochastic program integrating parallel machine scheduling, batching decisions, and perishable inventory management. The formulation captures key operational features, including drug stability, vial reuse, technician availability, and patient cancellations. To address the resulting large-scale problem, we develop a solution approach based on a mixed-integer approximation and a reconstruction heuristic.

Computational experiments on real-world instances from a cancer center in Quebec show that the proposed method significantly reduces both tardiness and material costs compared to current practices. The results highlight the value of jointly optimizing batching and anticipation decisions under uncertainty.

**2 - Scaling up surgery capacity using an integrated surgery simulation model**
*Melanie Reuter-Oppermann, Michael O'Sullivan, Thomas Adams*

With the support of the Julius von Haast Fellowship by the Royal Society of New Zealand, we designed a conceptual model for a whole-hospital simulation model to analyse the benefit of integrated planning and be able to analyse patient pathways and processes along the hospital. In a workshop with practitioners in Auckland, New Zealand, we jointly designed a conceptual model for a surgery simulation component with the aim of scaling up surgery capacity and analysing the resulting effects on related departmnets and facilities. In this talk, we want to show and discuss the conceptual model and present priliminary results.

**3 - Optimizing patient flow from the emergency department through flexible ward assignment and early discharge**
*Johanna Leweke, Christina Büsing*

In an emergency department (ED), crowding arises when demand for emergency services exceeds available capacity and is associated with reduced quality of care. It is often caused by inpatient boarding, where admitted patients cannot be transferred from the ED to appropriate wards due to limited bed availability. In this talk, we focus on two operational strategies to reduce boarding: flexible ward assignment of emergency patients in a centralized bed management system and early discharge of inpatients during demand peaks. Both problems extend the patient-to-room assignment problem in which patients are allocated to hospital rooms under capacity and gender constraints. First, we present new combinatorial insights, analyze the complexity, and develop exact algorithms. These insights help to design better algorithms and provide practical guidance for case management. Second, we conduct a computational study based on realistic data to evaluate the impact of flexible ward assignment on boarding and to measure the need for early discharges.

**4 - A tactical level integrated planning simulation model to improve patient flow for elderly patients with frailty**
*Joe Viana, Anders N. Gullhav, Heidi Dreyer, Marte Holmemo, Aud U Obstefelder, Øystein Døhl, Ingebrigt Meisingset*

The healthcare sector faces rising demands from aging populations and workforce shortages, requiring innovative solutions for service coordination. In response, Trondheim municipality and St. Olavs hospital are developing integrated planning tools within the Research Council of Norway funded HARMONI project. This initiative aims to bridge the gap between service demand and capacity through tools that offer a systems-wide overview of patient flows. We present an early iteration of a tactical level integrated planning hybrid simulation model—functioning as a digital twin of the patient journey—that spans key primary and specialist care providers. This includes the municipal Health and Welfare Office, which evaluates eligibility and allocates primary care capacity. We evaluate "What-if" scenarios derived from ongoing workshops with stakeholders to test policy interventions. The model tracks strategic, tactical, and operational metrics—including bed occupancy, resource utilization, volume of discharge-ready patients, and throughput. By integrating data across the care continuum, the model provides a comprehensive decision support tool to improve the transition of frail elderly patients between hospital and community care.

# ■ TB-02

*Tuesday, 11:00-12:30 - Room: Bell Lecture Theatre*

## Surgery scheduling

Stream: Presentations
*Contributed session*
Chair: *Guillaume Lamé*

**1 - A data-driven implementor-adversary framework for robust elective surgical advance scheduling**
*Martina Doneda, Gabriele Gabrielli, Giuliana Carello*

Operating theater (OT) management is one of the most extensively studied subjects in operations research applied to healthcare services, with elective surgery advance scheduling (assigning routine procedures to specific dates and OTs) standing out as an especially central problem. Indeed, this decision plays an important role in shaping the rhythm of daily OT operations, yet it remains poorly handled in practice. Because of the non-deterministic nature of surgery times, routine schedules frequently result in overtime, worsening working conditions and, over time, driving staff burnout. This work addresses a robust version of this problem via a data-driven approach, with the goal of keeping overtime under control while maintaining an high level of throughput. We develop a method generating robust solutions that adapt to data variability across different robustness profiles. The approach uses an implementor/adversary framework: an implementor produces a solution for known parameters, while an adversary introduces solution-violating realizations that are passed back to the implementor. A probabilistic regression model trained on historical data generates realistic surgery time distributions, offering full flexibility to the adversary in defining the uncertainty set. This is iterated until the adversary can no longer violate the solution, which is deemed robust. Computational tests on realistic data show satisfactory solution quality and computational efficiency

**2 - Surgery scheduling under joint uncertainty: Controlling the number of overtime events**
*Frank de Meijer, Theresia van Essen*

Surgery scheduling in hospitals is a complex decision-making problem in which patients must be assigned to operating rooms and time slots under limited resources. A key complicating factor is the high uncertainty in surgery durations. Existing approaches address this uncertainty at a local level by considering the risk that a single operating room incurs overtime on a given day. Although a single overtime event can often be managed by surgical staff, the primary challenge arises when multiple operating rooms incur overtime simultaneously. We study the operational surgery scheduling problem under joint uncertainty by incorporating the probability that more than a specified number of operating rooms incur overtime simultaneously. We propose two approaches: a stochastic approach and a distributionally robust approach. The stochastic approach accounts for the underlying Poisson-binomial distribution using tractable approximations. The distributionally robust approach yields a two-stage problem with integer recourse, which we solve using a constraint-and-column generation algorithm. We evaluate both models using a real-world dataset from a large academic hospital.

**3 - Risk-Aware Surgical Episode Scheduling in Single-Entry Networks**
*Maryam Daryalal, Pedram Peiroasfia, Vahid Roshanaei*

We develop a Risk-Aware Surgical Episode Scheduling in Single-Entry Networks (RA-SENSE) framework for elective same-day surgeries across collaborating hospitals in the University Health Network (UHN) in Toronto. The framework centralizes intake and coordinates hospital capacity to improve access and efficiency under uncertainty. We formulate the problem using stochastic mixed-integer programming (MIP) and constraint programming (CP) to capture the many linked resources involved before, during, and after surgery. To control system-wide completion times of surgical episodes, we incorporate coherent risk measures in the objective function, such as the risk-averse Conditional Value-at-Risk (CVaR). To solve this large-scale problem, we develop logic-based Benders decomposition methods that integrate MIP and CP in two- and three-level frameworks, strengthened with problem-specific cuts, valid inequalities, and a graph-based timing reformulation. Our results show that the decomposition design matters more than the solver alone. Multi-level decomposition improves scalability, with the three-level approach giving the most reliable performance. We also find that uncertainty in operating rooms can spread and intensify downstream, causing congestion that OR-focused models might miss. This shows the importance of risk-aware network-level scheduling, especially in publicly funded healthcare systems where capacity, efficiency, and equitable access must be balanced.

**4 - Coordinating and rescheduling in the surgical suite on the day of surgery: a qualitative study**
*Anem Dupré, Oualid Jouini, Guillaume Lamé*

On the day of surgery, the planning of patient flows and the management of resources crucially mediate patient safety, workers' quality of work and cost-effectiveness. Yet current practices in the domain remain poorly documented. Understanding scheduling work "as done" is useful both to improve practice, but also for the design of decision-support tools, including powered by OR algorithms. We describe how the surgical suite is managed in real time through allocation of operating rooms, staff and equipment for both scheduled and emergency procedures. We conducted semi-structured interviews with 46 healthcare professionals to investigate current practices across 13 surgical suites. Participants reported numerous and dynamic logistical and medical constraints, handled and integrated through two parallel activities: coordination and rescheduling. A great deal of work consisted in information recovery and negotiation. In some surgical suites, these activities were the purview of dedicated staff, usually a nurse and/or an anaesthesiologist, whereas in others, a decentralised approach was adopted, relying on individual surgical teams. Differences in control configurations were associated with different challenges for example related to the status, workload, and authority of the implicated staff. These findings suggest system redesigns or interventions, when related to the decision-making system and its outcomes, should consider each individual context in its complexity.

# ■ TB-03

*Tuesday, 11:00-12:30 - Room: MAPTC OG/017*

## Healthcare policy modelling

Stream: Presentations
*Contributed session*
Chair: *Felipe Rodrigues*

**1 - Statistical literacy of clinicians - a scoping review**
*Irene Abi-Zeid, Anaïs Pellerin*

Statistical literacy of clinicians, namely the ability to understand, interpret, and communicate data in a clinical context, is essential for making evidence-based decisions, correctly interpreting medical literature and implementing appropriate patient-centered care. However, numerous studies suggest that healthcare professionals struggle to understand and utilize medical statistics. Given the fragmented nature of the existing literature, a comprehensive synthesis was lacking. We therefore conducted a scoping review where the objective was to map current knowledge regarding the statistical literacy of clinicians. In this talk, we present our results, based on 45 studies (1978-2025), organized into five analytical domains: basic numeracy, diagnostic reasoning, therapeutic effect measures, population screening, and critical appraisal. The findings reveal persistent gaps, including deficient Bayesian reasoning (3-49% accuracy for Positive Predictive Value), vulnerability to framing effects, and a lack of knowledge regarding screening statistics. These results highlight the urgent need to reform medical training and standardize assessment tools, ensuring clinicians can apply critical thinking as AI becomes more integrated into practice.

**2 - Investigating alcohol consumption and its consequences using systems modelling**
*Elin Williams, Daniel Gartner, Paul Harper, Geraint Palmer*

Alcohol consumption and its consequent harms are globally recognised public health concerns that transcend traditional sectoral boundaries, involving healthcare, social care and criminal justice sectors. Evidence suggests that harms have increased following the COVID-19 pandemic. Together, these three sectors form interconnected components of the 'alcohol system'. Nevertheless, they are scarcely modelled in combination. This talk presents the process of developing a systems model of the 'alcohol system'. Initially, a Causal Loop Diagram (CLD) is constructed to provide a qualitative visualisation of the alcohol system and to identify structural patterns influencing alcohol consumption. CLDs in the literature serve as the starting point, whilst stakeholder engagement helps refine existing CLDs, elicit further key variables, and define connections between variables. Following construction and validation of the qualitative model, the CLD is translated into a quantitative stock and flow system dynamics model. Regional data from Gwent, South-East Wales, is used to parameterise the model, and initial findings are presented. The model will be used as a tool for exploring the potential impact of intervention and prevention strategies to support resource planning, and inform policy decisions aimed at reducing alcohol-related harm. Modelling from a systems perspective can provide a more comprehensive understanding of the demand and harms resulting from alcohol consumption.

**3 - Midwifery-led birth centres in France: practices and outcomes from AUDIPOG (Association for a perinatal information system) nationwide database**
*Catherine Crenn-Hebert, Olivier Riviere, Françoise Vendittelli, France Artzner*

WHO published in 2024 the paper Transitioning to midwifery models of care. After guidelines from French authority for health issued in 2017, experimental study and national assessment in 2018-2019, midwife-led birth centres (MLBCs) are allowed in France since 2021. To retain their operating license, each centre provides annual reporting of maternal and neonatal outcomes with description of risk factors and antenatal, perpartum, neonatal transfers for women who planned birth in their centre. 445 maternities and 9 MLBCs were working in 2024. The aim now is to allow each MLBC to compare their practices and outcomes indicators with published national ones. Method: The analysis are undertaken by AUDIPOG statistician, since 2018, then returned to each midwife-led birth centre, from input structured data of the legal annual report. Results: 8 MLBCs sent data in 2024. 1049 pregnant women contacted them, 1014 were eligible and 602 births occurred in these centres. 75 indicators are analyzed and presented as dashboard example with a focus on birth practices for benchmarking. Discussion-Conclusion: AUDIPOG created national maternities sentinel network in 1994 with objectives of perinatal health indicators monitoring. This second AUDIPOG data base keeps on assessing quality and safety of perinatal care as well for women who plan birth in midwife-led birth centres, which is more recent in France. It is necessary because MLBCs don't produce routine data as maternity discharge summary.

**4 - Extensions to Optimal contract policies for improving access to child and youth public funding: the case of the Ontario Autism Program**
*Felipe Rodrigues*

This extends a queueing-game framework for designing contract policies in publicly funded child and youth intervention programs. Based on our previous work, we explore a few main extensions. First, we incorporate parallel assessment capacity via analytical bounds and discrete-event simulation of multi-server settings. Second, we introduce age-dependent utility functions. Third, we calibrate the model using data made available via the Freedom of Information and Protection of Privacy Act of Ontario. Families choose between exclusive reliance on public funding and partial private service uptake while remaining in the queue, while now the funding authority jointly optimizes service capacity and rebate mechanisms. Numerical experiments and simulations illustrate how contract parameters influence waiting times, equity of access, and social welfare across policy regimes. Results provide important insights to policymakers and demonstrate the applicability of queueing-contract models to publicly funded health and social service programs beyond autism services.

# Tuesday, 13:30-14:30

## ■ TC-01

*Tuesday, 13:30-14:30 - Room: Emeleus Lecture Theatre*

### Plenary Professor Christine Currie

Stream: Plenary sessions
*Invited session*
Chair: *Laura Boyle*

**1 - Grand Challenges in Healthcare Simulation**
*Christine Currie*

Looking ahead over the next ten years, the keynote will explore the likely directions for research in healthcare simulation coming up with a set of grand challenges for the community. We will discuss seven themes that seem likely to have a significant impact: digital twins and real time simulation, open science for simulation, validation, improving the integration of the health system, decision support, human behaviour, and finally equity and health inequality. Drawing on earlier work in these areas and trends in healthcare delivery, the talk will provide a viewpoint of where best to focus research over the next decade.

# Tuesday, 14:30-15:00

## ■ TD-01

*Tuesday, 14:30-15:00 - Room: Emeleus Lecture Theatre*

### Poster pitches

Stream: Plenary sessions
*Invited session*
Chair: *Laura Boyle*

# Tuesday, 15:00-16:30

## ■ TE-01

*Tuesday, 15:00-16:30 - Room: Emeleus Lecture Theatre*

### Posters

Stream: Posters
*Contributed session*
Chair: *Melanie Reuter-Oppermann*

**1 - A Comparison of Neural Network and Classical Linearization Techniques for Overtime Constraints in MILP-Based Surgical Scheduling**
*Cindy Pistorius, Theresia van Essen*

Uncertainty in surgery durations continues to be difficult to account for in operating room scheduling. In particular, it remains complex to accurately incorporate uncertainty in surgical overtime constraints within mixed-integer linear programming (MILP) models. Therefore, we propose a method that integrates feedforward neural networks (FNNs) into MILP models to approximate the total surgery duration in these overtime constraints. The proposed approach is evaluated using real-life hospital data and compared against two classical approaches: scenario-based modelling and piecewise linear function approximations. We demonstrate that with a relatively small FNN, we achieve competitive operating room schedules in terms of both solution quality and computational performance. The FNN-based approach is the most computationally efficient with an optimality gap lower than 2% in all cases, achieves the highest operating room utilization in six out of eight considered cases, and on average produces simulated overtime probabilities closest to the predefined target.

**2 - Optimization Models and Decision Support Tools for Staff Shift Planning in Home Hospitalization Services**
*Blessing Ikechukwu, Inês Marques, Daniel Santos*

Home Hospitalization also known as Hospital at Home (HaH) is a model of healthcare in which patients receive acute care at home, thereby reducing length of stay and readmission rates at the hospital. HaH models have increasingly been adopted by healthcare systems as a means of improving patient outcomes, reducing hospital congestion, and optimizing the use of healthcare resources. However, it introduces complex operational challenges, particularly in planning and scheduling of healthcare professionals. Demand is uncertain, and staff resources may be shared between HaH units and other hospital departments. This research aims to develop optimization models and decision support tools to support tactical staff shift planning in HaH services. The objectives are to: Develop a conceptual framework for staff shift planning in HaH units; engage with healthcare stakeholders to identify relevant policies, constraints, and performance priorities for staff scheduling; incorporate uncertainty in demand and patient distribution; and design efficient algorithms to solve the proposed models. The expected outcomes include: Novel optimization models tailored to the specific context of HaH; methodological contributions integrating shared workforce and stakeholder-informed constraints; efficient algorithms capable of handling multi-objective and large-scale staff scheduling problems; decision support tools that can be adapted to different HaH contexts and healthcare organizations.

**3 - Forecasting health protection operational workload in Northern Ireland: a digital pipeline using negative binomial generalised additive models**
*Sarah Arnold*

The health protection team in the Public Health Agency Northern Ireland responds to cases, outbreaks and enquiries relating to infectious diseases and public health hazards. Short-term forecasting of operational workload would support staff and resource planning. The COVID-19 pandemic caused significant disruptions to historical patterns, complicating model development. Negative binomial generalised additive models (GAMs) were fitted for four response streams (cases, contacts enquiries and situations) using routinely collected HP Zone data, incorporating trend splines, cyclic seasonality, day-of-week effects, bank holiday indicators and autoregressive lag terms. Training windows were selected empirically using rolling origin cross-validation. Models were validated on holdout data across pre-COVID, COVID and post-COVID periods. Residual diagnostics confirmed distributional assumptions were met. The pipeline was built in R and Quatro and deployed via Posit Connect, producing automated 14-day forecasts with 80% prediction intervals. The cases model explained 75.8% of deviance while the enquiries model explained 81%. This work demonstrates the feasibility of embedding automated short-term forecasting into routine operational planning for public health services.

**4 - Statistical Modelling of Ambulance Fleets and Emergency Calls in Belfast, Northern Ireland.**
*Nathan Maguire, Laura Boyle, Hannah Mitchell*

Emergency ambulance services play a vital role in healthcare by providing rapid assistance to people in urgent need. A key objective is to reach patients quickly while using limited resources efficiently. This is especially challenging in urban areas, where high call volumes, uneven demand, and complex road networks affect ambulance movement and availability. In the United Kingdom, ambulance service within the National Health Service have experienced steadily rising demand. Many emergency calls result in ambulance dispatch and hospital transport, though this is not always the most appropriate response. Unnecessary dispatches can reduce efficiency and increase risks for patients, ambulance staff, and the public. When ambulances are assigned to non-critical incidents, fewer are available for serious emergencies, which lead to longer response times. Reducing these delays is essential, as faster treatment often improves patient outcomes. This research explores how ambulance service data can be analysed using simulation techniques and spatial modelling. These approaches help represent ambulance workflows and system constraints while allowing different operational scenarios to be tested realistically. By examining how demand changes over time and across locations, the study identifies ways to improve efficiency without compromising response times. Overall, it demonstrates how combining simulation with spatial analysis can support better planning and decision-making for ambulance.

**5 - Does the patient really want to come to the hospital? Quantifying and optimizing time savings from patient preference-informed pre-assessment**
*Jan-Willem de Jong, Jedidja Lok - Visser, Joan Doornebal, Joris van Dijk, Gréanne Leeftink*

Outpatient clinics (OCs) face increasing patient demand and provider shortages. Remote patient monitoring strategies, including pre-assessment based on patient health data, is increasingly used to improve care delivery. However, patient preferences are rarely incorporated.

Our goal is to quantify and optimize the potential time savings from pre-assessment and estimate the added value of incorporating patient preference into this framework. Using retrospective Dutch nephrology OC data, we compare a dynamic pre-assessment scheduling approach incorporating uncertainty in patient preferences with a static scheduling policy. We estimate annual appointment time per patient under both approaches and use these as input for a stochastic programming model.

To derive an optimal capacity allocation policy under patient appointment request uncertainty from pre-assessment outcomes, we develop a stochastic programming model solved with Sample Average Approximation. We evaluate scheduling performance with and without patient preference information, as well as a baseline scenario without pre-assessment, thereby quantifying the added value of incorporating patient preferences in both demand estimation and scheduling.

Our results show that value-driven scheduling reduces the annual appointment time per patient by at least 18%. Incorporating patient preferences better aligns care delivery with actual patient needs and enhances patient-centeredness in outpatient scheduling.

**6 - Evaluating air-based rapid responders in emergency medical services using hybrid simulation**
*Lieke Jansen, Durk-Jouke van der Zee, Iris F.A. Vis*

Emergency Medical Services (EMS) in rural regions often struggle to meet response time targets due to long travel distances and limited resource availability. Emerging electric Vertical Take-Off and Landing (eVTOL) aircraft offer an opportunity to complement ambulances by serving as rapid responders, but assessing their operational effects requires systematic evaluation over time as both the technology and associated planning questions evolve. We present a hybrid discrete event and agent-based simulation architecture designed to support extension and adaptation across multi-modal EMS planning questions involving both ambulances and eVTOLs. The architecture captures dispatching interactions, battery constraints, and the dependency on ambulances for patient transport while separating structural and configurable model components. A case study for the Dutch province of Friesland demonstrates how the architecture enables systematic comparison of fleet configurations and operational policies and illustrates the potential of eVTOL rapid responders to improve EMS response time performance in rural settings.

**7 - Development and adaptation and of a system dynamics model to project the burden of chronic kidney disease in England**
*Ka Keat Lim, Steffen Bayer*

Background: Chronic kidney disease (CKD) poses significant burden for England which has seen rising CKD prevalence in recent years. This study aims to project the burden of CKD in England using a system dynamics model, which can be used to explore the potential impact of policy interventions in the future.

Methods: We adapted the published system dynamics model by Ansah et al 2021, which examined policy interventions on CKD burden in Singapore. We are currently replacing the epidemiology parameters with those from England. Other planned adaptations include (1) adding an explicit stock for transplant which flows from dialysis to better reflect the higher transplant rates in the UK, (2) estimating the total cost of CKD, rather than the cost of dialysis only. The adapted model will then be validated and if necessary, calibrated against the number of patients with CKD and those requiring dialysis 2010 to 2023 published by Health Survey for England and UK Renal Registry.

Results: Upon validation of the model against past trends, we will project the number of CKD, number requiring dialysis, and total cost of CKD from 2024 to 2033. We will also compare the projections of CKD clinical and economic burden against those published earlier using other methods.

Conclusion: The model will be helpful for researchers and policy makers to explore the potential impact of policy interventions on CKD burden, before any implementation.

**8 - A Data-Driven Digital Twin Framework for Adaptive Short-Term Forecasting in Emergency Departments**
*Nirmani Amarasinghe, Laura Boyle, Adele H Marshall*

Short-term forecasting of Emergency Department (ED) is important for operational decision-making. However, traditional Discrete Event Simulation (DES) models often use static inputs, which limits their ability to respond to changing system conditions. This study presents a data-driven Digital Twin (DT) framework that improves DES by introducing adaptive parameter updates and system-state feedback. The proposed method uses historical data windows for individual components to dynamically estimate patient arrivals, length of stay and capacity, allowing each process to reflect its own time based pattern. In addition, a feedback mechanism adjusts patient discharge times based on real-time occupancy levels, helping the model capture crowding and bottleneck effects.

The framework is evaluated using real ED data across multiple 12-hour forecasting scenarios with repeated simulation runs. Results show that the DT approach improves prediction accuracy compared to a baseline DES model. It performs better at capturing changes over time and system behavior. The results also show that combining data-driven updates with feedback makes the model more responsive and realistic. This study provides a practical method for using adaptive DTs in short-term healthcare forecasting and operational decision-making.

**9 - Preference-Based Allocation Simulation Model for Long-Term Care**
*Weiyi Liu, Alexander Rutherford, Saad Ahmed, Krisztina Vasarhelyi*

Aging populations are a serious global issue, and a major contributor to the increased demand for long-term care (LTC) facilities. Many elderly patients who require LTC end up admitted to hospital due to a lack of other care options, and hence occupy acute care capacity. Enhancing the admission process to provide more choice to different levels of care could improve access to LTC beds, as well as improve flow out of acute care. We develop a queueing model to support healthcare policy makers in achieving this goal. To improve the waiting time for LTC, we integrate an allocation method into the queueing model to assign clients to LTC homes based on their needs. Clients can rank their preferred LTC facilities. The ranking scores and waiting times are used to derive utility functions for access priority. This approach strengthens wait list management and reduces mismatch between clients and LTC homes. Hence, it reduces exchanging LTC beds and can improve the living experience of clients. We also implement this queueing model as a simulation model to replicate the admission process for LTC facilities. The simulation results show that there is a trade-off between receiving beds early and obtaining preferred LTC placements. Furthermore, our queueing discipline provides a mean waiting time that is lower than separate queues and higher than shared queues.

**10 - Reusable Frameworks for Process Mining in Hospitals**
*Aidan Dures, Steffen Zschaler*

Operational processes in hospitals are often complex and have potential to be changed for the better. Process mining provides a set of methods to improve understanding of such processes and provide evidence-backed steps towards their improvement. Currently, there is a lack of detailed re-usable frameworks for applying process mining to specific sets of hospital processes. The development of such frameworks, including re-usable methodologies and tools, could improve the accessibility, speed, and cost of implementing process mining projects, ultimately leading to process improvement. In my PhD project (2025-2029), I will complete process mining projects in collaboration with a local NHS hospital trust and build towards a framework for process mining a specific set of hospital processes. The framework will be evaluated by the usefulness and validity of its component methods and tools, using standard evaluation methodologies; and by peer and clinical review of the usefulness and validity of the framework in the context of existing process mining tools and methodologies.

**11 - The Impact of AI Scribe on Primary Care Workload**
*Kimia Ghobadi*

Primary care clinicians have historically spent nearly double the direct patient care time on electronic health record (EHR) documentation, contributing to clinician burnout and reducing the time available for urgent patient needs. Recently, LLM-based AI tools have been dispatched to primary care settings with the goal of reducing clinical burden and improving efficiency. This study aims to quantitatively investigate the impact of such AI medical scribe tools on clinics and clinician work hours across an eighteen-month period. Using a database of over 20,000 patient encounters, we investigate 23 primary care facilities, employing over 900 providers, around 300 of whom are active scribe users. The study contains a pre-/post-analysis on the AI scribe's impact on visit volumes, documentation hours, and EHR time across the US, with varied facility and provider backgrounds. We examine uptake patterns by facilities and clinicians, providing insights into the benefits and drawbacks of these emerging technologies.

# Thursday, 9:30-10:30

## ■ HA-01

*Thursday, 9:30-10:30 - Room: Emeleus Lecture Theatre*

### Plenary Dr Peter Cosgrove

Stream: Plenary sessions
*Invited session*
Chair: *Adele H Marshall*

**1 - Upstream: Designing the Inputs to Healthcare Operational Research**
*Peter Cosgrove*

For half a century this community has applied operational research to health services, and for much of the last decade it has examined the gap between its methods and their real-world impact. This talk points to one source of that gap upstream of the model itself: the clinical data-capture layer that produces every model's inputs. Routine data faithfully records constructs chosen for administrative and operational convenience — which are not always the constructs the analytic question needs. This is not poor data quality to be cleaned, but a substitution of one construct for another at the point of capture, and no amount of downstream sophistication reverses it. Drawing on paediatric emergency care, where the signal that triage compresses away can itself be measurably predictive of serious illness, I will argue that the capture instrument is not a fixed given but an operational-research object in its own right, open to value-of-information reasoning, to group model-building with clinicians, and to deliberate design. Which construct a system substitutes is local to that system; that one is substituted may be near-universal.

# Thursday, 11:00-12:30

## ■ HB-01

*Thursday, 11:00-12:30 - Room: Emeleus Lecture Theatre*

### Staffing and rostering (2)

Stream: Presentations
*Contributed session*
Chair: *Aina Goday*

**1 - Healthcare workers rostering with joint consideration of equity, preferences and flexibility**
*Guillaume Joubert, Yannick Kergosien, Pierre Desport*

The conception of tactical cyclic schedules for healthcare workers in hospitals is a complex task. These schedules must cover the daily needs for each shift worked, and comply with legal requirements defining e.g. several working hours limits and sufficient occurrences for off days and weekends. This problem, known in the literature as Nurse Rostering Problem (NRP), has been extensively studied for 60 years. Authors typically optimize the schedules considering healthcare worker preferences or workload balancing to improve their well-being at work. In the context of French hospitals, only a limited set of cyclic schedules can be assigned to healthcare workers, preventing from full personalization. Although, weeks to days before operations, healthcare workers usually ask to switch some of their shifts between each other. In the context of OptiHSoins project from French Research Agency, we investigate a variant of the NRP that jointly integrates equity constraints among cyclic schedules per contract, maximization of the preferences, and flexibility of the planning by allowing shifts exchanges among healthcare workers. We present a MILP for this problem that lexicographically optimizes overstaffing smoothing, healthcare workers preferences, and planning flexibility to increase further their satisfaction. To solve harder instances more efficiently, we decompose the problem and solve it using Branch-and-Price, where columns represent individual cyclic schedules to be assigned.

**2 - Evaluating staffing recommendations for midwives in French maternities: from observation to simulation**
*Louis Niffoi, Oualid Jouini, Marija Jankovic, Pierre-François Ceccaldi, Guillaume Lamé*

Midwifery staffing in French birthing areas is governed by the 1998 perinatal decree and recommendations from experts. Both frameworks implicitly assume that midwives are fully available for direct patient care, and consider the annual number of births as the only indicator. To test this assumption, we conducted a 308-hour workflow time-and-motion study across three maternities, observing 21 midwives during full 12-hour shifts with the WOMBAT software. Direct patient care accounted for only 28% of working time. Administrative tasks, communication, and interruptions absorbed much of the shift. These findings grounded the availability parameter of our simulation model. We then built a discrete-event simulation (Simul8) of patient flow in a level 2b maternity performing 3,500 deliveries per year, calibrated on 10,401 birth episodes (2020-2023) and 2,312 room-occupation records. Inter-arrival times and activity durations were fitted with distributions across four time-of-day windows. Seven staffing configurations were crossed with five availability levels, yielding 35 scenarios evaluated through the patients-per-midwife ratio. Results show diminishing returns beyond 3.5 midwives and confirm that availability has as much impact as headcount. Hiring alone cannot guarantee continuous support: staffing policies must integrate availability, clarify midwives' tasks and reduce their non-clinical workload if they want to ensure direct care to the patients.

**3 - A MILP Model for Radiologist Rostering in a Hospital**
*Francisco Parreño, Ramon Alvarez-Valdes, Consuelo Parreño-Torres, Miguel Reula Martín*

One of the main challenges faced by hospitals, particularly in radiology departments, is the assignment of shifts and on-call duties to radiologists while considering multiple operational and staff-related requirements. These include staff suitability, time preferences, reduced working hours, and constraints arising from night shifts, among others. It is also essential to account for the specific characteristics of each service and the priorities for service opening, while ensuring an efficient and balanced allocation of work.

This study proposes a mixed-integer linear programming model (MILP) for radiologist rostering. The model aims to maximize staff satisfaction, open as many services as possible according to a predefined priority order, and balance the workload among radiologists. The proposed approach is implemented through a user-friendly tool based on Excel and SolverStudio, which facilitates data input, model execution, and the analysis of results by hospital managers. We describe the project experience, from data specification and problem modelling to the adjustments required during the validation phase, showing how the approach can support improved schedule management and better working conditions in the hospital environment.

**4 - An Optimization-Based Decision Support Tool for Physician Rostering: A Case from a Norwegian NICU**
*Aina Goday, Simen T. Vadseth, Thomas Bovim*

In Norwegian hospitals, physician rosters are typically created manually. This is a time-consuming and complex task that requires balancing regulations, preferences, contract percentages, competencies, service coverage and fairness. The Neonatal Intensive Care Unit (NICU) at St. Olavs Hospital therefore wanted a tool to automate the rostering of physicians.

We developed an optimization-based decision support tool with a user-friendly interface that generates rosters by assigning on-site call shifts, days off and daily activities. The underlying model is a mixed-integer program (MIP) that minimizes planned overtime while ensuring compliance with staffing requirements and work-time regulations. Model development followed an iterative process in close dialogue with the lead physician and HR to capture context-specific requirements.

The tool is operational and generates complete rosters within minutes. Initial results are promising, but further fine-tuning is needed before the rosters fully meet the NICU's expectations. The tool has received very positive feedback from the hospital's network of lead physicians, and we are exploring how it can be adapted for use in other clinics.

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# ■ HB-02

*Thursday, 11:00-12:30 - Room: Bell Lecture Theatre*

## Blood logistics (1)

Stream: Presentations
*Contributed session*
Chair: *John Blake*

**1 - A Multi-Period Optimisation Model for Integrated Blood Collection Planning**
*Ngo Duc Anh Nguyen, Xiang Song, Graham Wall*

Blood supply systems face increasing challenges in meeting demand in a timely manner due to uncertainty and fluctuating donor availability. These challenges are further complicated by the need to coordinate facility location decisions with detailed operational scheduling, including operating days, collection times, and workforce allocation.

This paper develops a multi-period optimisation model for integrated blood collection planning. The model determines strategic facility locations and operational collection schedules. This includes detailed scheduling decisions and capacity allocation across fixed and mobile sites, while accounting for donor availability and operational constraints such as limited daily mobile team deployment. The model adopts a weighted multi-objective formulation to minimise weekly shortages while balancing donor accessibility, operational costs, and travel distances.

Due to the scale and complexity of the problem, exact optimisation becomes computationally challenging. To address this, a two-phase heuristic approach is proposed, combining site selection with week-by-week schedule construction. The model is evaluated through computational experiments. Results indicate that near-optimal solutions can be obtained with significantly reduced computational time, demonstrating the effectiveness of the proposed approach for practical decision support.

**2 - Rule-Based Scheduling Policies for Blood Component Production**
*Aleyna Gürsoy, Roberto Pinto, Pieter Smet, Greet Vanden Berghe, Ettore Lanzarone*

Blood units collected from healthy donors are separated into components at dedicated facilities such as blood centres and hospitals. Despite its relevance in health care, blood supply chain research has not resulted in a straightforward methodology for scheduling blood component production. This process, which combines the challenges of managing a perishable resource with the need for high-throughput operations, requires advanced scheduling methodologies due to its computational complexity. In prior work, we developed an ILP model to optimally schedule the separation operations. While the model produced high-quality schedules and enabled extensive analysis, it required long computational times. In this context, we now propose a set of rule-based scheduling policies to generate implementable solutions fast. These solutions explicitly account for both machine processing times and the manual tasks performed by human operators at the start and completion of each operation. The objectives are to generate high-quality schedules within reduced computational times and to define practical decision-making policies for operators, thereby providing actionable insights into the production process. The proposed approach was validated using a real-life case study at Niguarda Hospital, Milan, Italy. Results show good-quality schedules with substantially reduced computational time. The rule-based policies offer clear operational guidance, enabling more informed decision-making.

**3 - Drone-aided mobile blood collection problem: A rolling-horizon-based matheuristic**
*Hossein Hashemi Doulabi*

This study introduces the drone-aided mobile blood collection problem, which integrates mobile blood donation vehicles with drones to improve operations related to the blood collection in urban areas. Each vehicle, carrying multiple drones, travels to several collection sites to conduct blood collection operations within a working day. Drones fly between vehicles to pick up collected blood bags and deliver them to the blood center. This collaborative framework enhances the performances of the collection system and ensures the freshness of collected blood upon arrival to the blood center. We develop a novel mixed-integer linear programming model to optimally synchronize the routes and collection schedules of mobile units and drones to ensure the timely delivery of collected blood to the blood center. We also develop a rolling-horizon-based matheuristic to solve large-scale instances of the problem. This algorithm combines a rolling horizon approach, which divides the problem into manageable subproblems solved sequentially, with a local branching technique that enhances solutions by exploring promising neighborhoods. Our computational results show that the proposed algorithm not only finds better solutions than those obtained by Gurobi but also outperforms other matheuristics, including the rolling horizon, relax-and-fix, and fix-and-optimize algorithms. Finally, we demonstrate the real-life applicability of the problem through a case study in Quebec City, Canada.

**4 - Facilities Planning at CBS to meet collection targets in the 2030's**
*John Blake*

This presentation updates prior work by incorporating a full set of experimental results from a national-scale optimization model of the Canadian blood supply chain. The model evaluates network design and operational policies over a ten-year horizon using a multi-objective framework prioritizing supply sufficiency, cost, waste, and donor access.

In addition to location and routing decisions, the model assesses the impact of donor behaviour and donation policies on infrastructure requirements. Results show that participation rate is the most influential driver of system infrastructure. Increased participation reduces system costs, lowers donor travel distance, and decreases the need for new collection facilities. Conversely, reductions in whole blood donation frequency increase costs and infrastructure requirements, particularly for plasma collection.

Key lessons learned are that modest improvements in donor behaviour can substitute for infrastructure expansion, and that policy levers are as impactful as network design decisions. We also highlight two practical use cases and discuss the organizational factors influencing model adoption.

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# ■ HB-03

*Thursday, 11:00-12:30 - Room: MAPTC OG/017*

## Outpatient appointments

Stream: Presentations
*Contributed session*
Chair: *Anders N. Gullhav*

### 1 - One More Thing... Information Asymmetry and Outpatient Clinic Efficiency

*Murray Côté, Tiffany Radcliff*

A perennial challenge in outpatient clinic management is maintaining efficient patient flow, which depends in part on patients fully disclosing their healthcare needs in advance so care demands can be matched with clinic resources. In practice, appointments are often scheduled to address a single primary concern, while other health concerns may remain undisclosed until the visit. During the appointment, patients may reveal additional concerns in hopes they can be addressed at that time. If accommodated, the visit may extend beyond its expected duration, delaying subsequent patients. Alternatively, the provider may end the appointment and request a follow-up visit, the feasibility of which depends on the nature of the concern, clinic capacity, and the patient's willingness and ability to return. Neither option is necessarily optimal for efficient patient flow.

Working with a large primary care practice, we surveyed patients and providers to better understand information asymmetry in outpatient care. In this presentation, we report: (1) survey findings on patient and provider behaviors related to disclosure of care concerns, (2) a simple stochastic model linking patient disclosure behavior to clinic resource efficiency, and (3) strategies for reducing asymmetric information in outpatient care.

### 2 - Integrating Walk-In Patients into Outpatient Schedules: A Two-Stage Optimization Approach

*Sirma Karakaya*

Global outpatient utilization has reached unprecedented levels, placing significant operational pressure on healthcare providers. In practice, pre-planned schedules are frequently disrupted by unscheduled walk-in patients—such as those seeking diagnostic result interpretations. Traditional "opportunistic" scheduling, where walk-ins are served only when gaps arise, often leads to long waiting times and operational instability.

This study proposes a systematic approach to integrate walk-in patients into a fully booked, single-provider schedule without altering the predetermined sequence of scheduled patients. We develop a two-stage mixed-integer programming (2SMIP) framework. In the first stage, optimal insertion positions for walk-in patients arriving at the session start are determined while preserving the relative order of scheduled appointments. In the second stage, the model incorporates stochastic service times for scheduled patients and relatively deterministic durations for walk-ins. The objective minimizes a weighted combination of expected waiting times for scheduled patients, walk-in waiting-time violations, and total overtime.

Using empirical data from an outpatient dermatology clinic, results show that the proposed approach reduces waiting-time variability and improves scheduling transparency. Managerial insights highlight trade-offs between slot durations, patient prioritization, and the value of stochastic modeling.

### 3 - Learning-based Adaptive Evolutionary Search for Multi-Objective Outpatient Appointment Scheduling

*Davide Duma, Sara Cambiaghi*

Outpatient Appointment Scheduling (OAS) involves repeatedly solving multi-objective optimization problems that vary in waiting lists but share structural patterns across planning periods. Traditional optimization methods typically solve each instance independently using metaheuristics, without exploiting knowledge embedded in past solutions. In this work, we propose a learning-based adaptive evolutionary approach that leverages historical data to enhance future scheduling performance under a fixed computational budget.

As a case study, we examine CT-scan scheduling in an emergency department, where outpatients, inpatients, and emergency cases compete for limited resources. The problem is formulated as a stochastic multi-objective program aimed at minimizing outpatient waiting times as well as completion times for inpatients and emergency patients.

We adopt the Non-dominated Sorting Genetic Algorithm II (NSGA-II), augmented with an adaptive warm-start mechanism. Specifically, a weighted k-Nearest Neighbors (k-NN) approach, combined with a predictive model and an optimal assignment procedure, is used to identify similar historical instances. Previously computed Pareto fronts are then exploited through a similarity-weighted bootstrapping process to construct a tailored initial population.

The proposed method is tested across multiple operational scenarios using real-world data from a trauma center in Pavia, Italy.

### 4 - Stochastic Demand-Driven Shift and Appointment Template Scheduling in Outpatient Chemotherapy

*Anders N. Gullhav, Nadia Lahrichi, Louis-Martin Rousseau*

Chemotherapy is one of the most common cancer treatment modalities and is frequently administered in outpatient settings. The scheduling in chemotherapy clinics is complex, as treatment involves a series of appointments following a medical protocol with strict temporal requirements, including maximum wait times for the initial appointment and fixed intervals between subsequent sessions. Furthermore, appointments require multiple resources and have varying durations and nurse-to-patient ratios. This paper addresses the tactical scheduling challenges in chemotherapy clinic operations, focusing on jointly devising a cyclical weekly shift schedule and appointment template under fixed resource constraints. Given a predetermined nurse workforce and chair capacity, the shift schedule determines how nurses are allocated across shifts, while the appointment template specifies when different treatment types are performed. The objective is to minimize expected under-capacity across treatment types and quantile levels. We propose a mixed-integer linear programming (MILP) model for the integrated shift and appointment template scheduling problem, incorporating a demand-flow mechanism that propagates downstream appointments induced by multi-cycle treatment regimes and a piecewise-linear approximation of stochastic demand. We validate the model on realistic data instances and evaluate the resulting schedules through simulation.

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# Thursday, 13:30-14:30

## ■ HC-01

*Thursday, 13:30-14:30 - Room: Emeleus Lecture Theatre*

### Emergency medical services and queuing

Stream: Presentations
*Contributed session*
Chair: *Paul Harper*

**1 - On the optimization of heterogeneous ambulance fleet allocations.**
*Mark Tuson, Geraint Palmer, Paul Harper, Sarie Brice, Daniel Gartner, Vincent Knight, Leanne Smith*

Our research programme is working with Indonesian emergency ambulance services and the Indonesian Government to help them make critical decisions on the optimal types, capacities and geographical locations of response vehicles. Such factors directly impact on the probability of patient survival, ability to respond to major disasters, and the overall quality of care provided. There are however many challenges faced in the country, including vast geographical areas, traffic congestion, inadequate numbers of ambulances and a lack of a co-ordinated service. This talk will describe findings and impact of the research project to date, including an analysis of ED survey data that we undertook across Jakarta hospitals, and an approach to consider EMS allocations for both heterogeneous populations (multiple medical needs) using a heterogeneous fleet (consideration of multiple vehicle types each with differing travel speeds). This has been achieved via the creation of an optimisation and simulation decision-support framework.

**2 - Reducing Simulation Costs in Ambulance Allocation Using Surrogate Models**
*Esther Ródenas-Moreno, Fulgencia Villa, Victor Sanchez-Anguix, Juan M. Alberola*

Efficient ambulance allocation represents a crucial challenge in Emergency Medical Services, where reducing response time can greatly influence patient outcomes. This study addresses the static ambulance allocation problem by investigating surrogate modelling techniques to alleviate the computational demands of simulation-based evaluations. Given that response time is a dynamic function, it is usually estimated through simulations. However, these simulations can become costly when integrated with metaheuristic optimisation methods. To address this limitation, various machine learning models are assessed as surrogate functions to approximate simulation outputs. Utilising real-world emergency call data from the province of Valencia, an extensive array of ambulance allocation configurations is generated and evaluated through simulation to train and validate nine distinct models. Their performance is compared based on ranking capability, which is measured using Spearman's correlation. The results indicate that certain models, particularly LightGBM, strike an effective balance between accuracy and speed. This capability reduces computational costs while still providing reliable solutions. These findings imply that surrogate models could effectively help explore a broader range of ambulance configurations within real-world healthcare systems.

**3 - About Service Disciplines in Priority Queues**
*David Stanford, Peter Taylor, Ilze Ziedins*

In the original queueing work by Kesten & Runnenberg on waiting times in priority queues, it was assumed that when the server was ready to select a customer from a particular priority class, it did so on a first-come, first served (FCFS) basis among customers of that class. Since then, other authors have considered models with other customer selection rules such as last come first served and random order of service. In the previous work, it has always been assumed that all priorities employ the same customer selection rule. However, in systems dealing with diverse health needs, it might be the case that different service disciplines are warranted within the various priority classes. Therefore, we consider queues where the selection rules may differ from one class to another. We show the waiting time distribution for a given class k does not depend upon the service selection rules for the other classes, so long as the system is work-conserving, and the priority structure among the classes is preserved.

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## ■ HC-02

*Thursday, 13:30-14:30 - Room: Bell Lecture Theatre*

### Blood logistics (2)

Stream: Presentations
*Contributed session*
Chair: *Ettore Lanzarone*

**1 - A Two-Stage Stochastic Model for A Blood Supply Chain Network with Emergency Transport Service**
*Xiang Song, Dylan Jones*

Managing blood inventory across Stock Holding Units (SHUs) remains a challenging task, as it requires meeting hospital demand in a timely manner while minimising wastage due to product expiry. These challenges arise from the inherent uncertainty in demand and the limited shelf life of different blood products. When demand from a hospital cannot be fulfilled by its designated SHU, it must be met by other, more distant SHUs, resulting in higher transportation costs.

This paper develops a two-stage stochastic programming model to determine optimal periodic review policies for multi-product blood inventory management. The objective is to minimise total transportation costs arising from shortages while maintaining blood wastage rates within acceptable limits. The proposed model is evaluated using real data from a blood centre. Results indicate that the expected transportation cost can be reduced compared to current practice, particularly in a simplified setting where blood type is the sole matching criterion between supply and demand.

**2 - Stochastic Simulation of a Distributed Blood Supply Chain for Precision Matching**
*Folarin Oyebolu, Marie Chion, Orod Razeghi, Sara Trompeter, Nicholas Gleadall, William J. Astle*

Automated blood matching using extended blood types derived from the mass genotyping of patients and donors has the potential to reduce alloimmunisation in sickle cell patients. Yet existing investigations of the benefits often assume simplified blood supply chains or centralised inventories.

We present a simulation model for the hierarchical supply chain of NHS Blood & Transplant in England that incorporates bilateral transhipments between stock holding units. By evaluating scenarios with differing transhipment constraints, we quantify the logistical impact of extended matching across the distribution network.

We demonstrate that alloimmunisation could be reduced by 59% given an eight-fold increase in the transhipment of units of red blood cells and investigate the trade-off between alloimmunisation and the volume of transhipment. Finally, we extend our analysis to cases where only small subsets of donors have been genotyped to assess the consequences of a gradual rollout of donor genotyping programmes.

**3 - Future-ready blood services: building strategic foresight for increasing efficiency and resilience of the blood supply chain**
*Marina Amorim*

Blood is an irreplaceable resource in healthcare, and ensuring its safe and timely delivery from donors to patients is the core function of the blood supply chain (BSC). Managing the BSC is increasingly challenging given uncertainty surrounding demographic shifts, technological advances, and evolving clinical practices. Conventional planning approaches cannot capture these complexities, motivating narrative scenario development. Using a decomposition-based framework, systematic literature review, and expert consultations, we identified

ten key uncertainty factors and four development paths each. Expert pairwise consistency ratings were used to select four internally consistent, maximally diverse scenarios: Strained Resilience, Thriving Transformation, Adaptive Automation, and Regulatory Rigidity. Cross-scenario analysis reveals three structural findings: voluntary donation remains irreplaceable regardless of advances in synthetic blood; no scenario achieves true stability, with apparent stability masking underlying fragility; and long-term resilience is determined by social and institutional conditions rather than operational capacity alone. Factors conventionally excluded from BSC analytical models such as civic trust, regulatory flexibility, cybersecurity resilience, and donor engagement emerge as the most consequential drivers of system resilience and robust strategic priorities across a wide range of possible futures.

## ■ HC-03

*Thursday, 13:30-14:30 - Room: MAPTC OG/017*

### Discussion session 1

Stream: Discussion talks
*Contributed session*
Chair: *Theresia van Essen*

**1 - A call for capacity effectiveness**
*Jedidja Lok - Visser, Anoukh van Giessen, Jan Gerard Maring, Gréanne Leeftink, Erwin W. Hans*

Funding is no longer the primary scarce resource in healthcare; the workforce is. Traditionally, operations research models applied to healthcare focused on improving accessibility and affordability. However, given the scarcity of healthcare personnel, the focus should rather be on utilizing the healthcare workforce as efficient and effective as possible. Thus, our models should focus on optimizing productivity, and more importantly, health outcomes.

To connect health outcomes to healthcare capacity, we propose a new concept: capacity effectiveness. This concept opens a realm of new research possibilities, on various levels of decision making. For example, on a national policy level, we could effectively allocate the healthcare workforce to either prevention or treatment programs for a specific disease. Or, we could optimize retraining programs for doctors or nurses, including the effectiveness of treatments and scarcity of personnel. On an operational level, we could design ED triage models that prioritize patients that optimize the health outcomes of the treatment, given the ED personnel required.

Our aim of this discussion session is to come to a broadly supported definition of capacity effectiveness and identify research opportunities together. We look forward to your contribution!

**2 - From Theory to Implementation: How can we, as Operations Research Experts, Make a Difference in the Lives of Patients?**
*Mariel Lavieri*

In this talk, I will discuss lessons learned over the course of my career, with a desire to directly impact patients by conceiving, designing, and implementing Operations Research models. I will not only discuss success stories but also some of the challenges faced and future directions, leaving an open question for us to learn from each other in this interactive session as we consider the steps needed to have our work implemented.

# Thursday, 15:00-16:00

## ■ HD-01

*Thursday, 15:00-16:00 - Room: Emeleus Lecture Theatre*

### Business Meeting

Stream: Plenary sessions
*Invited session*
Chair: *Roberto Aringhieri*
Chair: *Melanie Reuter-Oppermann*

# Friday, 9:30-11:00

## ■ FA-01

*Friday, 9:30-11:00 - Room: Emeleus Lecture Theatre*

### Simulation-Based Decision Support for Health Service Planning

Stream: Presentations
*Contributed session*
Chair: *Christos Vasilakis*

**1 - Developing a Discrete-Event Simulation Model to Support Placement Planning in Mental Health and Substance Use Supported Housing**
*Mina Moeini, Jessica Stockdale, Saad Ahmed, Krisztina Vasarhelyi, Alexander Rutherford*

Stable housing is a key part of community-based care because it can help prevent crises that lead to emergency visits or hospital admissions. Supported housing combines stable accommodation with social and health-related supports to help people with mental health and substance use (MHSU) challenges live safely in the community. However, planning access and client flow is difficult because referrals, client needs, housing resources, discharge pressures, and service capacity are intertwined.

We are developing a discrete-event simulation model to evaluate placement strategies and inform operational decision-making in MHSU supported housing services within Vancouver Coastal Health, British Columbia, Canada. Model development began with structured working sessions with clinicians, program managers, and researchers to map client pathways, processes, constraints, and key decisions. The process map was reviewed with frontline and operational stakeholders and is being integrated with linked administrative data.

The model will compare placement policies, including hospital versus community prioritization, demand surges, and temporary capacity expansion. Outcomes will include wait times, placement flow, congestion, and resource use. This work will provide a decision-support tool for testing scenarios and informing service planning in a complex supported housing system.

**2 - DigiSim: A hybrid simulation model to support primary care planning during a pandemic**
*Shakir Bilal, James Duggan*

Primary care acts as a gatekeeper to health care systems across the world and particularly in countries of the Europe Union. During pandemics, as highlighted by the COVID-19 pandemic, regular care is impacted, with detrimental consequences for patients' wellbeing attributable to increased demand and disruption of scheduled visits, changes in care-seeking behaviour, and absenteeism of doctors due to illness or fatigue. Use of digital health services by patients can help provided essential care and reduce deterioration of health conditions due to missed appointments and care postponement. Here, we present a hybrid simulation model of a generic primary care practice where all patients attending the practice are registered patients. We use synthetic patients based on demographic and chronic disease marker conditions profiles from Eurostat and CBS for the Netherlands, specifically the Nijmegen region, and validate the model via user feedback. The impact of digital health pathways are assessed, using performance indicators such as appointment access times, queue sizes of scheduled visits, missed appointments, and hospital use. Additionally, the performance indicators are evaluated against other mitigation strategies such as working overtime. Our results show that digital health can mitigate stresses on GP practice and improve patient outcomes during a pandemic, however the resulting increase in in-person visit demand should be addressed through careful use of overtime work.

**3 - Digital twins in healthcare: white knight or white elephant?**
*Sally Brailsford*

The half century since the foundation of ORAHS has seen steady growth in the size of OR models, due largely to the exponential increase in computing power combined with developments in software and the availability of large electronic datasets. This trend has culminated in the concept of a digital twin: a computer model that receives real-time (or near real-time) data from the system it represents, performs various calculations, and then feeds back the results to the real-world system, thereby changing its behaviour and improving its performance. It is this cyclic exchange of information in (near) real time that distinguishes a digital twin from a regular OR model, regardless of size. This talk challenges the concept of a 'whole hospital' digital twin, both in terms of feasibility and desirability, and argues for a return to the roots of OR modelling in which it is the problem to be solved that determines the nature of the model, not vice versa. This argument is illustrated using some examples of small, simple models that have achieved a real-world benefit in healthcare.

**4 - Automation in Aseptic Pharmacy: Modelling the System-Wide Effects of Automated Drug Compounding Adoption**
*Christos Vasilakis, Hannan Tureci Isik, Benedict Rogers, Melih Celik, Vimal Dhokia, Lorenzo Giunta*

Chemotherapy drug compounding in hospital aseptic units is labour-intensive, capacity-constrained, and exposes staff to occupational risks. Automated Drug Compounding (ADC) systems promise improvements in safety and efficiency, yet their system-wide operational implications are not well understood. This study reports on the development of a workload-driven discrete-event simulation model, parameterised using three months of production data from an NHS aseptic unit, to evaluate alternative ADC configurations.

The model captures key process stages, staffing constraints, and session-based operations, and is used to compare baseline manual compounding with scenarios varying ADC capacity and processing speed. Results show that ADC adoption can increase throughput and reduce skilled staff workload, with certain machine configurations operating up to 20% faster than manual processes. However, results also highlight the importance of appropriate system sizing and integration, as poorly planned implementation may shift bottlenecks rather than resolve them.

The findings highlight that automation is not a standalone solution: effective implementation requires careful alignment with existing workflows and supporting resources. The study demonstrates the value of simulation modelling in informing investment and design decisions for hospital aseptic services.

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## ■ FA-02

*Friday, 9:30-11:00 - Room: Bell Lecture Theatre*

### AI in healthcare

Stream: Presentations
*Contributed session*
Chair: *Gillian Cameron*

**1 - Benchmarking Large Language Models for In Vitro Diagnostic Regulation (IVDR) Knowledge and Hallucination Risk in Healthcare Regulation**
*Rayyan Waseem, Gary Mason, Sean Gilmour, Maria Salman, Jonathan Wallace, Raymond Bond, Ian McChesney*

Large Language Models (LLMs) are being explored as support tools in healthcare and regulatory work, but it remains unclear how much specialised knowledge they hold and where they may give confident yet

unreliable answers, known as confabulations or hallucinations. This talk presents a baseline study using an In Vitro Diagnostic Regulation (IVDR) question answer dataset to compare responses from four LLMs: GPT2, Pythia, Gemma2 and Llama 3. The questions cover practical regulatory topics such as legal representatives, performance studies, sampling, sponsors and post market duties. The study follows three steps. Firstly, each model was asked the same set of IVDR related questions. Secondly, the answers were manually reviewed for factual accuracy, completeness and clarity. Thirdly, responses were checked for signs of hallucination, such as unsupported claims, missing uncertainty or confident answers to questions requiring regulatory interpretation. The aim is not to replace regulatory experts or offer legal advice. Instead, the work provides a baseline assessment for deciding whether a future regulatory AI system should use prompting, retrieval or fine tuning prior to formal human review, maintaining a Human in the Loop model for Responsible AI. The presentation will share early findings, discuss gaps between general language ability and specialist regulatory knowledge, and raise questions about how AI tools should be tested before use in regulatory compliance related workflows

**2 - Understanding Patient Acceptance of AI in Oncology: An Exploratory Study Based on Healthcare Professional Perspectives**
*Julien Francois, Anne-Françoise Audrain-Pontevia, Alexis Desmonts, Aurélien Corroyer-dulmont*

Artificial intelligence (AI) is increasingly integrated into oncology care pathways, including imaging, diagnosis, treatment planning, and care organisation. While many patients believe AI may improve outcomes, a significant proportion express concerns related to reduced human interaction, lack of transparency, and risks of error. Moreover, many remain poorly informed about the actual use of these technologies in their care.

This qualitative study explores how healthcare professionals perceive patients' understanding, attitudes, and concerns regarding AI in oncology. It aims to analyse professionals' own perceptions of AI and to identify, through their observations, those of patients. Eighteen professionals (oncologists, radiologists, physicists, and technologists) from a Unicancer centre participated in semi-structured interviews, which were thematically analysed.

Findings reveal contrasted views of AI, seen either as a decision-support tool or as a potentially transformative innovation. Patients are generally described as having limited awareness of AI, which remains largely invisible in care pathways. However, some concerns are emerging, particularly regarding depersonalisation, trust, and accountability.

These results highlight key challenges related to communication, transparency, and governance, and underline the need for further research on patient perceptions.

**3 - AI Systems for Flexible Healthcare Data Analysis**
*Kimia Ghobadi*

Healthcare operations increasingly depend on timely, reliable interpretation of complex clinical data. In high-acuity settings such as emergency departments and intensive care units, clinicians and operational leaders must make decisions under severe time pressure while facing continuous streams of physiological signals, electronic health record data, laboratory results, and clinical notes. Yet much of this information remains difficult to use in real time. As a result, operational decisions about monitoring, escalation, staffing, resource allocation, and care coordination are frequently made from compressed or delayed summaries of the patient state.

This talk will discuss emerging AI approaches for transforming complex clinical data streams into actionable information for healthcare operations. Rather than treating prediction as an isolated technical task, we will frame data analysis as part of a broader decision-support pipeline, e.g., sensing the patient state. We will highlight opportunities and challenges in using modern AI systems to analyze physiological waveforms and contextual clinical information, with particular attention to reliability, generalizability, missing data, and the relationship between learned representations and operational usefulness.

**4 - Predicting clinical outcomes in Employee Assistance Programmes: A machine learning analysis of 30,000 clients**
*Gillian Cameron, Maurice Mulvenna, Raymond Bond, Edel Ennis, Siobhan ONeill, David Cameron*

The increasing availability of routine mental health data presents substantial opportunities for improving health service planning, yet analysis is often challenged by noise, data access, data wrangling/cleaning, heterogeneity, and real-world complexity. Machine learning (ML) approaches offer a means of identifying clinically meaningful patterns that support mental health service optimisation and outcome prediction. This study develops and evaluates ML models to predict clinical outcomes and treatment intensity in a large real-world Employee Assistance Programme (EAP) dataset. The analytical sample comprised 30,821 clients who accessed counselling services between 2012 and December 2024. Clinical outcomes were operationalised using CORE-10 (a validated measure of psychological distress). Logistic Regression, Random Forest, and XGBoost were applied to predict two binary clinical outcomes (reliable change and recovery) and session count, using eight predictors/features including baseline psychological distress, demographic characteristics, occupational sector, primary presenting issue, and temporal contextual factors. Model development and validation are currently ongoing, and comparative performance, feature importance, and predictive accuracy for clinical outcomes and session count will be presented at the conference. Findings will be discussed in terms of their implications for early risk detection, demand forecasting, and resource planning in mental health services.

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# ■ FA-03

*Friday, 9:30-11:00 - Room: MAPTC OG/017*

## Cost effectiveness and health economics

Stream: Presentations
*Contributed session*
Chair: *Marion Rauner*

**1 - A multi-objective optimisation and simulation-based ranking approach for coupling the generation and evaluation of health-informed energy retrofitting strategies**
*Sara Mallah, Marius Huguet, Xavier Boucher, Lionel Perier, Jonathan Villot*

The socio-economic impacts of health effects are urging the public decision-makers to rethink the design of the energy retrofitting strategies, thereby making crucial the optimal selection of retrofit programs. However, existing decision-support frameworks often rely on a limited set of predefined expert-based renovation scenarios, which may restrict the exploration of more efficient strategies. This paper proposes an extension of a simulation-based multi-criteria decision-making framework by introducing a multi-objective optimisation layer for the automatic generation of renovation scenarios. The proposed approach formulates the retrofit planning problem as a multi-objective optimisation model aiming to optimise public health outcomes among other usual objectives. A nominal estimation of health impacts is used within the optimisation process to generate a set of Pareto-optimal scenarios. The latter are then evaluated using an iterative process of Monte-Carlo simulation and a dynamic-based ranking to account for uncertainty in health-related parameters and produce probabilistic rankings of scenarios, allowing the assessment of their robustness over time. The results prove the ability of the optimisation stage to uncover efficient retrofit strategies, while also enabling the assessment of the quality and robustness of the predefined scenarios. This work can further be refined by integrating uncertainty directly within the optimisation process through a stochastic formulation.

**2 - Promoting home-based dialysis for ESRD Patients**
*Mojtaba Araghi, Maryam Afzalabadi, Salar Ghamat*

Healthcare payers are actively seeking ways to improve the quality of life of patients with end-stage renal disease (ESRD) while reducing treatment costs by increasing the use of home dialysis. In this paper, we develop a game-theoretic model to study two incentive schemes, target-based and rank-based, offered by a payer to encourage effort by two heterogeneous providers to increase home dialysis utilization among ESRD patients. We show that, by carefully setting the performance benchmarks, the payer can achieve the first-best home dialysis rates under both schemes. To our knowledge, this is the first paper in the incentive payment literature to model and study compound incentive mechanisms that include both improvement and rank-based benchmarks. These benchmarks motivate diverse providers to work toward receiving the award despite their different characteristics. Finally, we present a numerical analysis that provides insights into the practical performance of these incentive schemes for the payer.

**3 - Remote Versus In-Clinic Pulmonary Function Testing for People with Amyotrophic Lateral Sclerosis (ALS) in the U.S.**
*Tiffany Radcliff, Matthew Griffith*

Respiratory failure is the leading cause of morbidity and mortality among people living with Amyotrophic Lateral Sclerosis (pALS). Regular spirometry is recommended to monitor progression of respiratory muscle weakness and implement non-invasive ventilation (NIV) when appropriate. Clinical guidelines recommend performing spirometry every three months; however, current adherence to this schedule and feasibility of alternative testing modalities to reach guideline concordance testing (GCT) are not well described. This project identifies the current frequency of spirometry for pALS in the U.S. Veterans Affairs (VA) Healthcare system and related cost estimates of expanding testing to reach GCT using in-facility and remote (at home) spirometry modalities. We use a retrospective cohort study design to identify pALS, current spirometry testing frequency, and related costs of testing. These estimates are are compared to GCT recommendations to identify differences in needed testing, and estimated costs to deliver testing that aligned with GCT. We found that spirometry occurs less frequently than recommended for pALS, potentially delaying supportive pulmonary therapies. Costs to increase testing depend on the stakeholder perspective used. However, integrating remote spirometry into ALS care pathways to supplement in-facility testing may enable pulmonary providers to rapidly identify clinically meaningful changes in lung function.

**4 - Health economic evaluation: a taxonomy for cost categories of chronic pain and the effectiveness of auricular vagus nerve stimulation**
*Marion Rauner, Stefan Andric, Faisal Schwab, József Constantin Széles*

The clinical and economic burdens imposed by chronic pain are well-documented, yet the cost-effectiveness of vagus nerve stimulation (VNS) remains unclear due to a lack of robust and consistent evidence. This study evaluates the health-economic assessability of VNS, with a particular focus on auricular, non-invasive approaches. It also develops a taxonomy that links clinical outcomes (effectivness) with cost categories. A systematic review indicates a marked imbalance between the available clinical data and the near absence of economic evaluations for auricular VNS. The outcomes reported are characterized by a lack of standardization, with economic parameters seldom captured systematically. The financial implications of chronic pain are frequently underestimated, with the indirect and intangible nature of the condition often not adequately addressed. The proposed taxonomy provides a structured foundation for future standardized economic studies and highlights the necessity for robust prospective evaluations to support evidence-based health technology assessment.

# Friday, 11:30-12:30

## ■ FB-01

*Friday, 11:30-12:30 - Room: Emeleus Lecture Theatre*

### Discussion session 2

Stream: Discussion talks
*Contributed session*
Chair: *Adele H Marshall*

**1 - How do we build collaboration and improve application in Health OR?**
*Martin Pitt, Jennifer Morgan, Adele H Marshall, Christos Vasilakis*

The Research Liaison Network (RLN) was established in 2025 and is hosted within the Association of Professional Healthcare Analysts (AphA). It incorporates and continues the seminal work of the UK Modelling & Simulation in Healthcare Network (MASHnet) founded in 2005.

The core aim of the RLN is to promote active dialogue and collaboration between health analysts and the wider research community to improve patient care. This is key to effective OR implementation both in the UK and internationally.

We believe collaboration between professional communities in delivering impactful research is fundamental if we are to respect the 'A' in ORAHS. The RLN can play and important role in this context.

At this formative stage we need to develop the activities and vision of this young network. We are keen to get your feedback and hear your views, learn from the experience across different countries, and encourage you to join and engage in the network to help shape the RLN's future.

If you would like to learn more about this exciting initiative and play a part in its evolution, please come along to this session which will feature a presentation of the current RLN rationale, activities and development, a panel discussion, and extensive opportunities to raise questions and issues.

More information about the Research Liaison Network can be found at: www.aphanalysts.org/research-liaison-network/

## ■ FB-02

*Friday, 11:30-12:30 - Room: Bell Lecture Theatre*

### Discussion session 3

Stream: Discussion talks
*Contributed session*
Chair: *Alexander Rutherford*

**1 - A Gender Perspective on OR Healthcare Applications**
*Melanie Reuter-Oppermann, Eda Yücel, Paula Carroll*

There are obvious anatomical and physiological sex differences between men and women. There are also differences between gender roles and psychological factors that may affect health outcomes. From medical research, we know, for example, that there are significant differences in the symptoms and causes of heart attacks in men and women. However, many people are unaware of these differences. Diagnostic tools and responses based on male norms can lead to negative outcomes for women. There is also a gender dimension to the provision of healthcare. For example, women are less likely to receive bystander CPR in the event of out-of-hospital cardiac events, reducing their chances of survival. Within healthcare Operations Research

(OR), to date, no analysis of results or recommendations from a gender perspective has been conducted to assess the impacts of these decisions on gender equality. As a basis, we have developed a framework for modelling gender-aspects in healthcare OR. In this talk, we want to discuss the relevance, chances and potential challenges of including a gender perspective in healthcare OR.

**2 - Operational Research Challenges and Insights in Transition to Supported Housing Models**
*Alexander Rutherford, Jessica Stockdale, Mina Moeini, Weiyi Liu, Saad Ahmed, Krisztina Vasarhelyi*

Transitional services in healthcare provide an important bridge for individuals moving from acute care settings to community-based environments, such as long-term care and supported housing. These services provide clinical, social, and functional supports aimed at ensuring that clients are matched to the most appropriate type of housing, as well as being medically and socially supported during this transition phase. I will describe two of our projects with Vancouver Coastal Health Authority on transitional services: long-term care placement and mental health and substance use supported housing. Some of the key challenges that we faced in these projects are mapping complex clients flows through the system and incorporating the impact of system pressures, such as pressure from hospitals to discharge patients, on the placement process. Typically, the demand for long-term care or supported housing far exceeds the supply of units, leading to long wait times. Operational research can contribute to improving placement algorithms to better match clients to the services they need and reduce "churn" in the system caused by inappropriate initial placements or interim placements caused by long wait times. I will discuss our approaches to modelling these highly complex processes and invite a wider discussion on applications of operational research to transitional services.

# Friday, 12:30-13:30

## ■ FC-01

*Friday, 12:30-13:30 - Room: Emeleus Lecture Theatre*

### Closing

Stream: Plenary sessions
*Invited session*
Chair: *Adele H Marshall*
Chair: *Laura Boyle*
Chair: *Roberto Aringhieri*
Chair: *Melanie Reuter-Oppermann*

# STREAMS

### Discussion talks

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**Track(s): 1 2 3**

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### Presentations

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