ORAHS 2024

Program

July 15, 2024

TECHNICAL PROGRAM

Monday, 9:00-9:30

■ MA-01

Monday, 9:00-9:30 - Room: Auditorium

Opening

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

Monday, 9:30-10:30

■ MB-01

Monday, 9:30-10:30 - Room: Auditorium

Plenary Stefan Nickel

Stream: Plenaries
Plenary session
Chair: *Roberto Aringhieri*

1 - Strategies for a lasting impact in healthcare: from day-to-day operations to policy
Stefan Nickel

Healthcare involves both medical and logistical activities. While medical professionals are responsible for designing medical aspects, Operations Research (OR) can offer quantitative decision support for designing logistical processes. This enables OR to influence individual decisions and contribute to policy development. Achieving this impact requires integrating several key elements. Communication with stakeholders is essential for gaining insights into healthcare systems and establishing trust in OR models. Real-world data is necessary to build accurate models, which, in turn, can guide the collection of relevant data. The models must be adapted to comply with differing, local legislation while aligning with the overarching goals of healthcare systems. This adaption can also lead to the development of novel OR models. Decisions and their impact on care quality and economic factors are the driving force and structuring element for developing models and prioritising research and implementation efforts. Bringing these elements together can be achieved through virtual planning environments such as discrete event simulation. Built on real-world data, they can be used to communicate with stakeholders, validate OR models, and understand the interdependence of decisions. Drawing on an ongoing project focused on emergency medical services, this talk will showcase concepts, models, and insights illustrating how OR can make a tangible impact and influence legislative changes.

Monday, 11:00-12:30

■ MC-03

Monday, 11:00-12:30 - Room: Room S2

Evaluation and Implementation

Stream: Regular talks
Contributed session
Chair: *Leslie Anne Campbell*

1 - Vulnerability evaluation and budget allocation for public health programs using multicriteria decision aiding
Irene Abi-Zeid, Roxane Lavoie, Jerome Cerutti

The Integrated University Health and Social Services Centres (CIUSSS) in the province of Quebec, Canada have been implementing actions through the Integrated Perinatal and Early Childhood Services program. This program finances and accompanies projects that promote the optimal development of young children and supports parents who are vulnerable in their roles as caregivers. A CIUSSS must allocate its budget among its different territories, to be managed by community organizers. However, this allocation was based on criteria that are more than 15 years old and do not necessarily reflect today's local realities. Some territories are overfunded while others are underfunded, which results in inequitable access to services. This situation led to the definition of a collaborative project that guarantees a transparent, inclusive and rigorous decision process. The specific objectives of the projects were: 1) to co-construct a multi-criteria diagnostic model and evaluate the territories' vulnerability levels, based on quantitative and qualitative data and taking into account the experience of community organizers; 2) to use this model as a decision-aiding tool for the equitable allocation of budgets. Our research project was conducted through facilitated online decision conferences with multiple actors, using the MACBETH method. In this talk, we describe our MCDA process, the criteria constructed, the vulnerability index and the decision support tool delivered.

2 - Clinical pathways optimization of long-term and chronic patients in Quebec by Process Mining Approach
Luca Murazzano, Paolo Landa, Jean-Baptiste Gartner, Andre Cote, Mohamed-Hakim Raki

Quebec has an increasingly aging population with a growing number of long-term and chronic conditions. Within these chronic conditions, pulmonary and respiratory diseases impact 8% of the overall Quebec population. It is important to meet the service demand effectively and efficiently for this population, analyzing the existing care processes and ensuring the right service configuration. The objective of this study consists of understanding and optimizing the organizational costs and performance of the treatments provided to the patients of the Cardiology and Respiratory University Hospital in Quebec, using a process mining approach. The application of this method will identify how the hospital organization can best deploy resources to meet the needs of the patients. Hospital data from 2018 to 2022 was collected from four macro clinical activities: Emergency Department, Ambulatory, Hospitalisation, and Medical Imaging. Data were processed through a subsequent cleaning and refining process to obtain the raw clinical pathways of the patients. Then a subsequent pass through a process mining tool enabled the identification of macro and micro trajectories for the different disease types. The results made it possible to identify critical points within the clinical pathways and where action is needed to make the care pathway more efficient.

3 - Transforming Mental Health Care in Nova Scotia: Implementing Health System Change in Child and Adolescent Mental Health Services
Leslie Anne Campbell, Debbie Emberly

The creation of client-centred, accountable care is a priority for many child and adolescent mental health services. Major philosophical and organizational shifts are required to replace traditional systems where "clinicians are experts, clients are help seekers", and that have little ability to actively engage clients and families in a tailored care process or measure client-centred outcomes. The complex adaptive nature of health care systems and different implementation contexts may contribute to unanticipated variation in outcomes. The Choice and Partnership Approach (CAPA) is a comprehensive transformational service model that incorporates collaborative, participatory practice with lean thinking for demand and capacity management. We aimed to develop a theory-informed understanding of the conditions that hinder or support the implementation of CAPA in Nova Scotia, Canada. Specifically, we asked "to what degree does CAPA work, for whom, and under what circumstances?". Using a realist approach, we generated, tested, and refined mid-range theories based on a scoping review, document review, and key informant interviews. Our findings highlight that implementation of CAPA is influenced by multiple highly interrelated levels of context. For CAPA to "work" as intended, the implementation process requires empowered leadership, transparency, intentional planning and resourcing of implementation, and an understanding of the influence of the service ecosystem.

■ MC-04

Monday, 11:00-12:30 - Room: Room S3

Analytics for Mis/Disinformation in Healthcare

Stream: Regular talks
Contributed session
Chair: *Ozgur Araz*

1 - Perceptions of Social Media Health Mis- and Disinformation with Cancer Beliefs
Jim Stimpson

Objective: We evaluated how perceptions of social media health mis and disinformation were associated with cancer beliefs.

Study Design: Cross-sectional analysis of the 2022 Health Information National Trends Survey 6. Outcome variables were level of trust in cancer information and worry about COVID-19 that would delay a cancer screening test. Independent variable was perceptions of false or misleading health information on social media.

Results: Perception of substantial social media health mis- and disinformation was associated with a lower likelihood of trusting cancer information from government health agencies (OR = .60; 95% CI = .47, .77), family or friends (OR = .56; 95% CI = .44, .71), charitable organizations (OR = .78; 95% CI = .63, .96), and religious organizations and leaders (OR = .64; 95% CI = .52, .79). There was not an association with levels of trust in credible sources of cancer information such as doctors or scientists. Perceiving substantial misinformation was associated with a 7% lower probability of worry about covid that delay a cancer screening test. Persons that perceived substantial misinformation and were worried about getting cancer were the most likely to worry about covid and delay a cancer screening test (26%; 95% CI = 23-30%).

Conclusion: Cancer beliefs varied by perceptions of social media health mis- and disinformation with the potential to harm public health efforts in cancer prevention and control.

2 - A New Approach to Sentiment Analysis in Spanish Language Social Media
Fernando Wilson

This study aims to develop and validate a Spanish version of the Valence Aware Dictionary and sEntiment Reasoner (S-VADER) for analyzing sentiment in Spanish language social media posts. The goal is to improve communication strategies and outcomes among Spanish-speaking populations by monitoring and mitigating mis- and disinformation concerning health or healthcare-related information such as eligibility for health benefits programs. A sentiment-labeled lexicon is

developed using a crowd-sourced platform (Prolific), analyzing 5,000 randomly sampled posts from Facebook/Instagram and Reddit. Native Spanish-speaking raters, based in the US or Spanish-speaking countries, will evaluate these lexical features on a scale of -4 to +4, denoting direction and intensity of sentiment. Raters will undergo screening for Spanish fluency and will be provided with a standardized set of criteria to ensure consistency in sentiment assessment. The validated S-VADER tool will be used to perform sentiment analysis on health-related social media content, helping identify the proliferation and impact of health mis- or disinformation across Spanish-speaking communities. The S-VADER tool can be applied in a number of ways to design and optimize targeted public health interventions and communication strategies that are culturally and linguistically tailored, including whether messaging is being accepted or rejected by Spanish speakers and the intensity of reactions to the spread of false information.

3 - Understanding COVID Vaccine Hesitancy via System Dynamics Modeling and Health Belief Model
Nasim Sabounchi, Justine Maffei, Rachel Thompson, Terry T.-K. Huang, Ozgur Araz, Mahdi Najafabadi, David Lounsbury, Denis Nash, Turner Canty

The purpose of this presentation is to demonstrate how psychological, socio-economic, and health policy factors influence the COVID vaccine acceptance and hesitancy in the U.S. through the application of system dynamics (SD) modeling and the health belief model (HBM). HBM constructs including perceived threat, perceived benefits, perceived barriers, and perceived self-efficacy can predict individuals' vaccine intention with reasonable accuracy. These essential constructs also capture how misinformation affects vaccine hesitancy and acceptance. Building upon HBM constructs, we have developed a simulation platform which is validated against actual reported perceptions towards COVID-19 vaccine over time by using the data trends collected from the CHASING COVID Cohort Study, a national, community based prospective cohort study of 6,745 U.S. adults. We use the SD simulation model to compare scenarios to predict long-term dynamics with the goal of better understanding the determinants of vaccine intention among different sociodemographic groups of people, and to get insights about more successful public health initiatives in reducing vaccine skepticism and hesitancy through a closed-loop simulation model.

4 - Role of Uninsured in the Spread of COVID-19: A Bayesian Approach
Ozgur Araz, Graham Liu

We develop and use several geospatial models to estimate the effects of health insurance status and vaccination coverage in the spread of COVID-19. Specifically, we focus on COVID-19 related mortality, infection, and fatality rates as outcomes. Utilizing these existing methods an analysis is conducted at the national level using data for every county in the United States, then a case is formed with analyses where the counties are restricted to those within Texas and Mid USA, which includes Nebraska, Iowa, Missouri, and Kansas. Results show that the percentage of the senior population, the vaccination rate and the uninsured percentage are the most important variables for predicting infection rates and the fatality rates, while the overall social vulnerability index has a huge impact on mortality rates and infection rates.

■ MC-05

Monday, 11:00-12:30 - Room: Room S6

(Multi)Appointment /1

Stream: Regular talks
Contributed session
Chair: *Paola Cappanera*

1 - Appointment Scheduling with Updates: An Exact and Optimal Approach
Alex Kuiper, Roshan Mahes

Traditionally, appointment schedules have been determined by minimizing a specific cost function consisting of clients' waiting times and server idling. Under stochastic service times, this intra-day problem is predominantly studied in a static sense, assuming that a schedule is fixed. However, technological advancements have opened up the possibility of communicating with clients during the day. Using such channels allows for updating appointment schedules on the fly, for example, by postponing appointments in case of overcrowding. Yet, while its promise is clear, sending updates at the wrong moments, or too many, may be ineffective or unrealistic, potentially causing client confusion and frustration.

Three rescheduling paradigms are introduced that can be solved to optimality via dynamic programming. The experiments indicate that total costs are significantly decreasing, even with relatively few updates. The benefits concentrate on increasing utilization (less idling). The magnitude of the decrease is moderated by the length of the grace period, which accounts for not sending updates to clients possibly underway. If the rescheduling decisions are chosen a priori, then they should be equally spread throughout the session to be most effective. The best performance is, however, obtained under the third paradigm of dynamic rescheduling in the case the desired maximum of clients in the system is exceeded.

2 - ILP based approaches for a Chemotherapy Appointment Scheduling Problem
Giuliana Carello, Mauro Passacantando, Elena Tanfani

The number of patients affected by cancer is expected to significantly increase in the next years, and the need for chemotherapy treatments will increase accordingly. This poses a great challenge: resources devoted to cancer treatments (medical and nursing staff, consultation rooms, seats and beds for the drug infusion) must be carefully managed to meet the increasing demand. In cancer centers, resources are shared among different specialties or pathologies, and hematological and oncological patients with different pathologies are jointly treated. This can improve the timeliness and quality of the cure, provided that resources and activities are carefully managed. The management of shared cancer centres involves different decision levels. In this work, we mainly focus on the chemotherapy multi-appointment scheduling problem, namely the problem of determining the day and starting time of the visit and infusion of the scheduled patients, which arises at the operational level. We consider different metrics related to patients' perspective and we formulate the problem as a multiobjective optimization problem tackled by sequentially solving three problems, in a lexicographic multi-objective fashion. We propose MILP based approaches to solve the three problems. The approaches are tested on real data from an Italian hospital.

3 - An optimization decision support tool for patient assignments based on clinical pathways
Valérie Bélanger, Eduardo Redondo, Angel Ruiz

Patient-to-worker assignment in healthcare clinics is crucial for ensuring quality care delivery while optimizing resource utilization. As new patients arrive dynamically, clinics face the challenge of efficiently assigning them to healthcare professionals for appropriate treatment. This process involves scheduling a series of clinical activities, such as examinations, consultations, and follow-ups, over days or months. This study proposes an optimization decision support tool to address the challenges of patient-to-worker assignment, leveraging the concept of clinical pathways. Clinical pathways guide healthcare professionals through patient treatment stages. By integrating clinical pathways into the assignment process, we aim to enhance the consideration of patients' overall treatment requirements, thus improving resource utilization and reducing delays. Through empirical analysis using a discrete-event simulation model, we have compared the performance of our approach with standard practices. The results demonstrate the effectiveness of our tool in minimizing patient wait times and optimizing resource utilization. This comparative analysis not only validates the efficacy of our tool but also provides decision-makers with valuable insights into the tangible impact of different management strategies on patient care and resource allocation, thereby enhancing their ability to make informed decisions.

4 - Patient-oriented scheduling policies in surgery pre-admission testing clinics
Paola Cappanera, Maddalena Nonato, Sal Agnihothri, Filippo Visintin

Pre-admission testing clinics are care units serving outpatients before surgical operation and performing procedure-specific tests to assess eligibility. Patients may need multiple tests, each performed by a specialized operator and delivered in any order. This study considers a patient-oriented service model in which a patient occupies an exam room until all the required tests are completed, and tests are administered by different operators inside the rooms sequentially, in any order. Thus, patients stay inside the assigned room while operators move between rooms. This service model has recently gained momentum as an alternative to the traditional service organization where each ambulatory room is assigned to an operator and patients move between rooms. However, in this new service model, rooms become bottleneck resources and their utilization needs to be optimized to increase system throughput and reduce patient waiting time. The advantages and disadvantages of this service model are discussed from the perspective of both the patient and the provider. While there is no doubt that careful scheduling of patient appointments is essential in running clinics, the adopted scheduling policy can significantly affect stakeholders' perceptions of the service. We thus propose and compare optimization-based offline policies and commonly used online policies in a variety of scenarios based on realistic data.

Monday, 13:50-15:00

■ MD-03

Monday, 13:50-15:00 - Room: Room S2

Integrated Planning in Healthcare /1

Stream: Regular talks
Contributed session
Chair: *Melanie Reuter-Oppermann*
Chair: *Sean Manzi*
Chair: *Gréanne Leeftink*

1 - Bed census prediction combining expert opinion and patient statistics
Hayo Bos, Stef Baas, Richard Boucherie, Erwin W. Hans, Gréanne Leeftink

Predictions of bed census are crucial for hospital capacity management choices, encompassing ward sizing, staffing, patient bed assignments, and surgical scheduling. Presently, these predictions heavily rely on doctors' estimated Expected Discharge Date (EDD). This presentation introduces two probabilistic models that integrate EDD with LoS distributions derived from data. By employing the Poisson Binomial distribution and probabilistic convolution, we generate full census distributions. Applying our approach to real hospital data demonstrates its ability to provide precise predictions, leading to valuable managerial insights. We will also show the implementation of our model in our partnering hospital.

2 - Better use of scarce nursing staff through implementation of bed census forecasting
Rob Vromans, Richard Boucherie, Aleida Braaksma

Background: Hospitals face shortages of available nursing staff, especially during the COVID-19 pandemic. At the same time the number of nurses present is not in line with the demand for care, which results in inefficient use of available nurse capacity. This holds also for the Dutch hospital Rijnstate. Meanwhile, literature contains models that have shown to help hospitals align staff to patients.

Objective: Improve the use of nurse capacity in surgical wards while decreasing peak workloads by aligning the nurse shift schedules with the number of patients.

Methods: Based on historical data of 2018 and 2019 we model the relation between the OR-schedule and the number of required beds. For this purpose we use a statistical model (vanBerkel, 2011) to calculate the distribution of the required beds per hour based on the future OR schedule. This bed census is converted into staffing requirements with nurse-to-patient ratios by department heads in a Tactical Planning Meeting.

Impact: Before COVID-19 started, Rijnstate was able to reduce the number of nurse shifts per week, while maintaining its surgical capacity. During COVID-19, Rijnstate scheduled more OR-sessions than expected in the remaining beds for surgical patients. After COVID-19, Rijnstate increased the number of simultaneous OR-sessions while maintaining the reduced staff schedule. This study shows the potential impact of the application of (vanBerkel, 2011) in a Dutch hospital.

3 - Steering Through Uncertainties: Dynamic Integrated Patient-Room and Nurse-Patient Assignment in Hospital Wards
Fabian Schäfer, Emily Lex, 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. Integrating both assignment problems enables the optimization of additional objectives that depend on the interaction of the two assignment problems. For example, minimizing the walking distances of nurses or assigning the minimum number of nurses to patients in the same room to mitigate negative effects, such as the spread

of infections between rooms by nurses or the disturbance of patients. Existing literature tackles the static version of this integrated problem, assuming full prior knowledge of patient and nurse parameters. However, real-world hospital operations are rife with uncertainties, including patient no-shows, emergency admissions, fluctuating length of stays, and unforeseen nurse absences. Enhancing predictability and forecasting reliability necessitates accounting for stochastic variations within the planning horizon. We have developed a decision support model that addresses the dynamic patient-to-room and nurse-to-patient assignment. The model is presented as a mixed integer optimization problem. We present an efficient heuristic to solve the assignment problem under data uncertainty. We conduct computational experiments on real-world and artificially generated instances. A comparative analysis against the static problem formulation underscores the efficacy and superiority of our dynamic extensions.

■ MD-04

Monday, 13:50-15:00 - Room: Room S3

Cost Effectiveness

Stream: Regular talks
Contributed session
Chair: *Evrim Didem Gunes*

1 - Pharmaceutical Pricing and Access Policies: A Study of the Impact of Physicians' Imperfect Adherence to Prescribing Guidelines.
Rezvan Shahabbasi, Greg Zaric, Prashant Chintapalli

The rising costs of prescription drugs pose a significant challenge to healthcare systems. To address rising costs and uncertainties associated with new drugs, many payers have implemented various risk-sharing or managed entry agreements. In this study, we introduce an analytical framework that considers the impact of physicians' imperfect adherence to prescribing guidelines when setting drug prices and coverage thresholds in risk-sharing agreements. In our model, physicians are categorized into three groups based on their level of adherence to prescribing guidelines. The goal for the public payer is to maximize net monetary benefit (NMB), while the manufacturer aims to optimize its profit. We use a Stackelberg game framework to model the decision-making process where the manufacturer moves first and sets the price, and then the payer determines the access conditions. Our results demonstrate that optimal policies vary based on the degree of imperfect adherence to prescribing guidelines and the proportion of physicians who prescribe imperfectly. This study underscores the importance of accounting for imperfect adherence to prescribing guidelines in healthcare decision-making, benefiting payers, patients, and manufacturers in the industry. In contrast to prior research, our findings reveal that physician's deviation from guidelines introduces variability in optimal decisions related to price and threshold which is influenced by the type and proportion of physicians involved.

2 - Minimum cost diagnosis by sequential tests
Tonguc Ünlüyurt

The costs incurred for the medical tests used for diagnosis are quite significant. These costs include testing costs and misclassification costs. There is potential for decreasing such costs by determining the order of tests in a better way. Essentially, the next test to apply may depend on the results of the previously executed tests and there is typically probabilistic information regarding the outcome of the tests. The goal is to find a strategy that minimizes a performance metric such as the total expected cost. There are some published papers that study related problems in the medical testing context. On the other hand, there is quite a number of studies on Sequential Testing problem where a similar problem setting is considered for various other applications. In this talk, our goal is to review this problem setting with different variations. We will discuss the results from the literature and possible research directions towards applications in medical testing.

3 - The impact of time preferences on diabetic patients' adherence to therapy
Hakan Kılıç, Evrim Didem Gunes, Şeyda Özcan, Oğuzhan Deyneli

Non-adherence to therapy for patients with diabetes is expected to result in the deterioration of their health status and otherwise preventable hospitalizations that create a costly burden to the healthcare system. In their long-term chronic disease therapies, patients' self-management efforts lead to better future health. However, a patient's time preferences in terms of impatience, procrastination and self-awareness about procrastination might diminish the perceived future health benefits of adherence to therapy and motivate the patient to not adhere. We empirically examine this impact of time preferences on patient adherence. The previous work on this topic presents mixed conclusions about the relationship between adherence and time preferences. Moreover, there is no study investigating the effect of self-awareness. In addition to filling this gap, we aim to establish new insights by considering all dimension of adherence (medication, self-monitoring, follow-up visits, diet, exercise) together with possible operations management control by continuity of care and number of physician visits. A survey was conducted targeting adult patients with type 1 or 2 diabetes. Results of the study will be shared.

■ MD-05

Monday, 13:50-15:00 - Room: Room S6

Emergency Department /1

Stream: Regular talks
Contributed session
Chair: *Fermin Mallor*

1 - Process Mining Unscheduled Attendances in a Paediatric Emergency Department in Northern Ireland
Adele H Marshall, Christine Kennedy, Danny McWilliams, Peter Cosgrove

Emergency departments (EDs) in UK, after the COVID pandemic, have seen increasing demand and high pressures on resources and staff fueled by challenges accessing routine services. Northern Ireland EDs have described excess patient mortality due to overcrowding and increasing four-hour waiting time benchmarking from 28.2% in January 2013 to 56.6% in September 2023. Paediatric Healthcare in Northern Ireland is under particular pressure driven by unscheduled attendances, exacerbated by risk-adverse approach to children, and mis-match of healthcare resources for specialty services.

This research uses routinely collected ED data for unscheduled attendances and admissions for paediatric care during 2022-2023 and applies advanced analytics and process mining to identify key characteristics for unscheduled pressures. The approach provides an understanding of flow of unscheduled care in the paediatric ED and a method for identifying clusters of patient-types who present at the ED. The characteristics can also be linked with each patient type, waiting time distribution in ED and subsequent stay in hospital and may be used to cost-effectively redistribute the allocation of resources to high-yield areas and to model future planning scenarios.

2 - A hybrid simulation and optimization approach to manage Emergency Department overcrowding and patient boarding
Elena Tanfani, Paolo Landa, Luca Murazzano, Marina Resta, Angela Testi

Overcrowding in the Emergency Department (ED) and long waiting lists for elective surgeries are the main areas of unmet need in public health systems and an evidence of poor management. Patient boarding, i.e. the practice of holding patients in the ED due to a lack of inpatient beds, has been proved to be a significant determinant of ED overcrowding. Bed management enables an improved organization of the

flow of patients, thus reducing patient boarding. A hybrid simulation approach is proposed to model the interrelated dynamics of emergent and elective patient flows and evaluate the impact of alternative bed management strategies. Further, an optimization model is developed to determine the best set of decision parameters used by the bed manager to facilitate the admission of emergent patients in hospital wards. The hybrid simulation and optimization approach is applied to a real case study of a medium sized public hospital. An extensive scenarios analysis is presented to compare alternative strategies using a set of indicators able to evaluate the performance from different stakeholder viewpoints. The results highlight that improving the bed management strategy can reduce the number of boarding patients and the boarding waiting time without increasing the number of hospital beds and not affecting the elective patient flows.

3 - Analysis of the Influence of Physician Heterogeneity on Emergency Department Performance Measures
Fermin Mallor, Miguel Baigorri, Marta Cildoz

Healthcare services, such as emergency departments, operate as queueing models where patients are customers and healthcare staff are servers. Analysis of these systems is commonly conducted using simulation models due to their ability to capture complexity compared to other approaches based on queueing theory or differential equation systems. Simulation models emphasize detailed patient representation, categorizing them based on personal characteristics, illness, diagnostic tests, etc., but often overlook potential heterogeneity in medical practice. In this work, we demonstrate the significance of physician heterogeneity in shaping key performance indicators (KPIs) in hospital emergency departments. Our analysis highlights the need to enrich discrete event simulation models with agent-based models that capture medical staff differences in providing care and their response to changing workload conditions in emergency services. Specifically, we propose an agent-based model for physicians where patient care time depends on current workload and accumulated fatigue during the shift.

Monday, 15:30-16:40

■ ME-03

Monday, 15:30-16:40 - Room: Room S2

Pharmaceuticals Public Policy and Regulation: Exploring pathways to improving access, affordability and availability of medicines

Stream: Regular talks
Contributed session
Chair: *R. M. Kazakov*

1 - Behavioural Considerations for Scenario Simulation of Public Policy Interventions in Pharmaceutical Markets
R. M. Kazakov, Penka Petrova, Yavora Rosenova

Healthcare and pharmaceutical markets are composed of interdependent resources and agents who adapt their behaviours in response to one another and to changing external conditions. A complex adaptive systems perspective highlights the interconnectedness of resources and agents in healthcare and pharmaceutical markets, and emphasizes the importance of understanding how these interactions shape market outcomes and influence the delivery of healthcare services. This paper provides a practical example of hybrid resource agent simulation for the exploration and evaluation of pharmaceutical policies, related to medicines prescribing and pricing regulations, aiming at increasing access to affordable medicines on the local EU markets. The paper presents what if scenarios, performed through the use of a public pharmaceutical policy scenario simulator. They have the task to elicit the effects of the regulation tool box and its elements in combination with important contextual regulatory and market competition factors. This project extends further the practice of public policy evaluation through simulation, bringing a comprehensive approach and providing interactive learning environments, where decision makers can design and test policies through experimentation. Using decision support tools like public policy scenario simulators can enhance the design and testing of robust regulation and policy interventions, outcomes forecasting and prospective evaluation for optimal decisions.

2 - The importance of Play in medicine
Jurriaan van Rijswijk

In traditional medicine access to (pharmaceutical) therapy very much depends on the interpersonal relation between pharmacist, physician, and the patient. In times of digitalization the interaction between the three seems easier and more frequent. Nothing could be further from the truth. Personal contacts got lost. Moreover, with the ageing population resulting in a growth of consultations in combination with the increasing shortage of healthcare providers contributes to lesser access and lower effective treatment rates. It all depends to the behavior of the three. A dramatic change in behavior is highly required to return to levels of the traditional medicine, where mutual trust was based on personal interaction. And without compromising further digitalization of the healthcare journey, including artificial intelligence. It is proven that play stimulates the interaction between humans and builds trust and engagement. Play stimulates behavioral change and adaptation to new behavior. In a recent study among elderly rheumatic arthritis patients, it was shown that playful digital eHealth solution increased retention rates of over 5 years with 32 contact moments per month and 9 hours per month. Play can become a therapy, as was proven by EndeavorRx, a FDA approved video game for the treatment of ADHD. Integration of play in the ongoing digitalization of healthcare journey supports and increases therefore access to healthcare proven and demonstrated in several researched case

3 - A first approach to develop immunization strategies guidelines

Marisol Sarai Romero Mancilla, Jaime Mora-Vargas, Angel Ruiz

Since the emergence of the COVID-19 pandemic, new immunization strategies have been proposed for implementation in future health crises. A pharmacy-based immunization (PBI) proposal was previously presented in a case study in Jalisco, Mexico. PBI has been implemented throughout history in the United States, Canada, and other countries, but in Mexico mass vaccination was chosen despite the large network of pharmacies it has. However, is this the best strategy? In what phase of pandemics/epidemics should the different strategies be implemented? The purpose of this research is to show the impact of mass immunization (MI) carried out in 2020, its benefits and limitations, and to propose a hybrid immunization strategy: PBI + mass immunization (PBI-MI), as well as its benefits and limitations. To this end, we propose a mathematical formulation for the demand allocation model to mass immunization centers and a demand location-allocation model to pharmacies and mass immunization centers. The case of Jalisco, Mexico is used to illustrate the performance of the proposed approaches, and to prepare a first guide to the implementation of immunization strategies.

■ ME-04

Monday, 15:30-16:40 - Room: Room S3

Home Care /1

Stream: Regular talks
Contributed session
Chair: *Yannick Kergosien*

1 - A bilevel approach to the Home Health Care Routing and Scheduling Problem
Maria Teresa Godinho, Maria João Lopes

In a number of societies we are witnessing a steady increase in the incidence of chronic diseases, resulting in a growth of the number of people requiring continuous, specialized health care support. However, long, repeated hospital stays are undesirable, both due to clinical and social-economic reasons. Loss of mobility, immune suppression, depression and cognitive decline are often found in patients with prolonged hospitalizations. One way of mitigating these problems is through home health care services. Many medical treatments can be carried out at patients' homes, freeing hospital beds and contributing to increasing the patients' (and their families) quality of life. The generic term "Home health care" covers several regulated programs of care delivered at the patient's home. In Portugal, social security and the national health system offer different levels of home care, including custodial care (CC), intermediate or integrated continuing care (ICC) and highly skilled hospital level care (HHC) Despite the significant clinical differences, the three types of care have similar logistical needs: in essence, organizing the caregivers teams and the visits to the patients. In this talk, we propose a bilevel single commodity flow model of the routing problem where the outer level problem focus on the total operation cost and the inner level deals with degree of the caregiver team's satisfaction. Preliminary computational results will be provided at the talk.

2 - Optimizing Home Healthcare Operations: A Case Study on Routing and Scheduling
Elvin Coban, Yagmur Selenay Selcuk

Healthcare providers keep extending their services to patients' homes as home healthcare service is especially crucial for older adults, individuals with disabilities, and chronic patients who may have limited mobility or require regular checks outside traditional healthcare settings. In this study, we address a real-life motivated home healthcare routing and scheduling problem. The patients vary according to their time windows and requirements. Some patients may require blood draw necessitating delivery of blood samples to the hospital lab considering the perishability of blood samples and allowing the same day treatment, such as writing prescription. Our objective is to minimize the total cost, comprising routing costs for healthcare teams and penalties incurred due to the violation of patients' time windows. We consider healthcare teams' lunch breaks and any preferences expressed by patients regarding the healthcare teams assigned to them. A mixed-integer linear programming model is developed for this real-life motivated home healthcare routing and scheduling problem and we propose a simulated annealing-based matheuristic algorithm. We analyze our proposed model and heuristics' performance while comparing with the current system applied in the motivating hospital.

3 - A new variant of the home biomedical sample collection problem with drop-off points
Yannick Kergosien, Angel Ruiz

Medical services, like blood samples, play a vital role in healthcare. To improve the quality of services, some countries have reorganized their sample collection and laboratories' networks by centralizing analysis activities in a limited number of strategic laboratories. Since samples are drawn at several collection centers, they need to be transported to laboratories via an inter-facility transport network that operates according to predetermined schedules. Meanwhile, a significant number of samples is also collected at home. In this case, caregivers visiting patients' homes must deliver the collected samples at their base. The study aims to investigate how these two independent transport networks can be coordinated so that home caregivers profit of local collection centers as drop-off points. Samples collected at patients' homes will be joined to those taken at the collection centers and transported together to laboratories using the inter-facility transport network ensuring that the lifespan of samples is not exceeded. This problem extends the classic home care routing problems since it also requires planning stops at drop-off points so that samples can be delivered to the laboratory on time. This aspect adds significant complexity to the design of caregivers' routes. We propose a iterative matheuristic to solve this challenging problem. Preliminary experiments have produced very encouraging results although the algorithm needs to be tested on real-sized instances.

■ ME-05

Monday, 15:30-16:40 - Room: Room S6

Workforce Planning

Stream: Regular talks
Contributed session
Chair: *Jan Schoenfelder*

1 - A matheuristic approach for solving nurse rostering problems
Cristian Belfiore, Rosita Guido, Domenico Conforti

The Nurse Rostering Problem is a challenging staff scheduling problem that aims to assign a set of nurses to shifts within a scheduling horizon. Nurses are characterized by one or more skills, are hired through a contract that regulates their work, and can express preferences about days off or work shifts. A preferred coverage is defined for each shift in the planning horizon, representing the number of nurses the hospital would like to have. Assignments have to satisfy sets of constraints derived from internal hospital rules and legal requirements and must consider the preferences expressed by nurses. The main goal is to ensure adequate shift coverage while maximizing staff satisfaction and workload balance. In this study, a version of the problem proposed in the literature was addressed through a revised version of the matheuristic FiNeMath. The proposed solution approach starts by finding a solution that is feasible for a relaxed version of the problem. This is then iteratively refined through the combination of several destruction operators used to define neighbourhoods. Each destructed solution is repaired by exact approaches. The approach was tested on small and medium benchmark instances. Preliminary results have shown that the matheuristic can determine high quality solutions in a relatively short time.

2 - Matching Employee Preferences - Implementing a Learning Scheduling System for Healthcare Shift Workers

Arne Henning Witteborg, Michael Römer

In healthcare, particularly within hospitals, the optimization of shift scheduling for medical staff poses a significant challenge. The scheduling of employees is compounded by the need to balance operational efficiency with employee satisfaction, amidst high burnout and turnover rates. Our cooperation with a hospital in Bielefeld led to a conceptual framework aimed at identifying and incorporating healthcare workers' scheduling preferences into an optimization model. This approach explores the implementation of a learning scheduling system tailored for physicians, focusing on the integration of individual preferences into an optimization model. In order to take their preferences into account, they must be known and formalized. Since preferences for schedules could often not be explicitly articulated and are rather implicit, a critical aspect of realizing such a model involves the recognition and formalization of employee preferences. Through a three-step approach involving qualitative interviews, learning and integrating preferences from a focus group and evaluation of the system's acceptance, we aim to demonstrate how a preference learning approach can provide a possible solution through learning meta-parameters for individual customization and incorporating them in a linear programming model. With this approach we address the critical need for an adaptive scheduling system that respects the needs of employees, potentially leading to higher employee satisfaction.

3 - Optimizing adaptive medical staff scheduling using recourse decisions amidst fluctuating patient demand

Jan Schoenfelder, Markus Schüller, Jens Brunner

Scheduling medical staff during periods of fluctuating patient demand poses significant challenges, particularly during events like the COVID-19 pandemic. Current rostering practices, based on long-term expected patient load predictions, often lead to a limited ability to react to discrepancies between expected and actual patient emergences. In response to this challenge, we propose a Mixed-Integer Program (MIP) to optimize the allocation of flexible medical staff, ensuring appropriate patient care.

Our MIP framework consists of a two-stage optimization model. Firstly, it constructs the initial schedule based on forecasts of patient emergence and acuity levels provided by partners of the PROGNOSIS consortium. Secondly, it incorporates dynamic recourse decisions to adjust staffing levels in response to realized patient demand. Given the inherent uncertainty in patient demand, we evaluate scenario-based rosters using Sample-Average Approximation to provide insights into short-term adjustments in personnel scheduling.

With a temporal scope of one week, our approach addresses the immediate staffing needs of healthcare facilities, offering a practical solution for managing workload peaks and ensuring quality patient care during times of uncertainty.

Tuesday, 9:00-10:30

■ TA-03

Tuesday, 9:00-10:30 - Room: Room S2

Healthcare Logistics /1

Stream: Regular talks
Contributed session
Chair: *Jean-Charles Billaut*

1 - Improving Patient Transport in Hospitals: A Literature Review of Operations Research Methods
Tom Lorenz Klein, Clemens Thielen

Most activities in hospitals require the presence of the patient. Delays in patient transport can therefore cause disruptions and costly downtime in many different areas and departments, which makes patient transport planning a central operational problem in hospitals.

This talk presents the first literature review of Operations Research approaches for improving non-emergency patient transport in hospitals. We structure the different patient transport problems considered in the literature according to several main characteristics and introduce a four-field notation for patient transport problems that allows for a concise representation of different problem variants. We then analyze the relevant literature with respect to different aspects related to the considered problem variant, the employed modeling and solution techniques, as well as the data used and the level of practical implementation achieved. Based on our literature analysis and semi-structured interviews with hospital practitioners, we provide a comparison of current hospital practice and the existing literature on patient transport, and we identify research gaps and formulate an agenda for relevant future research in this area.

2 - The Final Frontier in Healthcare Operations Research
Amy Cohn

Foundational developments in OR, ranging from optimization to simulation to AI/ML and more, have enabled a substantial body of applied research to address critical problems in healthcare delivery, operations, and treatment. To ensure that this research has maximal real-world impact, we must push this work even further to fully encompass all of the messiness of applying solutions in the real world. This is not solely a question of implementation science or change management, but also of deeply multi-disiplinary collaborative efforts that ensure our models and algorithms are robust enough to incorporate the nuances that make-or-break succesful implementations. Drawing from my "double life" as an IE/OR professor and as Chief Transformation Officer of a major academic medical center, I hope to facilitate a lively discussion about the challenges and opportunities for our community in this space.

3 - Using Data-Driven Models for Critical Care Decision Support
Daniel García-Vicuña, Ana María Anaya-Arenas, Janosch Ortmann, Angel Ruiz, Fermin Mallor

The dilemma of the last available bed highlights the lack of ICU beds and the difficult decisions hospitals must make when resources are limited. With a surge in demand, hospitals are often compelled to prioritize patients, leading to the postponement of surgeries or premature discharges. Such actions, while necessary, pose significant logistical challenges in ensuring that all patients receive the necessary level of care. Effective management of hospital beds becomes paramount in optimizing patient treatment, particularly during times of healthcare crises. To address this challenge, this study endeavors to develop innovative methodologies utilizing real patient data. These methodologies aim to provide healthcare professionals with valuable insights for making informed decisions regarding resource allocation and capacity planning. By leveraging a comprehensive set of patient characteristics and medical history, we seek to predict the length of stay for patients in the ICU. This predictive modeling approach enables us to anticipate patient needs more accurately and allocate resources more effectively. By illustrating our findings with real-world data and simulations, we aim to demonstrate the practical utility of these methodologies. Our goal is to empower healthcare professionals with tools that can enhance decision-making processes, ultimately improving patient outcomes and optimizing resource utilization in healthcare services.

4 - A Medical Samples Dispatching Problem
Jean-Charles Billaut, Hélène Blasco, Marina Vinot

For many rare diseases (e.g. amyotrophic lateral sclerosis), no diagnostic and prognostic biomarkers have been identified to help ensure good patient care and medical research in these areas is generally very active. For each disease, several centers treat cohorts of patients, with regular visits for clinical and biological explorations. In the field of health research, many research projects are based on the exploration of biological fluid samples and involve different hospital centers. The need to centralize samples in specialized laboratories responsible for specific biological analyzes is crucial. The Medical Samples Dispatching Problem is how to organize the flows to optimize the use of these precious samples. We consider that several biological fluids (blood, cerebrospinal fluid, etc.) are collected from each patient of each cohort in several tubes of varying quantities. Each product must reach the other centers, which express needs for each product. Three constraints complicate this (sort of flow) problem: (1) dividing a sample into several portions is a tedious aliquoting operation, (2) a shipment requires a freeze/thaw operation, and (3) a patient sample cannot arrive in two different tubes on the same site. We minimize the maximum number of aliquoting operations and limit the number of freezing operations. We show that this problem is NP-complete, propose an MILP model, a lower bound and heuristic algorithms.

■ TA-04

Tuesday, 9:00-10:30 - Room: Room S3

Epidemiology and Prevention

Stream: Regular talks
Contributed session
Chair: *Sally Brailsford*

1 - Screening Strategies for Type 2 Diabetes in Low- and Middle-Income Countries
Dursen Deniz Poyraz, Harwin de Vries, Qingxia Kong

In low- and middle-income countries, Type 2 Diabetes (T2D) can more easily be overlooked due to limited resources and develop into more severe health conditions such as diabetic foot, retinopathy, kidney disease, stroke, and heart attack. Medical studies signal the importance of early detection and show that lifestyle changes and a healthy diet can help not only stop T2D from developing but also recover a prediabetic patient back to a healthy state. To tackle this huge preventable disease burden, countries and organizations are putting efforts into early detection. One key strategy is to scale these efforts up through active screening campaigns. Though screening campaigns are effective at detecting cases, required resources are scarce, making it crucial to optimize policies that guide the deployment of such campaigns. Two decisions of such policies are i. the frequency at which to screen a given population, and ii. the criteria for including people in the screening. Institutions such as the American Diabetes Association and World Health Organization have guidelines with a fixed frequency and risk threshold for populations when there appear to be strong reasons to differentiate. To address the issues on screening for T2D in a limited resource setting, we model the disease progression as a Markov chain. We use an optimization model that maximizes the total quality-of-life score under a budget constraint, and simulation to evaluate the performance of various simple policies.

2 - Modelling risk-factors for non-communicable diseases
Steffen Bayer

Non-Communicable Diseases (NCDs) are the leading public health challenge globally, with disproportionately higher rates in developing countries due to unhealthy diets, physical inactivity, tobacco use, and harmful use of alcohol; systemic, and structural factors include weak and non-performing health systems as well as problems such as air pollution. Programmatic inefficiencies and operational failures of both the health and food systems also contribute to the rising burden of NCDs. In addition, population ageing acts in tandem as older individuals have an increased risk of NCDs. This presentation will introduce a hybrid modelling approach to simulating the effect of risk factor management on (primary and secondary) prevention of cardio-vascular diseases and diabetes. The model allows to compare the effect of public health interventions on long term health status of the population and can support health policy making.

3 - EpiMORPH: Expediting the Workflow of Epidemiological Modeling
Esma Gel

This talk introduces EpiMoRPH, a groundbreaking tool for advancing epidemiological modeling. It provides a robust framework for rapid model development and evaluation, promoting automation, collaboration, and deeper understanding of epidemic dynamics. EpiMoRPH features an advanced optimization toolkit, empowering public health practitioners to make informed decisions on intervention placements and strategies.

4 - A tale of two viruses
Sally Brailsford

This talk reflects on the role of OR with respect to two different viruses, HIV and COVID-19. In both cases, the emergence of a new disease with high public visibility (and associated government funding) stimulated a significant modelling effort in the OR community. However, in a Web of Science search of the literature (limited to the category 'Operations Research Management Science' and excluding authors based outside Europe), the string 'HIV not COVID' returned 63 hits since 1988 whereas the string 'COVID not HIV' returned 640 hits since 2020. Expressed in terms of papers per year, this gives a ratio of 1.7 for HIV/AIDS and 128 for COVID-19. Is this huge disparity merely due to the expansion in the numbers of new journals since 2010, combined with increasing pressure on academics to 'publish or perish', or is it related to the diseases themselves? Certainly, AIDS did not turn out to be a global pandemic on the scale of COVID-19, although in the early years no treatment was available and epidemiologists were extremely concerned that the virus might spread into the general population. A more encouraging hypothesis is that since 2000 OR has become a recognised and valued discipline in the field of infectious disease modelling, with a vibrant research community, since OR can address practical problems of resource allocation and logistics in a way that mathematical epidemiology cannot.

■ TA-05

Tuesday, 9:00-10:30 - Room: Room S6

Operating Room Scheduling /1

Stream: Regular talks
Contributed session
Chair: *Massimiliano Ronzani*

1 - Operating room scheduling with balanced sterilization activities
Dariush Zahmatkesh, Maria Di-Mascolo, Aida Jebali

Every year, millions of surgeries are performed worldwide, generating a large portion of hospital revenues. Improving surgical efficiency, such as by adding one more surgery per room daily, could therefore significantly boost hospital income. A crucial aspect of Operating Room (OR) efficiency is tied to managing the sterilization of Reusable Medical Devices (RMDs) to prevent delays and so cut surgery costs. Despite its importance in OR scheduling, integrating sterilization remains largely unexplored. This study seeks to show how OR scheduling can streamline sterilization, reducing surgery delays caused by unavailable RMDs. Beyond financial gains, this scheduling will enhance patient and staff satisfaction. We propose a mathematical model to minimize RMD volume variability sent from ORs to the Sterilization Unit (SU). Our model employs optimization techniques to cut OR costs and balance SU activity. Simulation compares current scheduling practices with our proposed model, aimed at improving sterilization and OR performance. A smoother RMD flow to the SU should enhance sterilization and OR efficiency, as reduced SU flow times increase RMD availability for reuse. Keywords: Surgery Scheduling, Sterilization, RMDs, Mathematical Programming, Optimization, Simulation.

2 - Operating room scheduling with consideration of the Post-Anesthesia Care Unit: a simulation study
Gabriela Pinto Espinosa, Aida Jebali, Erik Demeulemeester

Operating Rooms (ORs) play a crucial role in revenue and cost generation within healthcare institutions. They are the bottleneck resource of surgical patients' care and highly impact the activity of other departments. Consequently, OR Planning and Scheduling is a vastly studied field due to its complexity, stemming from the uncertainty of the OR environment and of the multiple resources it involves. Building on Schoenfelder et al. (2021), we propose a simulation study to test and compare different scheduling heuristics and management policies for the Daily Scheduling problem. Our objective is, first, to evaluate heuristics proposed by Schoenfelder et al. (2021), Wang et al. (2022) and Jung et al. (2019), but with a key contribution of integrating the Post-Anesthesia Care Unit (PACU) in OR scheduling and simulation. Specifically, we consider PACU bed availability and OR blocking, with uncertain surgery and anesthesia recovery durations, as well as elective and non-elective patients with uncertain arrivals. Then, we introduce novel heuristics, considering the PACU in the decision making, for the sequencing of surgeries in the OR, assignment of patients to PACU beds and online policies after the realization of uncertainty on the arrival of non-elective patients and surgery and recovery durations. We analyze the performance of the proposed solutions by studying KPIs related to cost, work-life quality of the hospital staff and patient satisfaction.

3 - Overcoming the bottleneck: data-driven strategies and analytics of operating room management from an integrative view
Haoliang Pan, Peng Gao, Xiaolei Xie

Operating rooms represent bottleneck units in most hospitals. Operating room managers are devoted to balancing the two contrasting goals of maximizing prime time utilization and minimizing overtime work. This task can be very difficult because it involves the uncertainty of surgery durations. In this study, we develop a data-driven framework to solve the surgery scheduling problem faced by many large hospitals. We utilize machine learning methods to capture the nature of uncertainty of surgery durations. Then, we construct a stochastic optimization model that addresses the managerial goals of resource utilization and the constraints of resource overuse of operating rooms. The model is hard to solve because of its complex structure under uncertainty, especially the chance constraints. In the light of this, we develop a novel data-driven approach to obtain a polyhedral approximation of the feasible region of the original model. By using real data from a large hospital in China, we find that our proposed approach outperforms classical sample average approximation approach. We emphasize that our approach demonstrates great potential in rapid decision-making scenarios, which are frequent and critical cases in healthcare systems. Our approach also yields managerial insights of quantitative relations among various operative goals of interrelated units in the hospital system, which could help hospital managers determine proper strategies and goals to pursue integrative benefits.

4 - Enhancing Scheduling Efficiency in Interventional Radiology through Optimization and Predictive Process Monitoring
Massimiliano Ronzani, Matteo Di Cunzolo, Roberto Aringhieri, Chiara Di Francescomarino, Chiara Ghidini, Alberto Guastalla, Emilio Sulis

Interventional Radiology (IR) is a growing medical field using imaging technologies for minimally invasive procedures. Despite similarities to operating rooms, IR poses unique management challenges seldom addressed in literature. This study introduces a novel approach, integrating optimization and predictive process monitoring (PPM) models, to address specific IR complexities. Results demonstrate improved scheduling efficiency and patient throughput compared to traditional methods, highlighting the effectiveness of PPM integration.

Tuesday, 11:00-12:30

■ TB-02

Tuesday, 11:00-12:30 - Room: Room S1

Advances in Health Economics and Healthcare Management

Stream: Regular talks
Contributed session
Chair: *Paolo Landa*
Chair: *Maude Laberge*

1 - Complexity, interface management and unintended consequences of planned interventions illustrated by the DRG financing of Austrian hospitals
Marion Rauner, Margit Sommersguter-Reichmann, Doris Behrens

This study explores scientific evidence on the repercussions of a large-scale public healthcare intervention in Austria. Diagnosis Related Groups (DRG) funding, implemented in Austria's public hospital inpatient sector in the late 1990s, has created numerous examples of past and ongoing adjustments to fix unintended consequences prompted by intervention-induced behaviour changes. We pay particular attention to interface management, which is essential in a highly fragmented healthcare system like the Austrian one. We track how the fragmentation and complexity of Austria's healthcare system have hindered the success of the planned intervention in a specific part of the healthcare system and caused a negative shock to other healthcare sectors. The paper illustrates that the incentives inherent in Austrian DRG financing set off a cascade of ongoing adjustments. These seemed necessary as the behavioural patterns that emerged to bend and bypass the rules of DRG financing would have nullified the intended effects of the intervention.

2 - Care trajectories of people with mood disorders in Quebec using latent class analysis and latent profile analysis methods
Maude Laberge

The prevalence of mood disorders has increased globally. People with mood disorders have been found to use more health services than the general population but a mood disorder diagnosis does not entail utilization of health services. This heterogeneity in health services utilization could make it difficult for governments to plan resources to meet the needs of people with mood disorders. We used a database of patient-level linked data from residents of Quebec, Canada, to model care trajectories of people who self-reported having been diagnosed with a mood disorder. The data from the Canadian Community Health Survey were linked to health administrative data for a 21-year period. We used latent class analysis and latent profile analysis to group people into categories. We identified four care trajectories using the latent class analysis. Class 1 consists of people who consulted a general practitioner. People in Class 2 use psychiatric services and/or the hospital. Class 3 is composed of people whose utilized is for specialists other than psychiatrists. Most participants were in Class 4, characterized by a null utilization. For the LPA, we found 4 profiles for medical services, and two profiles for hospital utilization. By classifying people into services utilization groups, these methods enable determining needs for a given population and can support resource allocation for health care decision makers.

3 - Increasing Cost-Effectiveness of AEDs using Algorithms to Optimize Location
Derya Demirtas, Robin Buter, Remy Stieglis, Hans van Schuppen, Erik Koffijberg

Volunteer responder systems aim to decrease time to defibrillation by dispatching trained volunteers to automated external defibrillators

(AEDs) and out-of-hospital cardiac arrest (OHCA) victims. AEDs are often underutilized due to poor placement. This study provides a cost-effectiveness analysis of adding AEDs at (near-)optimal locations to maximize quality-adjusted life years (QALYs).

We simulated combined volunteer, police, firefighter, and EMS response scenarios to OHCAs, and applied our methods to a case study of Amsterdam, the Netherlands. We compared the competing strategies of placing additional AEDs, using steps of 40 extra AEDs (0, 40, . . . , 1480), in addition to the existing 369 AEDs. Incremental cost-effectiveness ratios (ICERs) were calculated for each increase in additional AEDs, using a societal perspective and life-time time horizon. The effect of AED connection and time to connection on survival to hospital admission and neurological outcome at discharge was estimated using logistic regression, using OHCA data from Amsterdam from 2006-2018.

Purchasing up to 1120 additional AEDs (ICER EUR 75,669/QALY) was cost-effective at a willingness-to-pay threshold of EUR 80,000/QALY, when positioned (near-)optimally. Compared to current practice, adding 1120 AEDs resulted in a gain of 0.111 QALYs (95% CI 0.110-0.112) at an increased cost of EUR 3792 per OHCA (95% CI EUR 3778- EUR 3807). The findings advocate for a substantial increase in the number of AEDs.

4 - A predictive model for patient length of stay and hospital pathway for specialized respiratory diseases hospital.

Paolo Landa, Marzia Angela Cremona, Luca Murazzano, Jean-Baptiste Gartner, Andre Cote

The analysis of hospital and department performances is a key element for understanding and enhancing the quality of services given by healthcare providers, enabling continuous improvements and benefits for the users, third payers, and community. Over the past decades, there has been increased interest in employing advanced data mining methods such as machine learning to improve hospital performance. The length of stay is often used as a surrogate for other outcomes, and it can define healthcare resource utilization. In this study, we present a predictive model for patient length of stay and hospital pathway definition of four clinical diseases (chronic obstructive pulmonary disease, pneumonia, lung cancer, and pulmonary fibrosis). Data were extracted from the electronic patient record system of the Pulmonary and Cardiology University Institute of Quebec for Respiratory and Cardiovascular diseases for hospital admissions and discharges. A total of 22,194 episodes, which contain 4,714 patient records from January 2018 to December 2022 at one Canadian hospital were analyzed by using parametric and nonparametric statistical methods. A regression analysis was carried out to model the length of stay and hospital pathway definition as a function of several independent variables such as lab tests, diagnostic imaging, admission type, and patient origin. The preliminary results show the possible economic and clinical implications for both patients and hospital management.

■ TB-03

Tuesday, 11:00-12:30 - Room: Room S2

Humanitarian Logistics and Blood Supply

Stream: Regular talks
Contributed session
Chair: *John Blake*

1 - Research Perspectives and Areas for Improvement in the Production of Blood Components from Donated Units

Ettore Lanzarone, Aleyna Gürsoy, Roberto Pinto, Federico Piccinini, Davide Ghezzi, Silvano Rossini

Blood is a vital resource for health care, but at the same time limited in that it can only be obtained from donations made by healthy individuals. The Blood Donation Supply Chain (BDSC) is responsible for managing the demand and supply of blood and blood component units, and consists of four echelons: collection, production, storage, and distribution. We focus on the production/separation of blood components (including erythrocytes, plasma, platelets and cryoprecipitates) from whole blood units, which is the least studied BDSC echelon in the literature. Generally, this separation is a make-to-stock process, and alternative fractionation sequences can be used to produce blood components from whole blood units. We address this production echelon from a scheduling perspective, which, to the best of our knowledge, has not been done so far in the literature. We first analyse the Immunohematology and Transfusion Medicine Department of the Niguarda Hospital, Milan, Italy. Then, we extend our analysis to a general class of systems and compare the European and US systems. Based on these analyses and a literature review, we evaluate future research directions to improve the management of this production system. In particular, we map the production of blood components within the de-manufacturing sector, to analyse the approaches applied in this sector that can also be effective for this special production.

2 - Designing an Alliance Network among dialysis centers for disaster preparedness

Evrim Didem Gunes, Sırma Karakaya, Burcu Balcik

Disasters pose significant threats to patients with end-stage kidney disease (ESKD), who rely on regular dialysis treatments to prevent complications and fatalities. Motivated by the problems observed during previous disasters, we introduce the Alliance Network Problem, aiming to establish a centralized alliance-based coordination mechanism for renal relief. We propose a two-stage mixed integer programming model that proactively sets alliance relationships among clinics and make patient-backup clinic assignments considering various factors such as a pre-determined limit on alliance sizes, patient demands and uncertainties in post-disaster clinic capacities. Through a case study focusing on a subset of dialysis clinics located in Istanbul-Turkiye, we demonstrate the effectiveness of our approach in bolstering disaster resilience for ESKD patients. Our findings underscore the importance of proactive alliance formations and centralized coordination mechanism in mitigating the impacts of disasters on dialysis treatment. We provide insights for policy development and highlight the benefits of integrating various resilience strategies with alliance formations. This study contributes to bridging the gap in disaster preparedness and response for renal relief, and aid public health authorities to be prepared for future disasters.

3 - Strategic positioning of mass transportation vehicles in the event of disasters

Florentina Hager, Melanie Reuter-Oppermann

Efficiently providing medical care during mass-casualty incidents, characterized by a sudden surge in demand, presents a complex logistical challenge. Time becomes a critical factor, affecting survival rates and emphasizing the need for rapid casualty transfer to medical centres. However, as local capacities in disaster-stricken areas can be congested, disaster managers must consider the establishment of temporary medical centres or the transport of casualties to distant permanent facilities. While temporary facilities provide relief to the congested capacities in disaster areas and minimise transportation time, they necessitate setup time and can only provide limited care. Conversely, mass transportation vehicles may facilitate rapid transfers but require careful positioning for optimal efficiency. However, in the optimal placement of mass transportation vehicles, decision makers should consider several aspects related to both the specific characteristics of the different types of disasters and the interaction between the different transportation modes. Our research therefore focuses on the strategic positioning of mass transportation vehicles for the transportation of casualties after a disaster. By optimizing the location for multiple transport modes simultaneously, we take into account the interaction of the different means of transport and at the same time the specific characteristics of a disaster.

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

John Blake

Following the end of COVID-19, a shift in blood donor behaviour occurred. Individuals are less likely to become donors and, if they donate, lapse more frequently. Changes in donor behaviour combined with the conversion of whole blood collection centres to dedicated plasma donation centres (PDCs) has led to a prolonged period of lower inventory at Canadian Blood Services; national stocks of red cells are lower than have previously been experienced historically.

An analysis of donor behaviour indicates that individuals are highly sensitive to distance and are less likely to be a donor the farther away from a collection site the person lives. The rapid decay for donor participation vs. distance suggests that additional donor collection opportunities (fixed or mobile) must be established if the collection targets are to be expanded. However, adding collection sites is only part of the solution. The placement of new collection centres into the CBS network will change its structure. In this presentation we discuss a model to optimize the blood supply chain in Canada for today and for the next decade.

■ TB-04

Tuesday, 11:00-12:30 - Room: Room S3

Modeling and Simulation /1

Stream: Regular talks
Contributed session
Chair: *Elisa Alessio*

1 - Discrete event simulation model to enhance decision making and product flow in Human Milk Banks
Marta Staff, Navonil Mustafee, Natalie Shenker

Human Milk Banks (HMBs) provide safe and screened donor human milk (DHM) which can be lifesaving for vulnerable premature infants in hospital settings. Provision for older infants in the community is also undertaken in cases where mother's own milk is unavailable (e.g. maternal illness or death). Feed volumes of DHM is a strong function of infants' age/size, with premature infants requiring significantly less than older community infants. Also, the requirements related to DHM's shelf life and quality are more stringent for hospital use. For these reasons HMBs may provide DHM in different bottle sizes, with different grades and shelf lives. Demand for DHM from hospitals is variable and HMBs have the opportunity to substitute hospital grade milk to community users in case of excessive stock holding of the former. This is aimed at waste reduction and allows for greater community provision. However, community use favours (both pragmatically and economically) larger bottle sizes, which points to a need to better understand production decisions in HMBs. A DES model is therefore presented which models stochastic hospital demand, and production constraints related to production capacity and processing times, and shelf life, which is used to explore decisions around production decisions related to the substitution of hospital grade DHM to the community. The DHM industry, mostly overlooked by the OR community, presents an impactful research opportunity to aid vulnerable infants.

2 - Navigating Hospital Operations Through Simulation: A Study of Urban Flooding Disasters and Physical Damage Impact
Sorour Farahi, Steffen Bayer, Stephan Onggo, Sally Brailsford

One consequence of disasters is physical damage to hospital buildings. In such situations, hospitals must continue operations despite being partly damaged or destroyed. Urban flooding is a specific example of a natural disaster that can result in physical damage to hospitals, affecting their ability to recover. While a number of studies have explored whole-hospital modelling, this research focuses specifically on investigating the effects of urban flooding disasters on hospital recovery and the influence of various policies. To address this, we developed a discrete-event simulation model of an entire hospital. A unique feature of this model is its ability to track patient outcomes using health utilities, which are assessed throughout the hospital process to evaluate performance. Focused on the dual challenge of disrupted treatment for routine patients and urgent care for disaster victims, this research examines the critical consequences of balancing the needs of these two patient categories. The model experiments with two categories of scenarios: disaster situations and response policies. The results from the simulation model will provide actionable recommendations for policymakers at the hospital level to apply in their hospital disaster management plans.

3 - Improving Patient Scheduling: A Case Study from a Mammography Department.
Marie Petit, Erik Demeulemeester

This study originates from a practical case analysis conducted within the mammography department of the University Hospital of Leuven (UZ Leuven). The process typically begins with the majority of patients undergoing either mammography or echography, followed by additional examinations based on initial findings. Historically, the department did not account for the examination types and the diverse patient profiles while planning appointments, as these were not predetermined. Consequently, the current scheduling approach involves random allocation of appointments per hour, with a higher concentration of patients scheduled at the beginning of morning and afternoon sessions, resulting in prolonged and uncomfortable waiting times for patients. The primary objective of this study is to devise a coherent scheduling system for the mammography department that achieves a balanced workload distribution among staff members while minimizing direct patient waiting times. To accomplish this, various scheduling scenarios are evaluated using simulation modeling. Based on collected data, predictions about the different types of patients are made and used to improve patient scheduling. Results demonstrate significant reductions in direct waiting times and improvements in workload distribution.

4 - Emergency Departments Demand Management: Introducing a New Scheduling Service through Virtual Triage Implementation
Elisa Alessio, Mattia Cattaneo, Sebastian Birolini

The emergency department (ED) plays a vital role in our society, providing 24-hour emergency care. However, overcrowding, caused by increasing "non-emergency" visits, limited resources, and operational inefficiencies, is a significant problem. This situation compromises the timeliness and accessibility of emergency care. Over the years, various solutions have been proposed to address the problem of overcrowding, but none has completely solved the issue. However, in recent years, a new technology is developing and could prove crucial in combating overcrowding: virtual triage. This tool allows patients to be assessed remotely, providing instant triage recommendations to avoid overestimates, reduce unnecessary hospital admissions, and evenly distribute healthcare demand. In particular, this study seeks to explore how this innovative remote solution can enable the identification of all those patients who, although not urgent, require specific investigations at the ED and thus introduce an appointment-based service that can improve the patient experience overall, reducing long waits on-site and optimizing the use of available resources. We will develop a simulation model based on current ED procedures to study the effect of this new service on ED performance. We will assess patients' willingness to use this system through a stated preference analysis in which subjects will be asked to indicate their preferences in relation to three main alternatives.

■ TB-05

Tuesday, 11:00-12:30 - Room: Room S6

Healthcare Management /1

Stream: Regular talks
Contributed session
Chair: *Christine Di Martinelly*

1 - Exploring the Role of Safety Culture Dimensions in Patient Safety using a Bayesian Belief Network Model
Mecit Can Emre Simsekler, Abroon Qazi, Al Ozonoff

There is a growing recognition of how a multi-dimensional safety culture impacts patient safety in healthcare organizations. However, understanding the interrelations among these dimensions and their relative importance remains unclear. To address this gap, we developed a Bayesian Belief Network (BBN) model using Hospital Survey on Patient Safety Culture (HSOPSC) SOPS Hospital Survey 2.0 data from U.S. teaching hospitals. Our study provides insights into the strength of influence among safety culture dimensions, explores primary factors contributing to patient safety, and guides decision-makers on optimal resource utilization by prioritizing safety culture dimensions. We found that 'communication openness,' 'supervisor support for patient safety,' and 'organizational learning - continuous support' are leading dimensions significantly impacting patient safety ratings. This analysis is crucial for decision-making, offering insights into how to prioritize dimensions for optimal resource allocation. The BBN introduces novel perspectives on critical cultural dimensions associated with patient safety, providing a visual representation of probabilistic relationships and potential approaches for enhancing patient safety in healthcare settings.

2 - How We Can Reap the Full Benefit of Teleconsultations: Economic Evaluation Combined With a Performance Evaluation Through a Discrete-Event Simulation
Marius Huguet, Marianne Sarazin, Vincent Augusto

This study evaluates the use of teleconsultations (TCs) for specialist consultations at hospitals in terms of costs, resource consumption, and patient travel time. The key feature of our evaluation framework is the combination of an economic evaluation through a cost analysis and a performance evaluation through a discrete-event simulation (DES) approach. A propensity score matching procedure was applied in the economic evaluation. To identify the best scenarios for reaping the full benefits of TCs, various scenarios depicting different population types and deployment strategies were explored in the DES model. The results of the cost evaluation reveal a higher cost for the TC group, mainly induced by higher volumes of (tele)consultations per patient and the substantial initial investment required for TC equipment. The incremental cost of TCs was not statistically significant: EUR 356.37 - EUR 305.18 = EUR 51.19 (95% CI 35.99 to 114.25; P=.18). Sensitivity analysis suggested heterogeneous economic profitability levels within subpopulations and based on the intensity of use of TC solutions. In fact, the DES model results show that TC performance is strongly related to the context and deployment strategy involved, depending on population characteristics, the amortization speed of telehealth equipment, and the locations of telehealth stations.

3 - Operating Room allocation Scheduling under Human Resources
Christine Di Martinelly, Xiajie Yi

Effective Operating Room (OR) scheduling holds significant financial implications for hospitals, particularly when dealing with inpatient procedures at the operational level. However, the duration of a surgery is often uncertain, and it is rather challenging to accurately predict. Estimates can vary significantly across different departments, leading to various extents of underestimations. As a result, it exacerbates nurse shortage issue in hospitals. To address this, we propose an approach to build robust surgery schedules in an OR theatre made of several rooms with different specialties and sharing nurses. Our method utilizes a two-stage stochastic optimization model. In the first stage, we determine the number of nurses working each day, while the second stage focuses on creating the detailed schedule. Additionally, we adopt the sampling average approximation (SAA) technique to address uncertainties in surgery duration. Based on the samples generated from real-life data, the simulation results imply that i) the surgery schedule could be fully scheduled with fewer number of nurses; ii) the nurse shortage/absence issue can be potentially avoided as we can accommodate uncertain duration better.

4 - Analytics in hospital operations management and healthcare services planning in China
Haoliang Pan, Xiaolei Xie

In this talk, I will start by introducing the basic features of the Chinese healthcare system and major healthcare organizations with the goal of identifying the focus and perspectives of the systems studies and implementation toward future smart care delivery. A few real-world research projects in the area of hospital operations management and healthcare services planning will be discussed. The models, methods and implementations will be presented. In the end, I will share the takeaways from these collaborations.

Tuesday, 14:00-15:30

■ TC-01

Tuesday, 14:00-15:30 - Room: Auditorium

Poster session

Stream: Posters
Award Competition session
Chair: *Melanie Reuter-Oppermann*
Chair: *Ettore Lanzarone*
Chair: *Alexander Rutherford*

1 - Emergency surgery allocation: Simulation-optimization approach incorporating scheduled elective surgeries under a hybrid emergency strategy
Chao Pan, Erik Demeulemeester

A sudden surge in emergency surgeries strains the critical and limited resources of the operating room (OR). Relying solely on human judgment for emergency surgery decisions may worsen congestion, leading to potential delays or cancellations of both emergency and elective surgeries. In the worst case, if the initially allocated hospital lacks capacity, the patient may face a second transfer, causing additional treatment delays. To address these risks, we develop a stochastic mixed-integer programming model for emergency patient allocation with a hybrid emergency surgery strategy. We then design a simulation-optimization approach to assess the expected maximum capacity for accommodating emergency surgeries. Our approach expedites decision-making in urgent cases, allowing decision-makers to make more rational choices swiftly. Specifically, we propose an improved sample average approximation method with a stopping rule for single-hospital cases, integrating it into the optimal computing budget allocation algorithm for multi-hospital settings. To demonstrate the efficiency of the proposed algorithms, we conduct experiments with real data from a 3A hospital in China. Our results illustrate the robustness of our methods through a sensitivity analysis of internal factors (overtime length), external factors (release time of emergency patients), and expected elective surgery durations. Additionally, we highlight the benefits of collaborative decision-making in multi-hospital setting.

2 - Simulation-based optimization for solid organ transplantation management
Arianna Freda, Gaia Nicosia, Maurizio Naldi, Andrea Pacifici

Organ transplantation significantly improves both life quality and longevity by replacing damaged organs. However, timely management of donors is crucial to prevent organ degradation. This work introduces a comprehensive approach to address these challenges. Initially, using real-world data—obtained from a number of successful solid organ transplant cases in the Lazio Region in Italy, in the years 2022 and 2023—we develop probability models for various activities, with a particular focus on the time required to obtain consent for organ donation, which is an essential step in the process. Moreover, we employ a UML activity diagram and Monte Carlo simulation to model the whole process from Donor's Brain Death Assessment to Organ Harvesting and evaluate its duration. Subsequently, we conduct multiple simulations to explore alternative procedures aimed at optimizing cost-performance trade-offs. Perturbations such as rearranging test sequences are investigated for their potential to achieve significant time reductions, though with potential cost implications if consent is not obtained. Our findings underscore the importance of efficient donor management strategies in organ transplantation and highlight ways for improving process efficiency while balancing associated costs.

3 - Optimizing dynamic reserved resource capacity in appointment scheduling with elective and semi-urgent patients
Jedidja Lok - Visser, Heleen den Hertog, Gina van Vemde, Jan Gerard Maring, Gréanne Leeftink

In appointment scheduling, it is a common practice to reserve some slots for (semi-)urgent demand arrivals, that require service quickly. The other slots are then given to clients that request an appointment upfront. To determine the number of reserved slots, the (semi-)urgent demand arrivals are often modelled as a distribution with static or seasonal distribution parameters. However, due to recent advances in remote monitoring and telemedicine, updated (semi-)urgent demand arrival information might become available over time. In this study, we use this updated information to dynamically optimise appointment schedules.

We propose near-optimal scheduling policies that reserve slots for (semi-)urgent clients, using updated information on the arrival distribution of (semi-)urgent clients in the near future. We formulate the sequential decision making problem as a Markov Decision Process. We test this model on a Dutch real-life case study in the neurology department of Isala Clinics, Zwolle. This neurology department implemented a brain rehabilitation program in combination with an e-coach for Cerebral Vascular Accident patients. We use the number of active patients in this monitoring application to forecast the number of semi-urgent requests for outpatient appointments. We discuss first results on this practical case study and theoretical instances, and present managerial implications of our near-optimal policies.

4 - Rescheduling of Surgeries in an Online Setting
Alexander Müller, Dominik Grimaldi, Alexander Martin, Lorenza Moreno, Sonja Weiland

A crucial task of ORs management is to coordinate the complex interplay between deviating durations of planned procedures, emergencies and changing resource availability. Thus, it is necessary to constantly make decisions during ongoing surgeries under time pressure and to take a variety of factors into account. With our optimization approach, we want to provide a decision support tool that assists in rescheduling surgical cases during live operation. Our model is based on a Resource Constrained Project Scheduling Problem (RCPSP). It is adapted to the requirements of operating room scheduling, with consideration for the optimization goals of the specific environment in the real-time scheduling of surgical cases. To obtain solutions within a short time, we develop a branch-and-price algorithm in which the pricing problem is solved using a dynamic programming approach. In branch-and-price algorithms, generating the columns is often one of the most time-consuming parts of the solution process. Therefore, the pricing problem, which is an (elementary) shortest path problem, is to be solved efficiently by cleverly excluding paths in the graph of the subproblem. To enable this exclusion of paths, approximations of both the primal and dual costs are used. In addition, it is investigated to what extent a better LP bound by applying cycle elimination in the pricing problem also reduces the effort for branching.

5 - Multi-Resource Elective Case Scheduling under Uncertainty
Sonja Weiland, Dominik Grimaldi, Alexander Martin, Lorenza Moreno, Alexander Müller

At the operational level, a central task in the operating room management is to plan upcoming elective surgeries. In the literature, this problem is referred to as Elective Case Scheduling (ECS). We consider the ECS with a planning horizon of one day and multiple resources such as anesthesiologists and trays and develop a decision support tool. Collaboration with German hospitals of different sizes provides us with both practitioners' requirements for the scheduling process and historical data.

First, we consider the deterministic ECS, where we assume that for every planned surgery its duration is given. We model this problem as a mixed-integer program that determines the operating room and the starting time for every scheduled surgery, subject to resource constraints. The main objectives are to minimize overtime, minimize the number of medical department changes within an operating room, and produce a schedule that can be adapted well to incoming emergencies. Using a commercial solver, we obtain solutions that meet the requirements of the practice.

We extend this approach to the stochastic version of the ECS, where the surgery duration is assumed to be uncertain. Applying a machine

learning approach to the historical data yields a discrete probability distribution of the surgery duration for each planned surgery. Based on this information about the distributions, we want to develop a stochastic optimization model.

6 - Longitudinal follow-up of patients with IBD, focusing on aggressive front-loading drug escalation

Thomas Xenos, *Ioannis Drygiannakis*, *Nikolaos Matsatsinis*, *Ioannis Koutroubakis*

Here, IBD patients are studied over time to analyse trade-off factors that determine disease burden, being classified on criteria related to its activity. Setting up a model to predict disease persistence and enhance decision making towards aggressive treatment with biologics is important. We aim to accelerate and maximise healing probability, deter disease relapse while reduce side effects avoiding surgery and other debilitating conditions. Similar issues were confronted with methods describing data in unambiguous way, comparing observed values to expected results however, considering neither time variables nor multiparametric nature of predictive criteria incorporated. Clustering by disease phenotype into abnormal biomarkers is the gold standard for treatment decision making in intestinal inflammation. Hence, multiparametric approach entails specific predictive criteria with concurrent incorporation of time, reflecting choices. Thus, when diseases are modified, we face an urgent need to realign required treatment and intervene to adapt the new conditions. Robust multicriteria models support us in optimising qualitative, quantitative clinical and laboratory cut-off values at which treatment escalation is both essential and effective. Usage of Ensemble Methods from Machine Learning and Multi-Criteria Decision Analysis, helps in the classification, based on recurrence risk assessment criteria, achieving a consistent classification of patients in need of advanced treatments.

7 - Optimising Operations in Emergency Departments: A Discrete Event Simulation Approach to Enhancing Quality of Care

Thamer Almohaya, *James Batchelor*, *Edilson Arruda*, *Steffen Bayer*

The global escalating demands on healthcare systems, coupled with the unpredictability of patient arrivals and the diversity of medical emergencies, underscore the urgent need for innovative operational strategies within emergency departments (EDs). This paper explores the application of a discrete event simulation model to optimise ED operations at University Hospital Southampton, aiming to enhance quality of care by minimising waiting times. Employing a simulation-based optimisation approach, this study calibrates the model using real-life case study data to ensure its accuracy and applicability. The findings predict significant enhancements in emergency department efficiency, providing strategic information that can aid in decision-making and policy formation. These insights aim to support the UK National Health Service (NHS) target for the emergency department, which calls for an average 4-hour patient stay from arrival to discharge, and ensure that this duration remains within reach. Achieving this goal requires a careful approach to analysing bottlenecks, improving patient flow, and identifying the necessary resources. This research contributes to the body of knowledge on applying modelling techniques in healthcare, providing a valuable framework for practitioners and researchers aiming to enhance ED performance through technological innovations.

8 - A stochastic optimization approach for scheduling CT scans and reports

Sara Cambiaghi, *Davide Duma*

In a hospital setting, the organization of the CT scan service is highly complex due to the examination being divided into two tasks - scanning and report writing - which require coordination. We present the case study of Policlinico San Matteo in Pavia, Italy, where further complexity arises from the presence of three different patient categories - outpatients, inpatients, and emergency - all sharing the same resources. The main issue in this operational context lies in the predominance of emergency cases, comprising 73% of total patients. Consequently, strategic planning of outpatient and inpatient appointments is crucial to avoid overlaps with emergency cases. In this study, we focus on scheduling appointments for outpatients, proposing a multi-objective optimization problem. Firstly, we aim to obtain predictions of the duration of examinations and reporting for outpatients. To achieve this, we relied on data from examinations conducted between June 2021 and November 2022, employing various machine learning and deep learning techniques. Furthermore, we introduce a stochastic programming model aimed at minimizing direct waiting times for outpatients and completion time for emergency patients. A genetic algorithm is proposed to efficiently solve the problem within a reasonable timeframe. Finally, a quantitative analysis is conducted to evaluate the effectiveness of the proposed optimization and machine learning approach in enhancing the efficiency of the CT-scan service.

9 - A Scheduling Tool for the Production of Blood Components

Aleyna Gürsoy, *Roberto Pinto*, *Federico Piccinini*, *Davide Ghezzi*, *Silvano Rossini*, *Ettore Lanzarone*

The production echelon of the Blood Donation Supply Chain (BDSC) is responsible for manufacturing/separating blood components, e.g., erythrocytes, plasma and platelets, from donated whole blood units. Different fractionation sequences are possible, all of which share the idea of centrifuging blood, so that the different components are divided according to density, and separating components from each other with an extractor. The main decisions concern the timing of operations, due to tight time constrains for processing blood and components, and the use of resources, e.g., equipment and human operators. We propose a two-phase approach for solving the scheduling problem of this production system, where the two phases refer to the activities performed before and after the so-called quarantine period, in which the semi-processed blood is refrigerated pending the results of the tests for infectious diseases. The problem of each phase is formalized through an ILP model. Problems are then addressed with a rolling horizon approach, and possible delays on a phase reduce the availability of resources for the next one. The proposed approach is applied to data from the Immunohematology and Transfusion Medicine Department of the Niguarda Hospital, Milan, Italy. Both its current system layout, to support production, and modified layouts, to identify the most promising ones, are considered.

10 - Enhancing Robustness in Surgical Scheduling for Elective Surgery Planning under multiple uncertainties: A Column-and-Constraint Generation Algorithm

Salma Makboul

This research introduces a novel approach to handling the challenges of the dynamic Master Surgical Schedule (MSS) and the advance scheduling problem under various uncertainties. We propose a Column-and-Constraint Generation (C&CG) algorithm with the main goal of minimizing assignment costs while considering different operating room (OR) restrictions and downstream resources capacity. These uncertainties include surgery duration, postoperative intensive care unit length of stays, and emergency arrival. We highlight the importance of robust optimization in managing the dynamic nature of surgical scheduling, where uncertain factors can disrupt operational efficiency. Our approach involves a two-stage robust optimization method and incorporates polyhedral uncertainty sets to improve the scheduling process's resilience. Through iterative refinement, our algorithm broadens the solution space, leading to better upper and lower bounds. We compare C&CG with the cutting-plane algorithm. Additionally, we analyze how risk adjustment affects the OR's utilization rate and the occurrence of cancellations using real data from a French hospital. This sheds light on how our methodology can optimize OR and downstream resources in hospitals, making scheduling and planning of the ORs more efficient and effective.

■ TC-05

Tuesday, 14:00-15:30 - Room: Room S6

IHTC-2024

Stream: Plenaries
Award Competition session
Chair: *Andrea Schaerf*

1 - The Integrated Healthcare Timetabling Competition (IHTC-2024)
Andrea Schaerf, *Sara Ceschia*, *Roberto Maria Rosati*, *Pieter Smet*, *Greet Vanden Berghe*, *Eugenia Zanazzo*

In this talk, we present the International Integrated Healthcare Competition: a new competition for optimization methods that intends to stimulate research focusing on the specifics of integrated scheduling problems in healthcare. We will provide an overview of all aspects of the competition, which will begin in September 2024 and will finish in March 2025.

First, we will introduce the considered problem, which integrates three critical problems in healthcare: surgical case planning, patient admission scheduling and nurse-to-room assignment. Second, we will describe all the necessary infrastructure provided to support the competition's participants: datasets, file formats, and solution validator. Finally, we state the rules of the competition.

All up-to-date information about the competition will be available in a dedicated repository on GitHub

Tuesday, 16:00-17:30

■ TD-03

Tuesday, 16:00-17:30 - Room: Room S2

Patient flow

Stream: Regular talks
Contributed session
Chair: *Jingui Xie*

1 - Applying a discrete event simulation tool across multiple cancer pathways and hospitals: challenges and benefits
Amalia Gjerloev, *Sonya Crowe*, *Christina Pagel*, *Yogini Jani*, *Luca Grieco*

Many European healthcare systems are increasingly challenged in delivering services to ever older and sicker populations. The Covid-19 pandemic made the situation worse, particularly in the UK where the NHS had little spare capacity and was forced to suspend many routine services during the height of the pandemic. Cancer services have been particularly impacted, with patients currently facing long waiting times and hospitals struggling to meet national performance targets. We developed a configurable discrete event simulation model of cancer pathways for use in partnership with hospital analysts. In this talk, we introduce the simulation tool and discuss successes and challenges in applying it to different cancer pathways across multiple London hospitals. The case studies we present feature varying levels of engagement with cancer services.

2 - Aiding decision making within Infection Prevention and Control (IPC): An Analytical and Simulation Modelling Approach
Nicholas Jelicic, *Sonya Crowe*, *Martin Utley*, *Tom Monks*

Infection prevention and control (IPC) decisions play a critical role in mitigating the spread of infectious diseases in healthcare settings. These include cancelling visitor appointments, isolating infected patients and quarantining bays. While these measures are introduced to reduce the spread of infections, some put restrictions on patient movement and thus worsen patient flow, creating organisational and medical issues. IPC nurses and hospital bed managers are therefore faced with hard decisions about how to reduce the risk of infections spreading without unduly impacting patient flow.

We developed a Discrete Event Simulation model to determine the consequences of an IPC policy in terms of a set of metrics which captures the impact on the spread of infection and patient flow. We also developed a Continuous Time Markov Chain Model that was used to validate the simulation model and to give exact results for simple scenarios.

In this presentation, I will focus on one use case of our models and describe methods we have established to support decision making; for example providing general rules of thumb about when policies are preferable. I will describe how they might be used in practice, including the benefits and drawbacks of each.

This presentation is an exploration of how models can be used to aid healthcare workers with complex decisions, in this case relating to trade-offs between the potential impact of IPC decisions on infection spread and patient flow.

3 - Post-triage patient reallocation in emergency department networks
Dario Nicola Marchese, *Mattia Cattaneo*, *Sebastian Birolini*

Over the past few decades, the timely provision of emergency care has emerged as a significant challenge due to a consistent rise in the number of visits to emergency departments each year, especially non-urgent. This increase is not matched by a corresponding expansion in

hospital resources and infrastructure, resulting in a high level of overcrowding. In this work, we aim to contribute to the issue of ED decongestion particularly focusing on the reduction of waiting times by proposing a reallocation scheme for non-urgent patients that leverages inter-temporal demand-supply imbalances across EDs within the same multi-hospital network. To implement this approach, we derive that reallocation is beneficial when there is imbalance between EDs congestion under steady-state conditions, albeit determining the optimal rate of reallocation poses significant challenges. For this reason, we develop a two-stage multi-objective optimization model for ED processes and planning, where arriving patients can be either admitted or diverted to another hospital according to system capacity and congestion, and subject to consistent vehicle routing and availability. This model is applied in a real-case study involving a multi-hospital system comprising four hospitals in northern Italy, within which a bound of the reallocation benefits is constructed to validate the robustness of the proposed approach.

4 - Optimizing Early Discharge: Trade-Offs between Capacity and Readmissions
Jingui Xie

In this work, we consider the ward capacity management problem with readmissions, where the decision-maker optimizes the elective schedule and early discharge policy, so as to minimize bed shortages. Existing research has shown that early discharge can lead to higher rates of readmission, and longer readmission length-of-stay. This sets up the need to balance the temporal trade-off between the immediate capacity freed up by early discharges and increased readmissions down the road. Such re-entry structure creates challenges when modelling via traditional methods. We appeal to the Pipeline Queues (Bandi and Loke 2018) framework, and propose an optimization model where the early discharge policy is expressed as a state-dependent decision rule. The model has a reformulation, which can be solved as a sequence of convex programs with asymptotically linear constraints. In our numerical study, we identify an intermediate region of the probability of readmissions where time-invariant policies can lead to as much as 77% more shortages. Ignoring the effects of early discharge on readmissions can lead to at least 75% and 150% more bed shortages in time-homogeneous and non-time-homogeneous settings respectively, even against un-optimized elective admissions. Using optimal early discharge strategies without jointly optimizing elective admissions will lead to 20% more shortages.

■ TD-04

Tuesday, 16:00-17:30 - Room: Room S3

Discussion session

Stream: Discussions
Contributed session
Chair: *Alexander Rutherford*

1 - Can the integration of healthcare services at regional level improve the quality and efficiency of the healthcare system?
Roberto Aringhieri, Davide Duma

A defining characteristic of today's data-rich society is the collection, storage, preprocessing, and analysis of immense amounts of data. This characteristic is cross-sectoral and applies also to healthcare. Big Data 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 the Health Care Management perspective, Big Data are a key enabling technologies to support detailed health system analysis.

We argue that the Health Care Big Data (HCBD) can power a detailed health system analysis using Discrete Event Simulation (DES) methodology: exploiting the HCBD, one can replicate the behaviour of the health system modelling how each single patient flows within her/his care pathway. The novelty of the proposed approach is therefore the use of the DES methodology for the health system analysis exploiting Big Data in order to better represent the variety of the patients accessing the health system.

In this talk, we will therefore ask how to answer the question expressed in the title by showing some examples and preliminary results exploiting the available HCBD of Piedmont Region, and we will ask the audience about possible system-level analyses and the potential of such analyses.

2 - A study on policy decisions to embed flexibility for reactive recovery in the planning and scheduling process in operating rooms
Babak Akbarzadeh

The endeavor for operational excellence in the operating room (OR) department is hampered by uncertainty underlying patient demand for healthcare resources. Incorporating this uncertainty is complicated since planning and scheduling decisions are organized according to a hierarchical decision structure in different phases. In this study, we link the strategic, tactical, and operational decision-making in the OR department and study the impact of policy decisions embedding flexibility in the OR planning and scheduling processes to improve the operational outcome, making the trade-off between efficiency and consistency. We consider a sequential but interrelated proactive-reactive decision framework that is guided by both generic assumptions from literature and real life. Analysis is performed via computational experimentation on a real-life dataset.

3 - Off-site Hospital Activities: Classification & Identification of New Challenges
Jedidja Lok - Visser, Erwin W. Hans, Jan Gerard Maring, Gréanne Leeftink

A recent trend in healthcare is that healthcare systems are shifting from a high-level, hospital-perspective to a more regional, patient-perspective. An important part of this trend is the relocation of hospital-based care outside of hospital buildings. Examples of these off-site hospital interventions are remote patient monitoring, parenteral medication infusion at patients' homes and geriatric teams on wheels.

These interventions pose new managerial challenges, where OR/OM techniques could (and should) support the decision-making. For example: (i) routing of hospital@home nurses; (ii) appointment scheduling of patients in remote monitoring, and (iii) the outpatient clinic scheduling of oncology infusion treatments in hubs. These interventions are often more data-driven than standard-of-care interventions, have more interactions between actors in the healthcare system, and impose new elements to the existing logistical challenges.

In this discussion session, we present a framework that classifies these interventions, showcases the specific characteristics of these interventions, and lays a foundation for relevant managerial decisions in the organisation of the ongoing transformation of healthcare. The goal of this session is to discuss these relevant managerial decisions with their specific characteristics, and to explore how OR/OM techniques could support these decisions.

4 - Grand Challenges in Healthcare Simulation
Alexander Rutherford, Christine Currie, David Matchar, Tom Monks

This discussion session will begin by reviewing some of the grand challenges in healthcare simulation from the perspective of the authors. We will then engage participants in a discussion on their experiences in simulation modelling applied to healthcare and thoughts on grand challenges. Some of the challenges that the authors have identified are: 1. How can modelling and simulation support integration of the healthcare system? 2. How do we incorporate data on individual behaviour and social determinants of health in simulation modelling? 3. How do we capture equity in the context of simulation modelling? 4. How do we make simulation modelling more accessible and enable widespread use of models through Open Science initiatives? 5. How can we best utilize the increasing availability of real time healthcare system data

for real time simulation and digital twins? We look forward to a lively discussion on these questions and other grand challenges in healthcare simulation.

■ TD-05

Tuesday, 16:00-17:30 - Room: Room S6

Ambulance Management

Stream: Regular talks
Contributed session
Chair: *Melanie Reuter-Oppermann*

1 - Ambulance stochastic optimization for EMS: a hierarchical compromise model and a matheuristic algorithm.

Imanol Gago-Carro, María Merino, Unai Aldasoro, Dae-Jin Lee

Health emergencies represent critical junctures where precise decision-making can determine between a dire outcome and a manageable situation. The efficiency of emergency medical service (EMS) operations hinges, to a large extent, on strategic ambulance positioning and real-time allocation. This study delves into the challenges of ambulance location-allocation within the geographical area of the Basque Country (Spain), served by a fleet of 90 ambulances composed of both ALS and BLS ambulances.

Leveraging historical data, we use a Box-Cox Cole and Green distribution to forecast response times. Our approach centers on a two-stage stochastic mixed 0-1 linear programming model aimed at optimizing the primary objective of maximizing expected coverage. Additionally, we account for secondary objectives, such as minimizing average response time and integrating risk aversion measures like Conditional-Value-at-Risk, within a hierarchical compromise framework.

Acknowledging the computational complexities inherent in our model, we introduce a novel matheuristic algorithm. This algorithm, employing primal decomposition, demonstrates promising efficiency in addressing the intricate EMS optimization problem across medium and large-scale instances. Our research enhances EMS effectiveness and responsiveness, ultimately improving patient care outcomes during critical emergencies.

2 - Heuristc algorithms with GIS for the ambulance location problem

Fulgencia Villa, Eva Vallada, Miguel Ángel, Yulia Karpova

The rapid intervention of ambulances when an emergency arises is of vital importance for the well-being and health of the people. The Static Ambulance Location Problem consists of determining the optimal location of emergency vehicles maximizing service coverage and its quality. A novel hybrid methodology is presented, merging Geographic Information Systems and the Greedy heuristic. The methodology is applied to a real-life case in the province of Valencia, Spain. In addition, a graphical tool is used that allows for a global visualization of the impact of different demographic and territorial characteristics. The results show that thanks to this methodology, it is possible to increase the percentage of the population covered compared to the current situation by optimizing the location of ambulances.

3 - Dispatching strategy with lookahead for the real-time management of ambulances

Alessandro Druetto, Roberto Aringhieri, Davide Duma, Alberto Guastalla

In the context of the Emergency Care Delivery System, several factors play a crucial role in the rate of morbidity in hospitals and mortality of patients. For example, the stochasticity of rescue requests can cause peaks in demand, increasing the arrival time within which ambulances are able to reach patients. These peaks can cause an uneven distribution of hospital workload, that negatively impacts the Emergency Department capability of processing all patients in time. On the other hand, a finely crafted and carefully studied management of Emergency Medical Service can make the difference to save more lives. The definition of static dispatching, routing and redeployment policies that are able to cope with those criticalities is sometimes not sufficient in order to guarantee a good utilization of ambulances while maximizing the number of emergency requests served. In the simulation and optimization model presented during ORAHS2019, the impact of predictive models in real-time management of ambulances was studied. While the former dispatching was based on static policies, this work provides a comprehensive dispatching strategy with lookahead based on online assignment models, which exploits pertinent information regarding ambulance status and, when accessible, oracle predictions for upcoming patient arrivals. Preliminary results of the new model show that such an online dispatch is able to significantly increase the number of rescue requests served within a time threshold.

4 - Discrete-event simulation model for German PSAPs

Melanie Reuter-Oppermann

Around 230 Public Safety Answering Points (PSAP) in Germany need to handle all kinds of calls, of which those arriving over 112 to ask for the emergency or fire services are usually urgent and must be answered immediately. In addition, patient transports can be arranged by calling 19222, and depending on the individual settings, many other telephone numbers for varying services exist. Besides answering the calls, PSAPs also need to dispatch emergency and fire services, patient transport ambulances and potentially other types of services. While in larger PSAPs the tasks are separated, i.e., call-takers answer the calls and dispatchers dispatch the services, in smaller PSAPs the tasks are integrated. Recent societal and organisational developments lead to many challenges PSAPs must face, including an increase in call numbers as well as significant staff shortages. We have developed a discrete-event simulation model of German PSAPs that can be used for staffing and workforce planning as well as to analyse effects of organisational changes. To derive practically relevant scenarios, we performed a written survey with PSAP managers in Germany and modelled those that were rated as most important. In this talk, we present the results of an exemplary German PSAP.

Thursday, 9:30-10:30

■ HA-01

Thursday, 9:30-10:30 - Room: Auditorium

Plenary Carl May

Stream: Plenaries
Plenary session
Chair: *Erwin W. Hans*

1 - Implementation Science: more than translating evidence into practice
Carl May

The field of implementation science seems to be growing, almost exponentially, with new journals, research centres, and funding schemes, appearing around the world. But can there truly be such a thing as a science of implementation? And, if there can be such a science, how can we find our way into it and share in its achievements? In this plenary talk, I will (a) set out some of the key features of implementation science as an empirical field of research and development; (b) consider some of its conceptual underpinnings - theoretical models that identify, characterize and explain the mechanisms that motivate and shape implementation processes; and (c), explore the ways that these may open doors for collaboration between Operational Researchers and Implementation Scientists.

Thursday, 11:00-12:30

■ HB-02

Thursday, 11:00-12:30 - Room: Room S1

Analytics

Stream: Regular talks
Contributed session
Chair: *Christos Vasilakis*

1 - On Reducing Medically Unnecessary Procedures Through Analytics: The Design of Financial Incentives for Maternity Care
Beste Kucukazici, Emily Zhu, Ting Wu

This work focuses on the design of financial incentives to reduce medically unnecessary C-sections, resulting in enhanced birth quality with alleviated economic burden for healthcare payers. To this end, we develop an innovative semi-supervised fuzzy clustering algorithm to classify pregnant women into low- and high-risk groups by analyzing approximately 18 million birth records from US. Our experiments on real-life and synthetic data demonstrate the efficiency of our algorithm for large datasets. Then, we validate the optimal delivery methods for two risk groups through post-delivery outcomes for the mother and the newborn by using inferential statistical analysis. Furthermore, we develop a metric to quantify the maternity risk index to be used in stylized analytical models. Next, we develop an analytical framework based on a principle-agent model to analyze the effect of different payment schemes from the quality of care and cost perspectives. We propose three payment systems, hybrid payment, risk-sharing model, and penalty contracts to alleviate the shortcomings of fee-for-service and bundled payment schemes, thereby facilitating system optimal decisions. Finally, we present a simulation-based numerical study to empirically verify our analytical results.

2 - A simulation-based analysis of machine learning algorithms for length of stay classification in the intensive care unit
Sara Garber

A recent report by the German Council of Experts on the assessment of developments in the healthcare sector shows that the German healthcare system is not crisis-resistant and not sufficiently prepared for the consequences of climate change or pandemics. In the event of crisis-related challenges, the intensive care unit is one of the areas particularly affected. In order to enable efficient capacity control in high-load situations, an accurate classification of the length of stay is essential. In the literature, binary classification is usually applied, however, a more precise distinction between more than two classes offers advantages in terms of capacity management. Therefore, we apply multiple machine learning algorithms for multiclass classification differing in terms of transparency and explainability on a real-world intensive care dataset. In addition to state-of-the-art performance indicators, we use a Monte Carlo simulation for further analysis and evaluation of the classification algorithms. This approach provides in-depth insights into the effects of an actual application of the machine learning algorithms in the intensive care unit.

3 - Exploring Dual Practice in Healthcare Operations Management
Fatemeh Tehranikia, Greg Zaric, Yang Li

This study investigates how multi-channel healthcare service provision affects patient decision-making and the efficiency of healthcare delivery. Our analytical model compares two practice regimes: solo practice (where the physician serves exclusively in public or private sectors) and dual practice (where the physician allocates their time between sectors). We explore the outcomes of transitioning from solo to dual practice, including changes in throughput, the percentage of patients treated, and wait times. Our model features a two-stage game.

Initially, the physician determines the private service fee and time allocation, which in turn establishes channel capacities. Subsequently, patients decide whether to opt for public service, private service or forego treatment altogether (balk). Their choice depends on their perceived value of the service, the private service fee, and the expected wait time in each sector. Our model contributes to the service operations management literature by challenging conventional field assumptions. This study is the first to consider both the private fee and channel capacities as decision variables, determined by physician-patient interaction. Our findings offer insights into the impact of dual practice on healthcare delivery and patient choice. Furthermore, we explore how a regulating body can influence the physician's time allocation between public and private sectors, as well as patients' decisions regarding treatment or balking.

4 - Understanding and improving patient flow in the NHS Talking Therapies programme
Christos Vasilakis, Elizabeth Yardley, Alice Davis

The NHS Talking Therapies (TT) programme in England follows a 'stepped care' approach for treating patients with common mental health problems, where effective but less resource intensive treatments are delivered to patients first and more intensive interventions are only provided if required. The programme, which treats over a million patients each year, faces challenges in managing patient flow due to limited resources and pressure to achieve service standards. Research has found variation in clinical performance and stepped care implementation across sites, and has identified associations between service delivery and patient outcomes.

We aim at developing innovative, advanced, analytical tools to help improve understanding and management of NHS TT services' demand and capacity. Our study analyses data from iaptus, the leading digital care record for psychological therapy services, to explore and model patient flows through talking therapy care pathways using process mining and other data-driven methods, to evaluate pathway performance and explore relationships between system performance and patient outcomes. The major impacts of this project are expected to be improved patient access to services, improved utilisation of resources, resulting in reduced waiting times, better recovery rates and reduced patient drop out.

■ HB-03

Thursday, 11:00-12:30 - Room: Room S2

Transportation in Healthcare and Social Services

Stream: Regular talks
Contributed session
Chair: *Ana María Anaya-Arenas*

1 - The intra-hospital patient transport problem with diverse rolling equipment
Angel Ruiz, Vinicius Martins Ton, Jose Eduardo Pecora

Intrahospital patient transportation is a crucial activity to hospital operations that also impacts patients' satisfaction. The problem consists in assigning each of the incoming transport requests to one of the available porters, in such a way that patients arrive to their destination on time, or their lateness is minimized. Some patients (i.e., hospitalized patients) are transported on the bed they occupy, while others (i.e., external patients) require a wheelchair provided by the hospital. Handling different types of transport equipment may require porters to switch equipment between two transport requests. For instance, a porter may have to visit an equipment depot to pickup (drop off) a wheelchair before (after) serving a request which requires it, increasing the total traveled distance, and reducing the availability of porters to answer other requests. To the best of our knowledge, this work is the first modeling and solving this realistic version of the intra-hospital patient transportation problem with various types of rolling equipment. We propose and compare the performance of several approaches (including a mixed integer linear programming model, a constraint programming model, a constructive heuristic, and a local search heuristic) with respect to metrics widely used by hospital managers over a set of instances inspired by a real mid-size hospital. The local search heuristic produced excellent results and proved its suitability to be used in real applications.

2 - Multi-objective optimization for home healthcare delivery
Andres Felipe Torres Ramos, Nubia Velasco, Fabián Castaño

This study addresses a multi-objective optimization problem in home health care (HHC) delivery aiming at assigning patients and routes to caregivers over multiple periods while considering the multiple stakeholders' perspectives and constraints. We consider a scenario where patients require treatments that should carefully follow specific visit frequencies and be served during a given time window. The goal is to find allocations of patients to caregivers and routes that balance the objectives of the key stakeholders in the service, i.e., patients, caregivers, and the HHC organization. This is done by optimizing the difference between the workloads among caregivers, the transportation costs for HHC organizations, and the patient's continuity of care, respectively. To achieve this, we have developed different exact and heuristic approaches to find solutions that pursue those objectives both separately, using single objective optimization (SOO), and simultaneously through multiple objective optimization (MOO) methods. These procedures seek a balance between objectives and allow a joint evaluation of different operational and stakeholder perspectives, enabling efficient decision-making in the planning and scheduling of home healthcare services. To evaluate the performance of these approaches, different numerical experiments are performed based on a set of instances adapted from the literature.

3 - A GRASP algorithm for the Non-Urgent Transportation Problem
Iván Giménez-Palacios, Jose M. Belenguer, Eva Vallada, Fulgencia Villa

Every day, hundreds of patients need to be transported to healthcare facilities for scheduled visits because they are unable to come by their own means. In this work, we deal with this problem, the non-urgent transport of patients, with time windows between which the pick-ups and deliveries of the different patients can be made. The solution to the problem is the set of routes that will be followed by each of the available vehicles so that the total time that the vehicles are in circulation is minimum. The time windows must be taken into account, with the time required to complete each of the trips, and the maximum capacity of the vehicles. To solve this problem, we propose a GRASP algorithm. The ultimate objective of this work is to develop efficient methods for solving this problem that is a daily occurrence in the healthcare environment.

4 - Transportation plans for Regional Social Care Services
Ana María Anaya-Arenas, Feike Weijzen, Daniela Guericke, Erwin W. Hans

Regional social services in the Netherlands faces logistics problems to fully support the beneficiaries, due to distance, geographical distribution or service capacity. In their program, a large set of beneficiaries, regional-wide spread, are offered one (or several) day(s) of care time in one of their multiple Care Providers Facilities (CPF), and it includes a transportation service door to door for each of them. The large demand and high costs of this logistic task motivates a restructuring process inside the region. In this talk we will explore the challenges of creating a new and efficient transportation plan for the region, considering different strategies that can be used in service allocation and transportation plan. Moreover, the routing decisions will need to respect practical restrictions that makes it a hard problem to solve, including the limited time restrictions to offer the services, the space, and the assistance requirements of the beneficiaries for each trip. We will cover a baseline that simulates the current practice of the region and explore the potential of a more collective regional strategies among the care providers.

■ HB-04

Thursday, 11:00-12:30 - Room: Room S3

Modeling and Simulation /2

Stream: Regular talks
Contributed session
Chair: *Hannah Johns*

1 - Simulating extended blood type matching in a hierarchical supply chain
Folarin Oyebolu, *William J. Astle*

Blood transfusions are a life-saving treatment in people with sickle cell disorder (SCD). Currently, blood group matching for transfusion is manual and uses incomplete red cell blood type information to determine the allocation of units to patients. We have been investigating alternative approaches to blood allocation that exploit extended blood type information measured by a new genetic test shortly to be introduced by the National Health Service in England to minimise the immunological incompatibility between donors and patients. We previously presented a blood inventory problem and formulated sequential allocation decisions as a Markov decision process. Using a simplified model of a blood supply chain which assumed a single central inventory, we studied penalty-based policies for matching which considered up to 17 blood group antigens. Our analysis demonstrated an 81% reduction in alloimmunisation risk to SCD patients compared to current guidelines. Here, we improve this model by incorporating the hierarchical structure of the supply chain and the transportation of blood units between stock holding units (SHUs), allowing units at one SHU to be reserved and transported for future appointments at another SHU. We carried out simulation experiments in a range of scenarios with varying restrictions on the transport of blood units between SHUs. We assess the impact on patient care, in terms of alloimmunisation risk and shortages.

2 - Working on: Capacity simulation for improving efficiency
Ismael Aguilera

There is a gap in the scientific debate about capacity simulation considerations among the micro to the macro level of management which in turn do not acknowledge the identification of mechanisms that drive agents to increase the mental health care capacity in the long term. Barroy et al. (2021) state, qualitatively, that public providers have a low incentive to improve efficiency, as long as they cannot take advantage of the efficiency gains. This paper attempts to measure the effect of allowing providers to conduct their own analysis of efficiency or management performance by developing a mixed discrete event and dynamic system (stock and flow) simulator that relates the macro-level components of patients and providers' resource sources. As a result, this work shows the long-term dynamics of flows when providers assess their performance, take action, and autonomously reallocate their budget to the most efficient areas. This analysis could reduce long stays and increase referrals of low-complexity patients to remote services. Preliminary conclusions provide new insights regarding the understanding of the dynamics of capacity at the macro level and in the long term of health systems related to mental health.

3 - Modelling for understanding and improvement of the Australian Hyperacute Pre-Hospital Stroke Care System, Part I: Design and validation of a conceptual model
Dominic Italiano, *Hannah Johns*, *Leonid Churilov*

Stroke is a life-threatening illness where swift diagnosis and treatment is essential. Prehospital stroke care is challenging in Australia due to the large geographical distances and diversity of organisations involved in the delivery of care. This includes ground and air ambulances, mobile stroke units and remote stroke retrieval, each with its own structure and processes. The Australian Stroke Alliance aims to improve access to stroke care in regional and remote Australia. It employs simulation modelling to understand the consequences that specific policy decisions will have on the overall system.

To develop a simulation model, we employed value-focused process engineering (VFPE) to build a conceptual model that will underpin it. VFPE provides an understanding of the relationship between components or processes of a system by linking the event-driven process chain method with value-focused thinking. It allowed us to identify structures, understand processes and reflect interactions between entities within the system.

In this presentation we describe the process of applying VFPE to develop and validate a conceptual model for the Australian prehospital stroke care system. We present the outcomes of this including: the structures to be represented in the simulation model; workflow models representing the individual processes of the system; and key research questions and scenarios for investigation. This provided solid foundation for developing a hybrid simulation model

4 - Modelling for understanding and improvement of the Australian Hyperacute Pre-Hospital Stroke Care System, Part II: Hybrid simulation of regional and remote care pathways
Hannah Johns, *Dominic Italiano*, *Leonid Churilov*

Stroke is one of the most significant public health challenges in the world today and requires rapid diagnosis and treatment. Prehospital stroke care systems are complex with many stochastic elements and interrelated decisions made under uncertainty. The Australian Stroke Alliance aims to investigate modifications to prehospital stroke care to improve access to timely treatment in rural and remote Australia.

Developing a conceptual model for the Australian prehospital stroke care system provided a clear understanding of the system and identified important policy scenarios to be investigated through simulation. We focus on aeromedical services such as the Royal Flying Doctor Service (RFDS) which provides emergency healthcare and aeromedical retrieval in rural and remote Australia. Imaging is crucial for clinicians to treat stroke swiftly and appropriately, and currently it is only possible in facilities equipped with capable devices. The development of new portable imaging devices that can be incorporated into RFDS services may provide opportunity to improve this.

In this presentation we discuss how conceptual modelling informed the development of a hybrid discrete-event agent-based simulation model for the Australian prehospital stroke care system. We detail the translation of information collected from conceptual modelling into a simulation model using AnyLogic. We illustrate the use of the model for aeromedical stroke care with portable stroke imaging devices.

■ HB-05

Thursday, 11:00-12:30 - Room: Room S6

Operating Room Scheduling /2

Stream: Regular talks
Contributed session
Chair: *Erik Demeulemeester*

1 - Operating room scheduling with surgeon assignment: a mixed integer linear programming and machine learning approach
Alice Daldossi, *Roberto Aringhieri*, *Sara Cambiaghi*, *Davide Duma*

This talk introduces a multi-objective Mixed Integer Linear Programming (MILP) model to deal with surgical case assignment and sequencing scheduling problems. The former concerns selecting patients from a waiting list and assigning an OR block to each of them. The latter addresses the decisions about the order of surgeries to be executed in the same OR block and the assignment of surgeons based on their compatibility and expertise. Then, a metaheuristic is proposed to ensure near-optimal and timely solutions applicable in real-world hospital settings. While the presented optimization model addresses the combinatorial complexity of OR scheduling, several machine learning (ML) techniques are used and compared to address the uncertainty of

the surgery durations. Since the proposed approach leverages data-driven insights to deal with such uncertainty, a comparison among the ML methods is executed considering standard accuracy indices of literature, but also evaluating the impact of errors on the quality of the resulting MILP model's solution. Computational analyses on real instances of the Vascular Surgery department of the hospital Città della Salute e della Scienza in Turin are presented. First, the effectiveness of the proposed metaheuristic is proved by comparing the solutions provided by such ad hoc algorithms with those of a general-purpose solver. Then, the trade-off between the considered objectives is analysed to represent possible preferences of decision makers.

2 - Stochastic surgery scheduling with downstream capacity constraints in the presence of side data

Ricardo Otero, *Erik Demeulemeester*

This study addresses the stochastic Advance Scheduling Problem with Downstream Capacity Constraints (ASPDCC), particularly focusing on scenarios where decision-makers have auxiliary data at their disposal. Our approach initiates modeling the stochastic ASPDCC as a two-stage stochastic program, employing a sample average approximation (SAA). We propose a data-driven framework that integrates a machine learning algorithm (decision trees) to estimate the conditional probability distribution for the surgery durations and the length of stay (LoS), in the presence of side data. Then, these estimated probability distributions are integrated into the SAA model. To improve the efficiency of our methodology, we implement a benders-branch-and-cut algorithm to solve the SAA model. Computational experiments conducted using data from a reference hospital in Colombia demonstrate that our algorithm generates schedules that surpass those generated by the conventional method of fitting a probability distribution for each surgery specialty.

3 - A Data-Driven Approach for Integrated Operating Room Scheduling and Bed Management

Dimitrios Karagiannis, *Nalan Gulpinar*, *Xuan Vinh Doan*

Operating room scheduling, with an emphasis on downstream unit considerations, presents a substantial challenge for hospital management systems. This study explores the integration of machine learning—emerging data-driven methodologies—and traditional operational research techniques to improve decision-making processes and resource utilization. We introduce a stochastic optimization model to address the uncertainties associated with initial bed occupancy at the commencement of a surgical week. We demonstrate the performance of this model using a real hospital case. Our approach demonstrates that minimizing variability in Length of Stay (LoS) through personalized patient LoS predictions, derived from machine learning, can significantly enhance ward management. Results indicate reduced last-minute cancellations due to bed shortages and smoother bed occupancy rates, enhancing scheduling efficiency.

4 - Optimizing Operating Theater Scheduling : A Comparative Study of Scheduling Models

Marc Chouraqui, *Salma Makboul*, *Alice Yalaoui*, *Farouk Yalaoui*, *Lionel Amodeo*, *Philippe Blua*

In this study, we introduce an optimization framework for the Operating Theater (OT) of a French Hospital utilizing a Modified Block Scheduling strategy. The framework offers an enhanced model for surgery scheduling, accommodating various resource constraints such as room availability, material supplies, and surgeon well-being. The primary focus is on minimizing makespan while ensuring non-overlapping operations within rooms and for individual surgeons. Additionally, the model addresses the need to minimize idle time for surgeons, thus contributing to improved efficiency and resource management within the OT. To solve the allocation scheduling problem, we present three modeling frameworks: Mixed-Integer Linear Programming (MILP), Constraint Programming (CP) and CP with intervals. Our evaluation compares these frameworks based on their effectiveness across different instance sizes. Results indicate that the MILP model efficiently determines optimal solutions for small-scale instances, while the CP model demonstrates effectiveness for small to medium-sized instances. The CP with intervals approach efficiently identifies acceptable solutions for medium-sized instances. This framework aims to significantly enhance the efficiency of OT scheduling operations, thereby improving patient care and resource utilization within the hospital setting.

Thursday, 14:00-15:30

■ HC-03

Thursday, 14:00-15:30 - Room: Room S2

Emergency Medical Services

Stream: Regular talks
Contributed session
Chair: *Isabel Wiemer*

1 - Nested boosting for probabilistic spatio-temporal forecasting of EMS demand
Mostafa Rezaei

Reliable forecasts of EMS demand can assist healthcare managers in improving both tactical and strategic decision-making processes. Prediction distribution estimates can offer significantly more value than point estimates of the mean but are inherently more challenging to obtain. This challenge is compounded by the sparse nature of EMS demand, which if not effectively addressed, can result in significant variance in estimation. In this paper, we introduce a novel boosting approach to probabilistic spatio-temporal forecasting. In contrast to other boosting methods, our approach allows the final ensemble to be represented as a single decision-tree structure, thereby enhancing interpretability for end users without compromising performance. Additionally, our approach can incorporate covariates such as special day indicators and weather data. Furthermore, it can simultaneously forecast for multiple interconnected time series, such as emergency calls to different departments. By utilizing over four years of data on emergency calls in Montgomery County, PA, we demonstrate the superior performance of our proposed approach compared to other high-performing machine learning models in forecasting various quantiles of future call volumes across different regions of the city and hours of the week.

2 - Impact of the multi-trauma standard for ambulance services in The Netherlands
Geert-Jan Kommer

In the Netherlands, the standard is to treat at least 90% of the multi-trauma patients (ISS score 16+) in the ten level-1 hospitals. In most regions, in 2021, the number of multi-trauma patients presented at the level-1 hospitals was between 13-90%. For the ambulance services there are different reasons not to present a multi-trauma patient to a level-1 hospital. First, in some cases the severity of trauma cannot be determined on the scene: the RTS score used by the ambulance services does not match exactly with the ISS score used by hospitals. Second, the risk perception of the ambulance service plays a role. This is related to the extra time the ambulance needs to transport the patient to the level-1 hospital instead of the (nearby) level-2 or -3 hospital. In this study, we analyse multi-trauma incidents for the past five years estimate the business time of ambulances and the extra drive time needed to bring the patient to a level-1 hospital. We also make us of a simulation model in which incidents are Poisson-distributed and service time Gamma-distributed and simulate the business time. Finally, we determine whether extra ambulances are needed to meet both the standard for multi-trauma patients as well as the ambulance service levels.

3 - A Bi-Objective Covering Location Model for Improving Fairness in Emergency Medical Service Systems
Isabel Wiemer, Jutta Geldermann

Emergency medical service (EMS) has to respond quickly and efficiently to all emergencies within a considered area. However, especially in areas with heterogeneous demand distribution like urban, mixed and rural areas, the level of coverage can vary widely. To reduce inequalities in coverage, many approaches take into account fairness as model objective by explicitly addressing the coverage of the worst-covered area. Thereby, the coverage levels of the second, third etc. worst-covered areas are not directly addressed. Therefore, we propose to maximize the average expected coverage of the set p of worst-covered areas. Our fairness objective explicitly considers the second, third etc. worst-covered area and aims to improve not only the coverage level of the worst-covered area, but the average coverage level of the set p of worst-covered areas. We combine our novel fairness objective with expected coverage to a bi-objective optimization model using the epsilon constraint method. In that way, we aim at maintaining an acceptable level of overall coverage. Our model's applicability is analyzed at hand of a real-world case study for the city of Duisburg (Germany). We examine different levels of overall coverage to analyze the influence on the individual coverage levels of the different areas. First results show that the proposed fairness model can improve the average coverage of the set p of worst-covered areas without giving up too much efficiency.

■ HC-04

Thursday, 14:00-15:30 - Room: Room S3

Healthcare Management /2

Stream: Regular talks
Contributed session
Chair: *Vedat Verter*

1 - Towards a richer understanding of implementation of OR in health services: a systematic review
Guillaume Lamé, Tom Bashford, Sonya Crowe, Luca Grieco, Coco Newton, Saba Hinrichs-Krapels

The limited implementation of OR methods within health services is a longstanding frustration for the OR community. Previous literature reviews have shown that about less than 10% of articles address implementation. However, little is known about what factors favor implementation (how and why does it 'work'?), and even the notion of implementation itself is often only vaguely defined (what type of impact do we expect?). Finally, there is little interaction between OR and the academic discipline of 'implementation science', which studies the transfer of scientific evidence into healthcare practice.

We searched the Web of Knowledge, Scopus, and PubMed for relevant articles. After deduplication, we included 4,992 abstracts for screening. We performed single-reviewer screening, with 10% double-screening. We retained 440 articles for full-text review. We included all articles discussing the practical implementation of OR methods (case studies that mentioned implementation, and studies focused on the process of implementation). We extracted information on what counted as 'implementation', the level of change, the extent to which implementation was described, and the mention of 'implementation science' concepts and frameworks. We offer recommendations for the conceptualization of implementation of healthcare OR and for the reporting of implementation in future healthcare OR studies.

2 - Time-and-motion studies in healthcare: a systematic literature review
Louis Niffoi, Oualid Jouini, Marija Jankovic, Pierre-François Ceccaldi, Guillaume Lamé

The recent 'Behavioural OR' movement has reinstated the importance of realistic modelling of human behaviour in OR. In particular, knowing what activities healthcare staff perform and how their working time is distributed is crucial to build reliable models. Time-and-motion studies (TMS) are the gold standard for obtaining this information. In this review, we analyse where and how TMS have been used in healthcare. We aimed to include journal articles reporting independent and continuous observation of the activities conducted by healthcare professionals over a period of time, published post-2000, in English. We searched PubMed, Scopus, and the Web of Science, and also included the references from 4 previous reviews as well as the articles

that cited them. We obtained 5,680 articles. Two researchers independently screened 10% of the articles based on title and abstract. Agreement was very good (Cohen's k = 0.84). One reviewer screened the remaining articles, and we included 889 articles for full-text assessment. After 10% double-screening, agreement was excellent (k = 0.94). One reviewer completed full-text screening. We included 189 articles. We extracted information on the objectives of the studies, the setting and profession of participants, and the research process. We analysed the results quantitatively to provide recommendations on the conduct and reporting of TMS, and discuss how these types of studies can be integrated with OR modelling.

3 - Measurement Noise and Judgment Bias in Hypertension Management
Vedat Verter, Manaf Zargoush, Mehmet Gumus

Hypertension is a major public health issue and the most important modifiable risk factor for cardiovascular disease. Effective hypertension management is hindered by (i) the noise in blood pressure (BP) measurements (technology factor) and (ii) the physicians' judgment bias (human factor). The latter refers to the physician's error in inferring the patient's true BP from the measurements. This study investigates the role of these two factors in hypertension management from the perspective of the clinical value of information.

We present an analytical framework with two main modules: a learning module that models how clinical judgments about the patient's underlying BP are made (with and without bias) and an optimization module that models how optimal treatment decisions are made under various learning strategies.

Our results suggest that the value of information concerning the patients' underlying BP depends on (i) the physician's judgment bias and decision flexibility, cardiovascular risk as well as the short-term and long-term BP variability of the patient, and the measurement noise of the device. In addition, among the two types of judgment bias (i.e., under-estimation and over-estimation), the value of information is much higher under the under-estimation bias, where the clinician undervalues the significance of the observed BP in inferring the true underlying BP.

■ HC-05

Thursday, 14:00-15:30 - Room: Room S6

Emergency Department /2

Stream: Regular talks
Contributed session
Chair: *Davide Duma*

1 - A multi-activity shift scheduling model for physicians in an emergency departments
Cong Tan Trinh Truong, Nora Touati, Anis Salhi

Effective shift scheduling in emergency departments (EDs) is crucial for ensuring optimal patient care while maintaining a healthy work-life balance for healthcare professionals, especially physicians. This article presents a new multi-activity shift scheduling model designed for physicians working in EDs.

The proposed model utilizes mathematical optimization techniques to address the complex scheduling problems inherent in ED environments. By considering the diverse activities that physicians engage in during their shifts, including patient care, administrative tasks, and breaks, the model aims to minimize physician fatigue, enhance productivity, and improve quality of care.

Key features of the scheduling model include flexible shift structures, consideration of physician's availability and preferences, equitable workload distribution among team members, and adherence to regulatory guidelines like maximum shift hours and rest periods.

We validate the effectiveness of this model through simulation studies and comparative analysis with existing methods. Results demonstrate improved efficiency in resource utilization and enhanced job satisfaction among physicians.

Overall, our model offers a systematic approach to address the complexities of scheduling physicians in EDs, contributing to better healthcare outcomes and staff's well-being in emergency medical settings. Future work may explore further optimization techniques, consider physicians desired working hours.

2 - Improving emergency department operations: the role of patient prioritization by clinical complexity
Mattia Cattaneo

Traditional triage processes in emergency departments (EDs) typically rely on the assessment of discrete levels of severity. However, severity is a composed of two primary factors, namely acuity and clinical complexity. While the former is well represented by discrete levels, representing the urgency of a timely intervention, the latter is often overlooked despite its significant impact on ED resource utilization. This study investigates the potential benefits of employing separate indicators for clinical complexity and acuity. Drawing on a 10-year dataset of 1.4 million ED accesses to a large multi-hospital network located in Northern Italy, we first conduct a confirmatory factor analysis on triage data to estimate these two distinct components. Next, we develop a model grounded on these two factors to analyze their effects on ED resource consumption. Finally, we compare traditional and model-derived evaluations and performances for simulated ED operations, employing prioritization based on continuous complexity scores within each ESI level. The findings demonstrate that incorporating clinical complexity into prioritization decisions within the same ESI level leads to efficiency improvements in queue and resource management, measured in terms of average patient waiting time and hospitalization rates.

3 - Patients who leave the Emergency Department without being seen: a dynamic approach based on survival regression
Davide Duma, Roberto Aringhieri, Vittorio Meini

The rate of patients who Leave Without Being Seen (LWBS) is an important performance indicator for Emergency Departments (EDs), reflecting operational efficiency. High LWBS rates are common in situations of overcrowding and signal critical issues in ED management. This leads to a risk for patients who did not receive the necessary medical attention, since their health condition could worsen due to limited or delayed access to care. While descriptive analytics are commonly employed to address this phenomenon, little attention is given to predictive and prescriptive analytics. Previous Machine Learning studies proposed predictive methods capable of identifying categories of ED patients at risk of abandonment, without capturing their behavior over time. At the same time, Operation Research studies focus on other metrics, such as the Door-To-Doctor Time (DTDT) and the Length of Stay.

This talk introduces a dynamic physician-patient assignment approach informed by predictive models. Survival analysis on censored data is conducted to learn patients' behavior according to their characteristics as the waiting time increases. In addition to enhancing decision-making in the patient admission process, survival regression models allow the generalization of scenarios with an increased DTDT with respect to historical records. A computational analysis assesses the effectiveness of the proposed approach, investigating the trade-off between the DTDT and the LWBS rate.

Thursday, 16:00-17:30

■ HD-01

Thursday, 16:00-17:30 - Room: Auditorium

Business meeting

Stream: Plenaries
Meeting session
Chair: *Roberto Aringhieri*
Chair: *Melanie Reuter-Oppermann*

Friday, 9:20-10:30

■ FA-03

Friday, 9:20-10:30 - Room: Room S2

Integrated Planning in Healthcare /2

Stream: Regular talks
Contributed session
Chair: *Melanie Reuter-Oppermann*
Chair: *Sean Manzi*
Chair: *Gréanne Leeftink*

1 - A matheuristic for integrated resource allocation to patient appointment series
Sara Bigharaz, Henrik Andersson, Anders N. Gullhav

Managing the time that patients wait for their next appointment is a well-known challenge in hospitals. Scarce resources must be efficiently planned to create schedules that allow a hospital to keep these waiting times below set targets. The problem studied in this work is based on the situation in the Orthopedic Department at St.Olav's Hospital in Norway, and we have developed a MIP model for the integrated operating room (OR) and outpatient clinic (OC) scheduling problem. The model combines a detailed representation of the queues of patients waiting for consultations and surgeries and creates tactical blueprints that assign activities to surgeons and rooms over a planning horizon. To evaluate the performance of the model in OC and OR, we create cases of different sizes and study two aspects of cyclicity, cyclic or non-cyclic availability of surgeons and non-cyclic room schedules. Due to the large size and complexity of the problem, we propose a matheuristic algorithm to solve the sub-problems iteratively within shorter planning horizons. The algorithm involves three phases; initially, the heuristic begins by solving the model using the rolling-horizon heuristic. If the solution is found to be infeasible, the feasibility phase starts, and finally the algorithm iteratively fixes and reoptimizes the allocation of resources to patient types. The matheuristic is able to find better solutions with lower gaps and less time compared to solving the model using a commercial solver.

2 - Integrated Emergency Department and Bed Planning
Joe Viana, Laura Boyle, Nikolaus Furian, Gréanne Leeftink, Sean Manzi, Sebastian Rachuba, Melanie Reuter-Oppermann, Fabian Schäfer, Clemens Thielen, Maartje van de Vrugt

Emergency Departments (EDs) are critical to healthcare globally, operating 24/7 as entry to hospitals. Efficient turnover from ED to ward is vital but increasing demand and limited capacity pose challenges. Solutions to reduce crowding, like Overflow Wards (OW), are being adopted where patients await correct Inpatient Ward (IW) placement. Research on improving patient flow and ED overcrowding is abundant, but few studies consider ED and IW integration, with minimal focus on OW impact. Recognising the importance of integrated planning, our study builds on generic frameworks to present a discrete-event simulation model that encapsulates ED processes and patient flow to wards. In this ongoing research we emphasize the need for more holistic models, as most studies only tackle specific aspects, neglecting the broader connections within the hospital system. The model evaluates data from hospitals in four countries - Australia, Germany, New Zealand, and The Netherlands, additionally considering practices from Norwegian, Austrian and UK hospitals. It provides a comprehensive view on ED processes, beds in IWs, OW use, ICU processes, and inter-department patient transportation. Our work contributes significantly to the hospital management domain, as we investigate the effect of OW on both ED and clinical wards, providing valuable managerial insights for hospital/ED managers.

3 - Integrated care planning of multi-service inter-organisation care pathways
Sean Manzi

Healthcare provision often involves multiple services provided by more than one organisation particularly for complex and long term conditions. The different services that a patient interacts with and the care they receive is the care pathway. Such pathways can occur organically or pre-planned. Pre-planned care pathways can increase the efficiency and effectiveness of healthcare provision through better continuity and use of resources. The pre-planning of complex care pathways can be informed by understanding how patients organically access services and are referred through the system. This knowledge can provide a starting point from which to plan and optimise the care pathway. Patient level referral data provides the chronological narrative of a patients interaction with different health service. Integrated datasets from the various organisations/providers of these services provide a more complete picture of the patient journey. Network analysis provides an approach for organising, analysing and visualising these large and complex datasets. It also enables the probabilistic simulation of the most likely treatment pathways. This approach has been trialled in a case study of care for people with eating disorders in Devon with the analysis presented in an online interactive analysis explorer.

■ FA-04

Friday, 9:20-10:30 - Room: Room S3

Home Care /2

Stream: Regular talks
Contributed session
Chair: *Henrik Andersson*

1 - Fairness over time for the allocation and scheduling of teams in home healthcare services
Alberto Guastalla, Roberto Aringhieri, Matteo Di Cunzolo, Semih Yalçındağ, Mario Bifulco, Franco Sansonetti

Home Health Care (HHC) service plays an important role in reducing the hospitalization costs while improving the quality of life of those patients who receive treatments at their home. HHC is one of the important services where the service providers have to deal with various complex operational problems such as the assignment, scheduling and routing decisions under various objectives and constraints. In this work, we focus on the long-term assignment and weekly scheduling decisions under full continuity of care. To this end, a new framework have been developed to assign patients to medical teams and to decide their weekly visiting plans, both under fairness considerations. Including fairness within an optimization approach could be a challenging task in terms of metrics and mathematical modeling. We explore the idea of fairness over time that is the unfairness of a single period can be smoothed in the long run. The framework has two steps. In the initialization phase a model is formulated in order to assign the patients to the teams according to visit requirements, skill compatibilities and daily team capacities. In the second phase, an adaptation of the same model assigns new patients to teams matching their need and considering the discharge of ongoing patients in such a way to keep balanced the workloads of the teams. We provide some preliminary results on real data provided by Molinette Hospital in Turin, partner of the Circular Health for Industry (CH4I) project.

2 - Comparison of two optimization models for a nurse scheduling and routing problem under uncertainty
Paul Fleurance, Olivier Péton, Maria I. Restrepo

In this work we study the combination of two complex problems: scheduling and routing of nurses in the context of Home Health Care (HHC) activities. We seek to determine an optimal planning and routing of a team of nurses by answering the following questions: which nurse is working on which day and during which hours? For each working day, what is the sequence of visits to the patients? We consider a time horizon of several days, continuity of care and legal constraints (min/max working hours per day/week, min/max number of days off per week, min resting time between two working shifts and

max number of night shifts in a row). In addition, we consider two sources of uncertainty that, to the best of our knowledge, have not been yet considered together in these types of problems: uncertainty on the service time and uncertainty on nurse availability (a nurse can get sick in the morning and not being able to visit their patients). We model the problem as a two-stage stochastic programming model, and compare the two following approaches: assigning nurses to patients in the first or in the second stage. The first model is expected to be less flexible but easier to solve (the second stage problems are travelling salesman problems). The second model is more flexible but harder to solve (the subproblems are vehicle routing problems). We solve both models using the L-shaped method and present our numerical results on a set of randomly generated instances.

3 - Operational planning for advanced home hospitals
Henrik Andersson, Anders N. Gullhav, Hilvi Fjose, Guro Larsen, Agnes Oftung Strandbu

Norway's first Advanced Home Hospital (AHH) was established at Ullevål University Hospital in 2008. AHH aims to enhance the resource allocation at the hospital, as well as facilitate a lifestyle for patients that is as normal as possible, despite being hospitalized. The AHHs are currently operating on a small scale, with the process of routing and scheduling being performed manually according to each patient's diagnosis and preferences. The manual process requires that the person responsible for planning oversees a limited number of patients, ensuring that they are well acquainted with each patient and their medical condition. This work is part of the OUS at Home Project, which aims to leverage technology to allow home-based treatment for patients where it is beneficial. By 2030, the goal is to provide 30% of patients with home treatment and follow-up. This requires decision support for logistical planning and analysis of the necessary capacity for efficient and medically responsible home care. We examine logistical and efficiency challenges in AHH through an optimization model at an operational level. In this presentation, we discuss the problem and a mathematical formulation of it. We also present an adaptive large neighborhood search algorithm for solving large instance. Finally, computational results on representative cases, reflections and insights will be given.

■ FA-05

Friday, 9:20-10:30 - Room: Room S6

Emergency Department /3

Stream: Regular talks
Contributed session
Chair: *Thierry Garaix*

1 - Improving Emergency Department services scheduling through a hybrid Discrete Event Simulation and AI approach: an applied case study to the University Hospital of Bologna
Luca Zattoni, Andrea Eusebi, Cristiano Fabbri, Marco Leonessi, Enrico Malaguti, Paolo Tubertini

Emergency Department (ED) plays a central role in many hospital contexts: with the aging of population and the increasing request for emergency services, the pressure on this structure and its staff has increased as well. While this represents a challenge, it's also an opportunity to highlight the potential impact of an effective quantitative-based decision making. Length of stay (LOS) is often used as a measure of the ED performance, reflecting the patient's experience. High LOS values might be considered as a symptom of overcrowding: this is one of the main problems in ED, as it could result in discomfort as well as aggravating patient conditions, and its causes usually lie in oversaturation of resources and inefficient services scheduling. In the scientific literature, simulation methods have been proved to be an effective tool to evaluate the ED dynamics, capable of considering the high variability in patients' emergency pathways, due to clinical criteria and required services. We propose a decision support framework, using a hybrid Discrete Event Simulation and Deep Learning paradigm, that aims to prevent overcrowding through dynamic queue management. By exploiting both structured and textual patient data, a predictive model is used to estimate the pathways development. This can be given as an input to the simulation replicating the behaviour of the system, so as to evaluate different policies for scheduling the required services, while considering patients' priorities.

2 - Investigating the effects of increased patient severity stratification on Emergency Department performance
Chiara Morlotti, Elisa Alessio, Mattia Cattaneo

A recent variation in the Italian emergency department triage coding system aimed to enhance differentiation among patients' urgency by raising the number of Emergency Severity Index levels from 4 to 5. This study investigates the impact of such intervention on emergency department performance within a multi-hospital network in northern Italy. Relying on a two-period dataset spanning one year before and one year after the intervention—which includes all visits to the emergency department across four distinct facilities—we employ time series models to analyze changes in daily average waiting times while controlling for emergency department size and patient characteristics. Results reveal that the intervention leads to an initial decline in emergency department performance. However, over time, a significant reduction in mean waiting times is observed, accompanied by an increase in the proportion of patients receiving timely care. Interestingly, the effects varied among the facilities, with more pronounced improvements observed in facilities that initially had a lower level of efficiency.

3 - Work time analytics in Emergency Departments using localisation sensors
Thierry Garaix, Marius Huguet, Canan Pehlivan, François Ballereau, Antoine Dodane-Loyenet, Franck Fontanili, Youri Yordanov, Vincent Augusto, Karim Tazarourte, Abdesslam Redjaline

Emergency department (ED) crowding has become a major public health issue in many countries worldwide. Crowding can be defined as a market failure when the demand for emergency care outstrips the availability of physical and human resources. In this study, we implemented an indoor positioning system to track the activities of healthcare professionals in an emergency department, aiming to gain a better understanding of the emergency care production process. Healthcare professionals wore a sensor to record their location within the emergency department. We analyzed a substantial amount of quasi-real-time data to objectively assess physicians' time allocation and movement patterns and their correlation with the emergency department's occupancy. Additionally, we developed a user recognition algorithm (i.e., random forest classifier) capable of detecting the job category of the participant wearing the sensor. We found that the proportion of time spent on care-related activities ranged from 26% to 39% for doctors. The burden of non-care-related activities appeared to be largely induced by the time spent on administrative duties and transit, and to be correlated with ED occupancy. Lastly, we developed a decision support tool to predict daily and hourly loads of patients in the emergency department. Using a deep learning approach, models show an accuracy greater than 90% in predicting occupancy levels up to 7 days ahead.

Friday, 11:00-12:30

■ FB-03

Friday, 11:00-12:30 - Room: Room S2

Healthcare Logistics /2

Stream: Regular talks
Contributed session
Chair: *Niki Matinrad*

1 - Mobile clinics routing and scheduling in the Witzenberg region of South Africa
Linke Potgieter

In South Africa, the Department of Health has introduced mobile clinics to improve access to healthcare for rural communities. In this study, we consider the Witzenberg region, where six mobile clinics have been deployed. The aim was to determine routes and schedules to improve the workload balance, fairness, and transportation cost, while ensuring patients get satisfactory care. The problem is modelled in three phases using both primary qualitative data and secondary quantitative data. In phase 1, a multi-vehicle routing problem is formulated to construct feasible daily routes for the mobiles. Phase 2 distributes the daily routes fairly between the mobile clinics to ensure fairness. Finally, in phase 3, a vehicle routing formulation is used to determine a 4-week schedule for each mobile clinic, by using the daily routes obtained during phase 2 as input. Four different service time estimations are used as input, resulting in four different schedules, each with their own advantages and disadvantages, including cost-effectiveness, robustness, fairness, and continuity of care. AHP was then performed with main decision makers to determine their preferred schedule. Final routes and schedules were determined based on model results, AHP results, and final practical input from the decision makers, resulting in an improvement in workload balance, a 23% reduction in total distance travelled and willingness by decision makers to implement the changes.

2 - Reducing open vial wastage with lateral transshipment in COVID-19 vaccine administration
Burcu Balcik, *Cagri Ozmemis*

Efficiently managing COVID-19 vaccination programs faces a critical challenge: minimizing vaccine wastage, especially with multi-dose vials at final administration points. Once opened, these vials expire rapidly, leading to significant waste due to uncertain clinic demand. Based on insights from healthcare practitioners, we propose a lateral transshipment strategy to transfer open vials between clinics, aiming to optimize resource utilization. This approach integrates a two-stage stochastic programming model to address demand uncertainty at family health centers. To solve the problem, we propose a practical heuristic approach in which we cluster the vaccination clinics based on their capacity. We present a case study focusing on family health centers in Tuzla, a district of Istanbul, and provide valuable insights. The results show that practicing transshipment can provide significant savings during low vaccination periods, the direction of transshipments usually occurs from small clinics to large clinics, and our heuristic approach is promising in solution quality and time.

Keywords: Vaccine administration, COVID-19, open vial wastage, lateral transshipment

3 - Locating emergency response volunteer centers
Niki Matinrad, *Tobias Andersson Granberg*

Many sparsely populated areas experience poor emergency services coverage. To address this issue, fire and rescue services (FRS) in Sweden have started volunteer initiatives. In these, civilians (volunteers hereon) are trained in cardiopulmonary resuscitation (CPR), first aid, and required actions when a person first arrives at a fire, traffic accident, or drowning incident. In the event of an emergency, these volunteers are alerted through a short message service (SMS), or via an app, on their mobile phones, simultaneously with the dispatch of professional emergency services. Due to limited budget, equipment, and manpower, it is impossible for professional emergency services to include and train too many civilians in the volunteer initiative. Therefore, it is important to determine where the volunteer centers should be located, that is, which regions should be selected for inclusion in the volunteer initiative. This decision is not always straightforward to make. Thus, we propose an optimization model to determine where the volunteer centers should be located to obtain the best possible emergency coverage. We use the area of a large FRS organization in Sweden, which currently has 20 FRS stations, as our use case. The results show that including volunteer centers will improve the emergency response coverage. More interestingly, the optimal solutions with two volunteer centers, were selected for implementation by the FRS organization-recruitment and training are ongoing.

■ FB-04

Friday, 11:00-12:30 - Room: Room S3

Artificial Intelligence

Stream: Regular talks
Contributed session
Chair: *Joseph Farrington*

1 - Digital twin of surgical care assessment and risk evaluation
Wang Yiyu, *Canan Pehlivan*, *Vincent Augusto*

In the era of Medicine 4.0, the operating room (OR) is a significant expense in hospitals due to the complexity of surgical procedures, specialized equipment, highly trained staff, and strict regulations. During surgical procedures, avoidable errors may occur. Our goal is to implement a system to identify these errors and predict the adverse events across different surgical types. We aim to develop a user-friendly and cost-effective digital twin for surgical procedures tailored for individual use, addressing the needs of surgeons.

We initialize our research by the creation of a synthetic database represented by event logs. These event logs serve as input for constructing a surgical workflow framework, enabling error detection and event prediction through process mining and machine learning methods. Subsequently, we simulate the entire surgical process using this framework until successful validation with real-time live usage.

Our research outcomes offer practical applications in the medical field and practical solutions to enhance academic studies, surgical practice, and healthcare management.

2 - Early salivary diagnosis using Raman Spectroscopy and Machine Learning
Marco Piazza, *Enza Messina*, *Mauro Passacantando*

Raman Spectroscopy is a technique based on the inelastic scattering of a monochromatic light beam used to observe low-frequency modes in a target molecular system. The scattering pattern can be viewed as a sort of "fingerprint" that encodes information about the chemical composition of a given target. Recently, Raman spectra of biofluids, and in particular saliva, have been proposed for medical diagnosis, leveraging the power of Machine Learning for automatic sample classification. In this talk, we will discuss the initial results of the CORSAI project, which focuses on utilizing this combined technology to develop non-invasive and portable early diagnostic tools. In particular, we address the problem of the black-box nature of ML algorithms by integrating into the classification pipeline Explainability methods based on Game Theory. This serves a double purpose: providing insights into the classification reasons for a specific sample and guiding medical research towards the identification of novel biomarkers associated with a specific disease. To assess the validity of the proposed system we evaluated it on the diagnosis of COVID-19, as well as on Chronic Obstructive Pulmonary Disease (COPD). The selected case studies are characterized by specific challenges that we discuss and address within our method.

3 - Development of a risk score to predict accidental falls in an elderly cohort
Rachda Naila Mekhaldi, *Julia Fleck*, *Phan Raksmey*, *Xiaolan Xie*

Accidental falls are the primary cause of accidental death among the elderly and a significant barrier to active and healthy aging. Early fall risk prediction can assist caregivers in defining interventions that reduce the risk and prevent a fall, thus significantly impacting healthcare services. In this study, our goal is to construct a risk score that accounts for the probability that an elderly individual will fall within six months. We use an open source database containing information on fall incidents, fall history, and fall risk assessment scores, among others, from a cohort of 301 patients aged 65 and over. To preprocess the data, we perform numerical data standardization and categorical data encoding, and use Boruta algorithms for feature selection. We assess the performance of three classification algorithms (Random Forest, Extreme Gradient Boosting, and Falling Rule List) whose hyper-parameters are optimized through Bayesian methods. We report our results using classification metrics including recall, precision, and F1-score. Our findings will guide future algorithmic developments in the context of an ongoing project.

4 - Charting the Pareto frontier: Multi-objective optimization for platelet inventory management using neuroevolution
Joseph Farrington, *Kezhi Li*, *Martin Utley*

Managing perishable inventory, such as platelets, requires balancing multiple objectives. In the blood product management literature, notional costs are often used to weight the relative importance of avoiding shortages and minimizing wastage because the consequences are not just monetary. The notional costs do not have an empirical basis and do not necessarily accurately reflect the preferences of decision makers. Estimating the Pareto frontier of feasible policies can illustrate potential trade-offs between objectives and support discussions with decision-makers.

We used evolutionary algorithms to fit the parameters of neural networks representing both replenishment and issuing policies. This enabled us to learn complex policies and use key performance indicators, including wastage and service level, as the objectives in multi-objective optimization algorithms to estimate the Pareto frontier. We compared the performance of these policies with heuristic replenishment and issuing policies and with an estimate of the optimal policies computed over a range of notional cost ratios using dynamic programming. Our findings show that the neuroevolution approach is competitive with other approaches and outperforms them in a number of instances.

In this presentation, we will also explain how this work was facilitated by using the Python library JAX to run algorithms in parallel on affordable, consumer-grade GPU hardware.

■ FB-05

Friday, 11:00-12:30 - Room: Room S6

(Multi)Appointment /2

Stream: Regular talks
Contributed session
Chair: *Anders N. Gullhav*

1 - Assessing the impact of overlapping shifts in multi-appointment outpatients scheduling
Marco Roma, *Paola Cappanera*, *Maddalena Nonato*, *Cristina Requejo*

Most chronically ill patients affected by Non-Communicable Diseases live at home but receive treatments and consultations (services, hereafter) at a hospital. A good practice is to schedule multiple services of a same patient on the same day. Once the set of services booked for a day is defined, a centralized management of the scheduling process allows for a better use of shared resources, which have a limited availability, in terms of time, during the day. This work deals with the problem of scheduling a set of patients requiring several services on a given day, abiding by the planned availability of the hospital operators. The duration of the services is given, and they are partitioned according to their type (the required medical specialty). Operators are likewise partitioned, and each operator can deliver all and only the tasks of the type they belong to. In addition, each operator has a specific working shift, thus, no service can begin before the start of the shift of the operator it is assigned to, nor exceed its end. Services can be delivered in any order, each operator can attend one patient at a time, and each patient can receive at most one service at a time, without preemption. The objective is to maximize the number of scheduled services, weighed by their duration. This study aims to assess the impact of different patterns for operator shifts, and to compare different scenarios to evaluate the consequences of different strategic decisions.

2 - Redistributing Oncology treatments to Regional Outpatient Clinics within Isala Clinics
Andre Poncelet, *Jedidja Lok - Visser*, *Christina Büsing*, *Gréanne Leeftink*

The scheduling of chemotherapy treatments and the corresponding allocation of staff and resources have been extensively explored in the operations research literature. Generally, this is based on a central treatment facility. However, this is not always necessary: Although some chemotherapy treatments must be administered in a clinic and with an oncologist and complex support systems nearby, many treatments only require limited equipment, personnel and additional safety regulations and can therefore be administered in locations such as doctor's offices and community centers with comparatively little additional cost. This may eliminate long travel times for patients, increasing patient satisfaction.

In this talk, we explore two research problems: Frist, how oncology treatments can be scheduled to maximize patient satisfaction (while considering cost and resource capacity) when there are multiple locations available. And second, if necessary, how to select additional locations that enable efficient treatment scheduling and minimize travel times.

We present multiple algorithms based on local search and greedy metaheuristics. The algorithms are then evaluated in a computational study using real-world data from the oncology department of a large, Dutch hospital, Isala Clinics.

3 - Appointment Scheduling of Multiple Classes of Patients for a Diagnostic Medical Facility
Simran Lakhani, *Ashutosh Mahajan*

We study appointment scheduling for a diagnostic facility within a resource-constrained, high-demand tertiary-care cancer hospital. For scheduling appointments, the patients are categorized based on their ability to pay into General and Private. They are further classified based on their treatment stage into New and Follow-up patients, thus giving a total of four categories. Due to high demand, patients experience high waiting times to get an appointment. The waiting periods are different for each category and quite high compared to usual. Generally, Private patients are prioritized over General patients, and New patients are preferred over Follow-ups as diagnostics facilities play a crucial role in planning treatment. The hospital follows certain rules for scheduling appointments for each category. We use simulation and queuing theory to study the arrival patterns of these patients, analyze existing schemes of scheduling patients, and examine the factors contributing to long wait times to book an appointment. We further model the impact of increasing resource capacity and managing the existing one by increasing the service rate.

4 - Integrated shift and appointment template scheduling for a chemotherapy clinic
Anders N. Gullhav, *Nadia Lahrichi*, *Louis-Martin Rousseau*

Chemotherapy is one of the most common cancer treatment modalities and often administered in outpatient settings. The scheduling in chemotherapy clinics is complex as the treatment involves a series of appointments, following a medical protocol with strict temporal requirements. These include maximum wait time for the initial appointment and fixed intervals between subsequent appointments. Furthermore, the 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 devising a cyclical weekly shift schedule and appointment template. The shift scheduling involves determining the start and end times for shifts and the number of nurses to assign to each shift. Simultaneously, the appointment template specifies when different appointment types are performed and aim to optimize the resource utilization while adhering to the requirements of the medical protocols. We propose a mixed integer programming (MIP) model for the integrated shift and appointment template scheduling. We validate our model using realistic data instances and evaluate the resulting schedules using simulation. Our findings demonstrate that these integrated schedules enhance clinic efficiency, serving as a valuable guiding tool in the online booking process.

Friday, 14:00-15:30

■ FC-03

Friday, 14:00-15:30 - Room: Room S2

Patient and Resource Scheduling

Stream: Regular talks
Contributed session
Chair: *Christina Büsing*

1 - Combining Equity and Utilisation in Surgery Scheduling
Thomas Adams

When scheduling surgeries it is important to take into account that not every operation on the waiting list is equally urgent. Instead the urgency of each patient can depend on many factors such as: the particular condition they have, their age, any other comorbidities, and how long they have been waiting.

In addition to concerns about the urgency of patients, healthcare organisations are interested in making efficient use of their resources. In terms of scheduling surgeries this means making sure that their operating theatres are well utilised. Often this can be in conflict with prioritising more urgent patients.

In this work we assume that the patients on the waiting list can be ranked in terms of most to least urgent. We also introduce the concept of a 'justified transfer' and using this develop a parameterised scheduling model that at one end strictly follows priority, and at the other maximises utilisation. We also explore the consequences in terms of equitable principles such as impartiality and consistency.

2 - Integrating Heuristics and Roommate Preferences into an OpenSource Framework for Patient-to-room Assignment
Felix Engelhardt, Tabea Brandt, Christina Büsing, Daniel Müller

We consider the dynamic management of a hospital ward with respect to the patient-to-room assignment (PRA). PRA is an operational problem with multiple objectives, including avoiding unnecessary workload, i.e. patient transfers, avoiding patient conflicts and respecting single room entitlements.

We focus on two extensions of the basic model: First, we propose variations of GREEDY heuristics that quickly compute initial feasible solutions. Second, we evaluate another possible objective, i.e. roommate preferences and showcase how these can be introduced into the existing modelling setup.

Both extensions are evaluated in a computational study that is based on real-world data provided by the RWTH Aachen University hospital. For the roommate preferences objective, we also provide some combinatorial results and consider the effect of different modelling decisions on the computational performance. Based on this, we derive recommendations for modelling multiple objectives in PRA.

The computational study is based on an OpenSource framework [1] for PRA based on Binary Integer Programming (BIP), implemented in Python and using Gurobi as a solver. The framework already provides options for solving both static and dynamic PRA, including transfers and single room entitlements as objectives.

[1] https://zenodo.org/records/10408092

3 - Optimizing Surgical Trays for Uncertain Surgery Schedules
Johanna Leweke, Hayo Bos, Christina Büsing, Felix Engelhardt, Gréanne Leeftink

Ensuring the availability of surgical instruments in hospitals is crucial for successful operations. In this context, grouping reusable instruments into fixed trays is common, as it offers the benefits of better inventory control and lower sterilization costs. Yet, instrument trays can

lead to wastage, e.g., through unneeded instruments being assigned to operations. Additionally, once a tray is opened, its instruments must be sterilized, regardless of use. While having a variety of trays available helps reduce sterilization costs by ensuring the best fit for each surgery, it can lead to significant storage expenses. Therefore, optimizing tray configurations and effectively assigning them to the surgery schedule constitutes a relevant and practical problem for many hospitals. In this talk, we start by presenting a mathematical model that considers the three decisions: tray configuration, determining the quantity of each tray type in the inventory, and assignment based on uncertain realizations of the master surgery schedule. In a first stage, we propose greedy heuristics to configure both trays and inventory such that the number of instruments is minimized while restricting the number of trays. For the second stage, an assignment to the surgery schedule is found that minimizes the sterilization costs. Afterwards, a local search algorithm allows for small inventory changes. All algorithms are evaluated in a computational study making use of real-word data from a Dutch hospital.

4 - A metaheuristic approach for surgical case assignment and admission planning problem considering perioperative pathways
Andrea Eusebi, Cristiano Fabbri, Marco Leonessi, Enrico Malaguti, Paolo Tubertini, Luca Zattoni

Modern healthcare systems face significant operational strain, particularly in managing surgical waiting lists. Employing quantitative methods is crucial for delivering effective and efficient care services, allowing for optimal utilization of the resources. We present a linear programming model for scheduling surgical patients, while considering the availability of operating rooms and beds across different specialty wards, and the intensity settings throughout their hospital stay. The schedule considers the anticipated perioperative path of each patient, and clinical details such as diagnosis and proposed surgical procedure. After observing that general-purpose solvers struggle in managing large instances of the proposed model, we introduce a metaheuristic algorithm to produce good solutions in short time. While considering clinical and organizational constraints, this algorithm not only manages the scheduling of patients, but also aids in making decisions on the allocation of the operating theatre time slots among different surgical disciplines. In addition, by considering existing patients on the waiting list as well as projections of future admissions based on historical data, the algorithm can support the hospital management in tactical and operational decisions. We present results at both levels, obtained by applying the described approach in a large academic hospital including 11 surgical departments and over 40 operating rooms.

■ FC-04

Friday, 14:00-15:30 - Room: Room S3

Policies and Networks

Stream: Regular talks
Contributed session
Chair: *Felipe Rodrigues*

1 - Perinatal and mental health: 2 priorities of the Regional health plan in Ile de France (IDF)
Catherine Crenn-Hebert, Wuthina Chin, Mohamed Ashraf, Julia Lexcellent

Perinatal mental health was one of the first new actions of the regional perinatal policy advisory committee through a multidisciplinary working group starting in 2019 with Global Alliance for Maternal Mental Health as an example. IDF region experienced elevated maternal mortality rate and suicide was the first direct cause, with estimated evitability greater than 50%. Postpartum depression is higher in IDF than in other hexagonal French regions. Some perinatal networks took part in territorial mental health projects (a national directive). National "1000 first days plan" focus on parents mental health (2020).

How to assess the impact of prioritization from Regional health agency followed by national actions?

We use our regional Perinatal health Information System data, meeting minutes of the working group and perinatal networks activity reports analyzes, allocated budgets in perinatal pathways and psychiatry.

The working group developed regional perinatal mental health plan is based on 5 axes: Mental health troubles systematic identification by every perinatal professional at any occasion with training among perinatal networks Multidisciplinary medico-psycho-social meetings during pregnancy Enhancement of territorial care resources in perinatal mental health Support structures Assessment

We can already establish a picture of the degree of achievement of this plan but measuring the results in perinatal mental health will need further investigation.

2 - Generalized or Specialized Hospitals: An Analytical Queuing Approach to Explore Clinical Service Configurations
Mohammad Aminjarahi, Navid Izady, Dimitris Paraskevopoulos

In multi-hospital networks (MHNs), a critical decision revolves around how to allocate clinical services across different hospitals with limited capacity. This decision typically falls between two extremes: a fully generalized configuration where all services are offered in every hospital, and a fully specialized configuration where each hospital exclusively provides one service. However, research and practical evidence indicate that neither fully specialized nor fully generalized configurations are optimal. In our paper, we present a mathematical model along with an exact analytical solution to explore the optimal service configuration within an MHN comprising two hospitals of equal fixed capacity and two services. Our model addresses uncertainty by incorporating queueing theory and economies of scale, crucial factors in service configuration problems. Through extensive numerical experiments, we demonstrate that, in most scenarios, a semi-specialized configuration emerges as optimal, maintaining one hospital as general and the other as specialized. Nonetheless, there are specific circumstances where alternative configurations, such as fully specialized or fully generalized, may prove optimal.

3 - Benchmarking data-driven policies to cope with absenteeism in nurse rostering using simulated predictions
Martina Doneda, Pieter Smet, Giuliana Carello, Ettore Lanzarone, Greet Vanden Berghe

Healthcare is experiencing a surge of interest in the use of Machine Learning (ML) for decision-making. However, employing ML as a silver bullet is a rather naive suggestion. In this work, we make a case for this argument using an example from nurse rostering and rerostering considering absenteeism, referring to instances derived from the Second International Nurse Rostering Competition.

On any given day, each nurse can be absent with a certain probability. When such a disruption occurs, the roster needs to be repaired. We assume that we can incorporate some robustness in the roster using reserve shifts. If the reserve shifts can not repair the disruptions on their own, we assume that ad interim nurses need to be called in, at an high expense. Suppose having a ML model capable of predicting how many nurses will be absent on a given day. How to determine whether using it improves system performance more than using a non-data-driven policy?

When using ML to help decision-making, usually i) the ML model is trained and tested, and ii) deployed in several simulated scenarios of the problem to evaluate its effectiveness. We purposely subverted this sequence, simulating the use of a nondescript ML model (an "oracle") at various levels of predictive performance, deploying it directly in several simulated scenarios. This inversion allows us to evaluate whether it is worth it to invest resources to implement a ML approach, and, be it the case, to determine what its mini

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

Access to public services in Canada has declined significantly, with the Ontario Autism Program (OAP) as a prime example. This publicly funded program currently has more than 60,000 children registered and waiting up to 2 years for provincial funding to access decentralized private services and treatments for autism spectrum disorder (ASD). We focus on the strategic decisions that families, service providers, and governments make in a decentralized system characterized by congestion, where competing interests have been introduced in asymmetric competition, providing a strategic queuing game behaviour among its players. We developed a general mathematical framework to explore the structure of optimal contractual agreements for the OAP in the presence of congestion and information asymmetry in offering public treatment services for autism. This preliminary framework can then be generalized to other decentralized congested healthcare services.

■ FC-05

Friday, 14:00-15:30 - Room: Room S6

Healthcare Management /3

Stream: Regular talks
Contributed session
Chair: *E. Lerzan Ormeci*

1 - Optimizing machine scheduling of central sterile services departments in hospitals
Robin Schlembach, Jens O. Brunner

Hospitals face major challenges as they have to reconcile financial constraints with the need to provide optimal patient care. While operating theaters are often the subject of extensive research, their functionality depends on the effectiveness of secondary departments, such as the central sterile services department (CSSD). Despite its critical role in the operational process through the provision of reprocessed medical devices, the CSSD has been relatively little studied in the existing literature. A high volume of instruments that need to be processed and the fact that missing or late medical devices lead to postponements and cancellations of operations and thus high costs and effort make efficient CSSD planning essential. To address this problem, we present a parallel batch scheduling model that optimizes the scheduling of sterilization machines. Our approach aims to improve capacity utilization by minimizing the maximum completion time of all sterilization processes in a day. The model will be applied to a case study of a German CSSD of a maximum care hospital with up to 380 instrument sets per day.

2 - Trade-off analysis of staffing decisions and shift systems with special consideration of flexibility
Milena Grieger, Stefanie Ebel, Jens Brunner

Personnel in hospitals generate the most relevant and biggest cost block. In particular, physician staffing and scheduling are of crucial importance. We focus on staffing decisions subject to a (flexible) shift system considering break assignments. The number of required physicians is minimized subject to essential constraints, e.g. the coverage of forecasted demand in each planning period as well as various legal regulations. We formulate the problem as an integer programming model and solve it with standard software. Random data representing eight distinct demand profiles, each comprising 25 instances, are utilized for our calculations. We explore inflexible (e.g. two twelve-hour shifts and no break), determinable (e.g. a maximum of five different shifts and a flexible break), and flexible models (e.g. multiple shifts and breaks), allowing for a comprehensive understanding of varying hospital conditions. Our findings underscore the significance of including breaks in shift systems and highlight the benefits of system flexibility in personnel scheduling. The examination of different demand profiles offers insights into the strengths and weaknesses of hospital requirements. Furthermore, tailoring the model flexibly to individual hospital conditions can significantly enhance physician satisfaction.

3 - Beyond Fee-for-Service: How Comprehensive Contracts Can Transform Primary Care
E. Lerzan Ormeci, A. Mete Ozbek, Hessam Bavafa, Evrim Didem Gunes

We study comprehensive contracts (CCs), which are performance-based reimbursement schemes for managing patients with chronic conditions. These contracts aim to transform primary care beyond the traditional fee-for-service model by inducing providers to offer various services, including preventive care, chronic disease management, and care coordination. We develop a stylized Principal-Agent model to study primary care practice (PCP) capacity allocation under a comprehensive contract. The contract is motivated by performance-based contracting systems for primary care. We first show that a pure fee-for-service contract fails to induce PCPs to allocate capacity for comprehensive care. We then analyze a comprehensive contract offering a capitation payment, a performance bonus, or a combination and show that such a contract is necessary but insufficient to induce a comprehensive care effort. We identify PCP effectiveness in delivering comprehensive care as crucial in designing comprehensive contracts. We show that offering CCs to highly effective PCPs enhances access to healthcare and improves outcomes. Characterization of the optimal CCs shows that they fail to achieve the first-best outcomes, even under the risk-neutrality of the PCP. Our numerical analysis suggests that a comprehensive contract with a strict budget limitation could fail to attract the majority of PCPs, and the payer should consider improving the revenue potential of PCPs for meaningful participation.

Friday, 15:30-16:00

■ FD-01

Friday, 15:30-16:00 - Room: Auditorium

Closing

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

STREAMS

Discussions

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Track(s): 4

Plenaries

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Track(s): 1 5

Posters

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Regular talks

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Session Chair Index

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Session Index

Monday, 9:00-9:30

Monday, 9:30-10:30

Monday, 11:00-12:30

Monday, 13:50-15:00

Monday, 15:30-16:40

Tuesday, 9:00-10:30

Tuesday, 11:00-12:30

Tuesday, 14:00-15:30

Tuesday, 16:00-17:30

Thursday, 9:30-10:30

Thursday, 11:00-12:30

Thursday, 14:00-15:30

Thursday, 16:00-17:30

Friday, 9:20-10:30

Friday, 11:00-12:30

Friday, 14:00-15:30

Friday, 15:30-16:00