ORAHS 2023

Program

July 17, 2023

TECHNICAL PROGRAM

Monday, 9:00-9:30

■ MA-01

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

Opening

Stream: Plenaries
Invited session

Monday, 9:30-10:30

■ MB-01

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

Keynote Talk I

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

1 - Integrated planning of health services - a little flexibility goes a long way
Erwin W. Hans

The staffing crisis in healthcare can, at least partly, be solved by reducing the siloed mentality of healthcare providers. Integrated capacity planning between and within healthcare providers can reduce access time, increase productivity, while at the same time reducing experienced workload for healthcare staff. Our research shows great potential for this, and also gives a hopeful message: a little flexibility goes a long way. . . Realizing this potential requires an interdisciplinary approach to overcome the barriers for implementation.

Monday, 11:00-12:30

■ MC-01

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

Operating Rooms I

Stream: Talks
Contributed session
Chair: *Fermin Mallor*

1 - Advance Surgery Scheduling with downstream constraints and cancellations
Anders N. Gullhav, Mats I. Schiøtz, Jostein H. Tysse, Lars Hellemo

The Advance Scheduling Problem (ASP) aims to fix a surgery date for surgical cases several weeks in advance, such that surgeries are performed efficiently. We consider an ASP where elective inpatients and outpatients can be treated in the same operating rooms, assumes dedicated resources for non-elective cases, and include the downstream recovery wards. The ASP contains uncertainty in the surgery duration and length of stay in recovery wards, and each surgical case is subject to a non-plan-specific cancellation probability.

We propose a stochastic optimization model for the ASP that minimizes access time and surgery schedule disruptions. The model is embedded a rolling horizon simulation framework and tested on data from the Orthopedic Department at St. Olav's Hospital in Norway. The study also investigates the impact of cancellations on the quality of the surgery schedule and identifies alternative scheduling strategies. The results show that the model is sensitive to objective function parameters and planning horizon length and that non-plan-specific cancellations can significantly affect the surgery schedule.

2 - A quantify uncertainty then optimize approach for the advanced scheduling problem with side data
Ricardo Otero-Caicedo, Erik Demeulemeester

Due to the complexity and uncertainty revolving around surgical procedures, creating optimal schedules in operating rooms continues to be a challenging task that attracts the attention of practitioners and researchers. Approaches that do not consider uncertainty perform poorly in real scenarios, leading to idle time, overtime and surgery cancellations. Stochastic approaches, such as stochastic programming (SP) and simulation-optimization (SO) require a precise characterization of the stochastic behavior of surgery times. This is frequently done by assuming, as the true data-generating process, for each surgical specialty, a lognormal distribution whose parameters are estimated using historical data. A drawback of the previous approach is that it does not include additional covariates that are relevant for surgery time prediction. In this research, we implemented several techniques to characterize surgery times uncertainty in the presence of covariates and test their potential to generate high-quality solutions for the advanced scheduling problem (ADP). For uncertainty quantification, we implemented classical machine learning algorithms as well as Bayesian neuronal networks (BNN). We then performed a deep experimentation using both a synthetic and a real data set from a reference hospital in Bogotá-Colombia. Results show that the quantify-uncertainty-then-optimize approach outperforms traditional approaches that use the surgical specialty as the only relevant covariate.

3 - Upstream and downstream resources optimization in operating room planning
Luca Murazzano, Paolo Landa, Roberto Aringhieri

This study deals the problem of operating room scheduling focusing on two hierarchical levels considering both upstream and downstream resources involved in the process. The two levels are the tactical level of OR sessions assignment to different surgical specialties and their teams, known as Master Surgical Schedule Problem (MSSP), and the operational level of assigning patients in waiting list to surgical sessions, or Surgical Case Assignment Problem (SCAP). The study emerged from the need for the University Hospital Center of Quebec City to reduce waiting lists for surgical procedures. The two problems were approached mainly using MILP models. The SCAP model consider only one surgical specialty and the availability of ward beds. A long-run analysis and a what-if scenario on the SCAP were also performed. Two different approaches were proposed for the MSSP with the aim of achieving a fair allocation of surgical sessions: the first one considers the minimization of the variance among the values of the gaps between the allocated and required sessions, while the second uses the minimax method. The models were developed using commercial solvers. The results of the first problem show how the presence of ward beds in the planning process affects the allocation and how the variation of the parameters impacts on the operating process within surgical specialties. The results of the second problem show the impact of the fairness on the solutions provided.

4 - An Online Optimization-based Tool for Surgery Scheduling and Rescheduling
Andrea Mancuso, Maurizio Boccia, Adriano Masone, Claudio Sterle

Effective management of operating rooms (ORs) is a challenging yet crucial aspect of ensuring the proper functioning of hospitals. One of the critical issues in ORs management is developing an efficient surgery schedule. This challenge is known in scientific literature as the Surgery Scheduling Problem (SSP). In its more general form, the SSP involves making decisions about when and where surgeries should take place, considering various operational issues and constraints. This work addresses the specific SSP faced by a hospital in Naples, with the aim of balancing two contrasting goals throughout the planning horizon: maximizing ORs utilization and being able to cope with unforeseeable events, such as surgery duration variations and emergency arrivals. To address these challenges, we propose a two-phases optimization approach. Phase I focuses on designing an efficient and proactive surgery schedule that maximizes ORs utilization while ensuring an adequate responsiveness to unforeseeable events. Phase II reacts to these events by minimizing deviations from the schedule established in Phase I, while remaining efficient and responsive throughout the planning horizon. Both phases are developed in an Integer Linear Programming (ILP) fashion and integrated into an optimization tool. The effectiveness and performance of the proposed tool are validated using real data provided by the hospital. Experimental results demonstrate the tool as a valuable decision support system.

■ MC-02

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

Intra-Hospital Integrated Planning

Stream: Talks
Contributed session
Chair: *Sebastian Rachuba*

1 - Evaluating the effects of emergency department inpatients on patient-to-room assignment for specialties with multiple wards
Felix Engelhardt, Tabea Brandt, Christina Büsing

We consider the dynamic management of multiple wards within a specialty with respect to the patient-to-room assignment (PRA). We focus on the interaction between elective patients' assignment and inpatient transfers from the emergency department (ED). Managing this patient flow is a relevant issue, as insufficient outpatient flow may lead to overcrowding in the ED. However, in some specialties, inpatient transfers from the ED constitute up to 80% of the patient arrivals. These unexpected arrivals lead to a high workload in the wards and in the worst case to the cancelation of elective patients. The proposed solution approaches are based on a pre-existing Binary Integer Programming (BIP) model for PRA at ward level. We propose three different approaches: First, we integrate several ward instances into a joint BIP.

Second, if we assume the transfers take place in batches of patients, we solve the assignment problem heuristically by repeatedly solving the ward level PRA to generate a Pareto-front of optimal patient assignment numbers and recombining them in a Master-IP. Third, we consider a GREEDY rule, where patients are assigned to the ward with the least utilisation. The approaches are compared in a computational study that is based on real-world data. Results show that using the above can reduce the number of transfers and contribute to balancing patient load. Furthermore, we give an outlook on how work to extend this in a joint project with hospital stakeholders.

2 - A tactical multi appointment scheduling problem with the integrated resources in outpatient clinic and operating room
Sara Bigharaz, Henrik Andersson, Anders N. Gullhav

The operating room (OR) is one of the most critical and resource-intensive departments in hospitals, where developing efficient scheduling strategies can be a challenging task. The efficiency of the OR department can be significantly improved through optimized appointment scheduling with the integration of the resources in outpatient clinics (OC) and ORs. To treat patients at the Orthopedic Department at St. Olav's Hospital in Norway, the patients need to follow care pathways that involve a series of activities required for treatment. The patients visit surgeons in the OC for consultations several times and if they were diagnosed with need for surgeries, the slots in ORs are assigned to patients. Following their surgery, patients have follow-up consultations with surgeons at the OC. To perform activities, in addition to surgeons, patients need resources including OC rooms, operating rooms and beds in wards for multiple appointments. In addition, patients need to wait on waiting lists for the activities to receive services in their care pathways. The aim of study is to develop schedules at the tactical level which not only allocate the patients to resources in time slots but also provide blueprint schedules for the surgeons. In order to investigate the impact of the proposed optimization model on the OC and OR performance, we compose four cases under different circumstances and we compare the solutions of two different optimization models in simulation experiments.

3 - Striving for Staff Satisfaction and Patient Care Quality: An Integrated Optimization Model for Patient-to-Room and Nurse-to-Patient Assignments
Fabian Schäfer, Tabea Brandt, Melanie Reuter-Oppermann, Clemens Thielen, Maartje van de Vrugt, Joe Viana

The COVID-19 pandemic has highlighted the crucial role of healthcare staff, particularly in hospitals, where many countries have experienced staff shortages even before the pandemic and are still experiencing shortages. Therefore, efficient staff scheduling that considers staff preferences and satisfaction is a crucial task for hospitals. The number of beds typically measures hospital size, but the number of staffed beds is more relevant to patient care. Assigning patients to rooms and nurses to patients are critical tasks that directly affect staff satisfaction, quality of care, and hospital efficiency. Nurse-to-patient assignments are typically agreed upon at the ward level at the start of each shift, making it reasonable to plan them jointly with the patient-to-room assignments on the same ward. Therefore, we present an integrated optimization model for patient-to-room and nurse-to-patient assignments to enhance staff satisfaction and patient care. However, the resulting integrated planning problem is inherently complex since even the subproblems for patient-to-room and nurse-to-patient assignments are known to be NP-hard and computationally challenging. To evaluate the model's practical applicability, we conduct experiments to assess run time and solution quality for various settings, including different numbers of patients, shifts, and rooms.

4 - Coordinating Oncologist Appointments with Chemotherapy Treatments Under Uncertainty
Tonguc Ünlüyurt, Serhat Gül, Ege Özyüksel

The limited availability of resources, high level of uncertainty in infusion durations and the critical nature of the cancer treatment, render the chemotherapy scheduling in outpatient chemotherapy clinics a quite challenging and important problem. In this regard, our study combines the oncologist consultation and chemotherapy scheduling while coordinating daily sequences and appointment times of patients who are assigned to the same day for their chemotherapy treatments. We develop a two-stage stochastic mixed integer programming (TSMIP) model that considers a continuous time frame for appointments and stochasticity in both infusion times and status of chemotherapy treatment approval following the oncologist consultation. The first stage of the TSMIP model ensures that the patients are sorted in a global sequence by taking their designated oncologists into account, while the second stage takes care of assigning patients to chairs, and nurses with identical skills. The objective function penalizes the weighted sum of the makespan of the chemotherapy clinic along with the patient waiting times. The model is solved after reducing the problem size using a scenario reduction algorithm. We test our Wasserstein metric based Local Search algorithm, using real data from a major academic oncology hospital in Turkey.

■ MC-03

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

Predictive Analytics in Healthcare

Stream: Talks
Contributed session
Chair: *Christina Bartenschlager*

1 - Extubation Decision Making with Predictive Information for Mechanically Ventilated Patients in ICU
Jingui Xie

Weaning patients from mechanical ventilators is a critical decision in intensive care units (ICUs), significantly affecting patient outcomes and the throughput of ICUs. In this study, we aim to improve the current extubation protocols by incorporating predictive information on patient health conditions. We develop a discrete-time, finite-horizon Markov decision process (MDP) with predictions on future information to support the extubation decision. We characterize the structure of the optimal policy and provide important insights into how predictive information can lead to different decision protocols. We prove that adding predictive information is always beneficial, even if the physicians overtrust the predictions as long as the prediction accuracy satisfies certain conditions. Using a comprehensive dataset from an ICU in a tertiary hospital in Singapore, we compare the performance of different policies and demonstrate that incorporating predictive information can reduce ICU length of stay (LOS) by up to 9.4% and, simultaneously, decrease the extubation failure rate by up to 18.9%. The benefits are more significant for patients with poor initial conditions at ICU admission. Furthermore, simply optimizing LOS using a classical MDP model without incorporating predictive information leads to an increased extubation failure rate by up to 6%. Both our analytical and numerical findings suggest that predictive information is most useful in identifying patients who can benefit from

2 - Using Machine Learning to Predict Patients Who Leave Without Being Seen in a Pediatric Emergency Department
Peter Vanberkel, Julia Sarty, Eleanor Fitzpatrick, Katrina Hurley, Majid Taghavi

Patients who seek care in an Emergency Department (ED) may choose to leave without being seen by a physician. This occurrence is labeled "left without being seen" (LWBS) and can account for up to 15% of all patients who come to an ED. Patients who LWBS do not receive the care they sought in the ED and may experience clinical deterioration related to delayed diagnosis or treatment. We test machine learning methods to identify which patients are more likely to become LWBS patients. This prediction is used in practice to prevent

adverse outcomes related to LWBS. This paper focuses on the Pediatric ED in Nova Scotia, Canada. We used triage records data including 101,266 observations of children aged 16 and younger who visited the ED during a three-year period. We utilized several classification machine learning algorithms including Logistic Regression, Decision Tree Classifier, Random Forest Classifier, K-Nearest Neighbors, and Extreme Gradient Boosting to predict high-risk LWBS patients. We used SMOTE to handle the class imbalance in our data set and evaluated the performance of the machine learning algorithms. We used feature importance on the best-performing model to identify the features that are associated with LWBS. The highest-performing model utilized SMOTE balancing and the XGBoost classification algorithm. Using this model, and data from our partner hospital, an easy-to-follow set of rules are developed for identifying patients at risk of LWBS in real time.

3 - An analytical approach to identify the potential delayed transfer of care patients and predict their date of discharge
Md Asaduzzaman, Sarahjane Jones, Ann-Marie Cannaby

Delayed transfer of care is a major challenge for the UK National Health Service (NHS). This is also referred to as 'bed-blocking' in hospitals in many other countries. Delayed transfer of care occurs when a patient is clinically ready to be discharged but cannot be discharged due to the unavailability of acceptable places. More recent data in the UK shows that between 8 June 2017 and 12 December 2019, the cost to the NHS over this period was '587 million overall, equivalent to '640,000 every day, or '27,000 every hour. In addition to the financial burden, there are significant negative physical and mental conditions associated with the impact of the delayed transfer of care. Although the problem is long-existent and there are numerous papers on policy-level issues, little attention has been paid in terms of identifying those potential delayed transfer of care patients and predicting their date of discharge. Our recent studies showed that a logistic classifier can correctly predict up to 79% delayed transfer of care patients with 69% specificity giving an overall accuracy of 70% based on routinely collected data. We are now proposing a more rigorous framework to predict the delayed transfer of care patients and their date of discharge incorporating a few more proxy measures and care pathways of the patients. The framework will be tested with two NHS trusts in the UK.

4 - A performance flexible Machine Learning classifier for predicting ICU capacity usage
Milena Grieger

The significantly increasing number of publications on Machine Learning in various application areas illustrates the increasing importance of the topic in recent years. In health care, probably fueled by the COVID-19 pandemic, this trend is also noticeable. Among others, researcher aim at supporting physicians, health care workers, and hospital managers by means of AI-assisted binary classification of patients (decision support systems). The application of binary classification enables, for example, an accurate prediction of whether a patient needs ward or intensive care unit treatment after surgery. In hospitals, intensive care units are a scarce resource, so any incorrect prediction can lead to a capacity problem as well as excessive workload for nurses and endangers patients' health. While the state-of-the-art application of Machine Learning methodologies focuses on the accuracy of the overall prediction, the priority in health care is often on a specific label, for example high sensitivity in case of the intensive care treatment label. With the development and implementation of weighted sensitivities, it is possible to prioritize a particular label while maintaining high accuracy. The performance of these weighted sensitivities is tested and evaluated based on a dataset of more than 26,000 patient courses after elective surgery and compared to various Machine Learning methods for binary classification, such as Logistic Regression. Funded by the Bavarian State Ministry.

Monday, 13:30-15:00

■ MD-01

Monday, 13:30-15:00 - Room A

Operating Rooms II

Stream: Talks
Contributed session
Chair: *Henrik Andersson*

1 - Levelling bed occupancy through stochastic master surgery scheduling and sequencing surgery groups
Theresia van Essen

The Sophia Children's Hospital in Rotterdam, The Netherlands, wants to provide their patients with a surgery date as soon as possible after the patient is diagnosed. To achieve this goal, we conducted a project consisting of three steps: 1) providing a master surgery schedule (MSS) tailored to the current waiting lists while taking into account uncertainty in surgery duration and length of stay, 2) sequencing surgery groups within the MSS while taking into account the closing time of the day care unit as well as the uncertainty in surgery duration and length of stay, and 3) investigating which steps are needed to implement the developed models in the hospital. In 1), we generate all possible combinations of numbers of surgeries of at most two specialties while limiting the probability of overtime using the Fenton-Wilkinson approximation for the sum of lognormally distributed surgery durations. We use these generated combinations as input for a solution method inspired by column generation which levels the bed occupancy using a discrete probability distribution. In 2), we take the MSS generated in 1) as input and sequence generated surgery groups within the MSS using column generation while modelling both the length of stay and surgery duration with a discrete probability distribution. In 3), we investigate the barriers and facilitators for implementing the resulting surgical blueprint in practice using the consolidated framework for implementation research.

2 - Master and activity scheduling in surgical departments
Thomas Bovim, Atle Riise, Anders N. Gullhav, Henrik Andersson

Surgical departments serve patients both in the outpatient clinic (OC) and in the operating theater. Patients require activities in both sections, and the surgeons work cross-sectional. We therefore argue for an integrated planning approach. Two types of tactical schedules are made. Cyclic master schedules cover the upcoming planning horizon, and here medical specialties are assigned to rooms each day of the repeated planning cycle. At regular intervals, activity schedules are assembled for the upcoming planning period. In the activity schedules, a number of activity types and surgeons are assigned to days in either of the sections, respecting the master schedules. After being referred, all patients require an initial consultation in the OC. Then, most patients require either a surgery, or a treatment consultation in the OC. Depending on the type of surgery, patients may need to recover in a bed for some days. Finally, one or several follow-ups are required in the OC. There are waiting lists for each activity, and the lists are managed according to a FIFO-policy. The objective is to distribute the available resources between all specialties and activities, such that waiting lists are kept below a target level. We apply simulation to evaluate the schedules in an operational setting. We test different scheduling policies, including the use of flexible rooms, altering the length of the planning period, and reducing the delay between planning and execution of the schedules.

3 - 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

Nowadays healthcare systems are subject to strong operational stress, especially for what concerns surgical waiting lists, where the demand is often larger than resource availability. The use of quantitative methods is essential to provide effective and efficient care services, and to optimize resource utilization. In this work, we propose an integer programming (IP) model for the surgical case assignment and admission planning problem. The proposed approach considers both the operating theatre resources, such as operating rooms, and the impact of patients' length of stay within the hospital through different specialty wards and intensity settings. The perioperative path of each patient is estimated on real-world clinical information such as pathology and proposed surgical procedure. Computational experiments have shown that the implemented IP formulation can be solved to optimality only for small instances. Therefore, we propose a metaheuristic algorithm for solving the problem. The algorithm is designed to support decisions concerning the assignment of operating theatre time slots to different surgical disciplines based on clinical and organizational constraints. The proposed approach can be applied to mid and long-term planning (e.g. one-year horizon), by switching between different weekly scenarios and supporting both tactical and operative levels. The algorithm has been tested on real-world case instances derived from data of the IRCCS AOU Bologna Sant'Orsola.

4 - Health Flow Optimizer for Surgery
Kjartan Kastet Klyve

We present the Health Flow Optimizer for Surgery, a comprehensive software developed in an innovation partnership with Oslo University Hospital, which leverages selected Operations Research methods. Two key features of the product are 1) algorithmic planning of surgeries and 2) A digital twin that combines automized planning with discrete event simulation to enable forecasting and advanced analyses. Furthermore, the product includes numerous other capabilities, e.g. a patient portal where patients can communicate their availability, a calendar view reflecting different patients' risk of no-show, a re-planning module for planning of emergency cases, real time surveillance of surgical activity etc. In our session, we will tell the story of how the innovation partnership in less than 9 months produced a functional Operations Research-based software customized to the Hospital's needs and demonstrate the use of our product.

■ MD-02

Monday, 13:30-15:00 - Room B

Appointment Scheduling and Bed Management

Stream: Talks
Contributed session
Chair: *Peter Vanberkel*

1 - A matheuristic to solve a multi-appointment scheduling problem of minimizing outpatients' waiting time
Simon Moulard, Yannick Kergosien, Pierre Desport

For many years in France, there has been a growing development of ambulatory care. The purpose of this shift is to avoid full hospitalization of patients when possible, to reduce hospitalization costs and to relieve hospital congestion. Ambulatory care services involve several types of care units and require effective daily planning to maintain a high quality of care and a steady flow of patients with limited or pooled resources.

In this context, we consider a daily multi-appointment scheduling problem in an outpatient department. We assume a set of patients who have booked their day in concert with the receiving facility and are waiting for time confirmation of their appointment. Each patient follows a defined care pathway, which is a set of multiple care activities (e.g. diagnostics, consultations, etc.). Consecutive activities are subject to partial precedence constraints and delays constraints. Each care activity requires a set of resources that are characterized by multiple time windows of availability.

The problem is to schedule all care activities and decide the allocation of the resources. The objective function consists in minimizing a linear combination between the total sum of the waiting times and the maximum waiting time. To solve the problem, we propose a new matheuristic based on a constraint programming formulation of the problem. We evaluate the performance of the proposed method on instances inspired from real data provided by a French hospital.

2 - Mathematical Programming for Scheduling Telemedicine Appointments
Charlotte Marshall, Daniel Gartner, Paul Harper, Geraint Palmer, Alka Ahuja, Gemma Johns

With telemedicine coming to the forefront during the COVID-19 pandemic, flexibility in terms of modes of care delivery has emerged. We are working in partnership with TEC Cymru, who worked to rapidly implement video consultations within NHS Wales during the pandemic and continue to promote the use of telemedicine in Wales. In this paper, we consider the scheduling of patients' appointments via three different modes of delivery: traditional face-to-face, video conferencing platforms, and telephone. The solution of the model not only has an impact on satisfying patient and clinician preferences, but also could potentially reduce travel for patients and staff. We present a multi-mode resource constrained project scheduling problem formulation to solve the problem. Our aim is to schedule appointments, while maximising how often the patients' and clinicians' preferences for delivery method are met. Once a schedule has been generated, it is imported into a simulation model built using the Ciw library in Python. This simulation model allows for variation in no-shows, lateness, emergency/walk-ins, and appointment duration to test how well the schedule performs under different scenarios. Performance indicators including clinician idle time, clinician overtime, and patient waiting time are evaluated and compared to a random schedule to test how well the model performs. These models will be evaluated with data from NHS Wales.

3 - Optimisation of patient planning in a cardiology outpatient clinic
Femke Boelens, Richard Boucherie, Anne Zander

We consider a cardiology outpatient clinic, where patients that need consultations may be divided into two groups: patients new to the outpatient clinic and patients with a follow-up consultation. While new patients need to be planned within access time norms set by the government, there is more freedom in the planning of follow-up patients. The need for a follow-up consultation is known directly after the previous consultation, making it possible to plan these patients far in advance. We assume that, on average, there is sufficient capacity to serve all patients but that the arrival rates of new patients and the total available capacity per week vary over time. The goal of this research is to develop mathematical models that support the planning of follow-up patients, such that both groups of patients can be planned within the desired time. We model this as a stochastic programming model, with time scale decomposition of the planning for new and follow-up patients. This model includes planning of new patients via a Markov Decision approach. The outcome of the stochastic program is an optimal capacity allocation to new and follow-up patients and provides advice on the planning of follow-up patients. Simulation results show that our method yields shorter access times for new patients and more predictability for follow-up patients, compared to the current planning strategy in the considered Dutch cardiology outpatient clinic.

4 - Patient-to-room Assignment: Combinatorics, Complexity & Exact Algorithms
Tabea Brandt, Christina Büsing, Felix Engelhardt, Sigrid Knust

Assigning patients to rooms is a fundamental task in hospitals and, specially, within wards. This so-called patient-to-room assignment problem (PRA) has gained more and more attention in the last few years and many heuristics have been proposed with a large variety of different practical constraints reflecting different settings in hospitals. In this talk, however, we will concentrate on two fundamental aspects

that arise in all hospitals alike: feasibility and single rooms for private patients. We will look at their combinatorial structure, discuss the complexity and present exact algorithms. Such insights help to design better algorithms for the practical problem, decrease their runtime and provide hands-on criteria for the case management.

■ MD-03

Monday, 13:30-15:00 - Room C

Analytics in Healthcare

Stream: Talks
Contributed session
Chair: *Sally Brailsford*

1 - The "Tournament Methods" Framework: A graph-theoretic approach for the analysis of complex and multifaceted patient outcome data inspired by MCDA methods
Hannah Johns, *Leonid Churilov*

There is a growing desire in medical research to use interpretable, patient-centred statistical methods which better capture the complex and multifaceted nature of health outcomes. A commonly proposed approach has been to consider all-to-all pairwise comparisons between patients, a method that has been reinvented in multiple areas with varying levels of success.

In this presentation, we introduce the "Tournament Methods" framework to describe these methods, leveraging the fact that such analyses may be considered as complete directed graphs. We draw from graph theory applications in Operations Research to provide theoretical underpinnings for this framework. We then demonstrate the use of the methods to analyse stroke research data.

2 - Where Multicriteria Decision Analysis and Clinical Trials come together: design and analysis of desirability-based outcome measures within "Tournament Methods" framework
Leonid Churilov, *Hannah Johns*

"Tournament Method" approaches for analysing complex and multifaceted patient outcome data in clinical trials requires a means of defining for each possible pair of patients, who had the better outcome. While this allows for the development of patient-centred research using an outcome measure that encapsulates the needs of patients, when these needs conflict, determining the direction of preference is non-trivial. Elucidating preferences among alternatives based on multiple, often conflicting criteria is a mainstay of multicriteria decision analysis (MCDA) methods, and many of the MCDA approaches may be applied in this context. In this presentation, we discuss how MCDA practices may be leveraged to rigorously design a primary outcome measure for analysis of clinical trials in a manner that encapsulates the trade-offs between multiple domains without the need for a formal utility function. We present real-world applications of this approach used by our team in the process of designing currently active stroke and epilepsy clinical trials.

3 - Using machine learning for automatic distribution of referral notes in hospitals
Fredrik Dahl, *Tore Gundersen*, *Haldor Husby*

We develop programs that read hospital referral notes and select the appropriate medical group using machine learning. The models are trained to reproduce the allocations made by humans on a large database of previous referral notes. As a baseline we use support vector machines (SVM), which do not consider the order of the words, but only associates words that are often used in the references to specific medical groups. It serves be a natural benchmark against which the more complex models will be measured. The more advanced models utilize deep learning with neural networks, including long-short-term memory (LSTM) and convolutional neural nets (CNN). The model works with multiple layers of calculations, which combine increasingly advanced concepts by combining the results from previous layers. Transformers are the latest trend in language models, used e.g. by the GPT-4 model. They allow the meanings of all the words in the text to be freely linked, and therefore require more training data than the LSTM and CNN models and may be too demanding for our dataset. The project is a work in progress, and the results are not yet available. Once a sufficiently good machine learning model is trained, we plan to implement it as part of the hospital's information flow. The goal is to make information processing faster and with less random variation and we plan to run experiments to evaluate the efficiency of the system in practical use.

4 - Advanced Analytics in Health Care: Promise Meets Reality
Margaret L. Brandeau

Advanced analytic techniques such as artificial intelligence (AI), have great potential to transform many aspects of health care - but despite this promise have only been implemented in a limited number of settings and in a limited way. This talk begins by discussing the potential of AI and advanced analytics to transform health care in areas such as disease diagnosis and treatment, disease monitoring, patient monitoring and clinical outcome prediction, health care operations, and health care administration. We then outline the many reasons why this potential has not been realized. As a microcosm illustrating the state of AI and advanced analytics applications, we describe a number of projects carried out at Lucile Packard Hospital Stanford. We conclude with thoughts about what is needed in order for AI to be successfully integrated into health care systems and the next steps that can be taken to advance implementation.

Monday, 15:30-16:30

■ ME-01

Monday, 15:30-16:30 - Room A

Integrated Planning Across Care Providers

Stream: Talks
Contributed session
Chair: *Joe Viana*

1 - Modelling at the interface between acute and community care: challenges and opportunities in studying patient flow across organisational boundaries
Christos Vasilakis, Zehra Önen-Dumlu, Paul Forte, Alison Harper, Martin Pitt, Richard Wood

Limited capacity in community and social care services is a recognised contributor to the pressures faced by hospitals. Waiting for capacity to become available causes delays for hospital patients requiring discharge to community and social care. In England for example, over 500K bed days were lost due to discharge delays even before the pandemic caused additional disruption. Our research aimed at helping to alleviate these pressures through capacity reallocation strategies across the pathway. We also aimed at improving awareness and familiarity of modelling (for healthcare analysts) and highlight the value of modelling and system-wide working (for healthcare leaders). We used queuing theoretic methods to demonstrate how, counter to intuition, pursual of a policy to eliminate delayed discharges from acute care is likely to be uneconomical, as it would require large amounts of community capacity to accommodate rare demand peaks, leaving much capacity unused. Working closely with healthcare managers, we also developed and deployed a versatile open-source simulation tool for modelling both the home-based and bedded community step-down pathways, known as 'Discharge to Assess' (D2A) in England's National Health Service. Coded in 'R', the tool offers scalable solutions for exploring different scenarios relating to demand, capacity and length of stay. Several scenarios were simulated to provide direct support for decisions around D2A service and winter pressures planning.

2 - A discrete event simulation model of hospital discharge to community care - the impact of delayed discharge and difficult to place patients
Laura Boyle, Christine Currie, Carlos Lamas-Fernandez, Ly Nguyen, Clare Halpenny

Patients, particularly those who are elderly or have additional care needs, can experience a 'delayed transfer of care' or a 'delayed discharge' at the end of their hospital stay, which means there is a delay between their being deemed medically optimised for discharge and their actual departure from hospital. Delayed discharge is a major problem in the UK National Health Service (NHS). These delays tend to result in poorer health outcomes for patients. Delayed discharges also limit the number of beds available for new patients and create a problem in the flow of patients through hospital. This is most visible in UK Emergency Departments which are under extreme pressure with record high waiting times.

In this work we present a discrete event simulation of the delayed discharge problem, where we model the flow of patients from hospital to home (with a care at home arrangement) or to placement in a nursing home. Delayed discharge can occur for many reasons e.g., lack of capacity, disagreement with a patient's family about the care placement, or funding. For this reason, we use an acceptance probability to represent the situations where a delayed transfer of care occurs due to reasons other than capacity constraints. We consider variation in the acceptance probability related to patient characteristics. This work is applied to the context of Southampton, but future iterations of the work will consider a reusable model that can be applied in multiple settings.

3 - Integrating access to health services via public transport into large-scale decision making
Davide Duma, Martina Fischetti, Stefano Gualandi, Juan Nicolas Ibanez, Claudio Tomasi

Efficient public transport networks lead to better citizens' health. In addition to the improvement of air quality and traffic safety, previous studies have shown the benefits brought by improved access by public transport to health services, including a decreasing rate of no-shows to medical appointments and an increase in visits to walk-in clinics. Furthermore, public transport plays a key role in promoting health equity for citizens living in rural areas and/or belonging to vulnerable social backgrounds.

In this talk, we present several use cases of VelociRAPTOR, a parallel solver for multimodal all-pairs earliest arrival path problems, developed in collaboration with the European Commission's Joint Research Centre. This solver has been designed to find optimal solutions to large-scale problems in a reasonable time, and by allowing the setting of constraints (i.e., means of transport, arrival time, number of transfers, and footpath distance) which can be employed to define different profiles of users of public transport.

We show examples of descriptive analyses at the country level, by defining accessibility metrics based on the possibility to reach healthcare facilities from any populated grid cell (1km by 1km) within a certain time window. These analyses allow for a comparison between different regions or EU countries and can contribute to the design of policies seeking to foster better coordination between public transport supply and healthcare delivery.

■ ME-02

Monday, 15:30-16:30 - Room B

Home Care and Long Term Care

Stream: Talks
Contributed session
Chair: *Nadia Lahrichi*

1 - A Chance-Constrained Program for the Allocation of Nurses in Acute Home Healthcare
Jedidja Lok - Visser, Hayo Bos, Erwin W. Hans, Gréanne Leeftink

Home healthcare capacity is under great pressure due to demographic developments. Existing literature has exclusively focused on the planning, scheduling, and routing of non-urgent care activities. However, similar to other healthcare settings, home healthcare also experiences urgent care activities that disrupt operational performance. We study the planning and control of an urgent care team for dealing with unplanned and urgent home healthcare activities. Particularly, we focus on determining the number of nurses per care level and their standby locations. For this so-called urgent care team location problem, we formulate a chance-constrained program. We solve the single location problem to optimality, which we test with real-life data. We solve the multi-location problem with sample average approximation, which we test on generalized Solomon instances. The results show that our approach enables decision makers to optimally configure their urgent care team, to respond quickly to urgent care incidents. From a managerial perspective, our research provides a model that supports tactical capacity planning in HHC organizations and presents a benchmark for urgent care management policies.

2 - Developing an empirically informed mathematical model to assist with the planning of care services for the management of patients with long-term conditions.
Gozdem Dural-Selcuk, Christos Vasilakis, Baris Yalabik

The clinical management of patients with long-term conditions involves frequent interactions with healthcare professionals, adding to the pressures faced by healthcare systems around the world. Remote-review clinics have been offered to alleviate the pressure, however, understanding the factors contributing to their successful implementation are difficult to predict given their dynamic and uncertain nature.Current studies state that both remote-review clinics and face-to-face consultation perform equally well and most patients are satisfied with remote-review clinics. However, there is limited number of studies that evaluate their effectiveness with quantitative models. On the other hand, it is also asserted that there is the issue of reliability with remote-review decision making as some studies have reported non-zero specificity and sensitivity rates. At this point, the prominence of employee training has been highlighted. In this study, we propose a system dynamics model that captures the features of a long-term condition that progresses over time and incorporate the aspects of specificity/sensitivity rates and learning curve of decision makers at remote-review clinics. The main objective of the proposed model is to develop a prototype decision support tool to evaluate the effectiveness of remote-review clinics from a perspective of healthcare resource utilisation and the reliability of remote-review decision making in terms of patient outcomes.

3 - Mobilie clinic deployment in the Witzenberg region of South Africa
Linke Potgieter

One of the reforms in the public health system of South Africa, to improve access to primary healthcare for rural communities, is the deployment of mobile clinics. From a tactical point of view, decision makers must schedule the mobile clinics, which includes the farm or village assignments per mobile clinic, their monthly visit schedules, and the base hospitals or clinics where they start and end their tours. These schedules are set up manually by the decision makers, resulting in sub-optimal solutions. In the Witzenberg region alone, six mobile clinics have been deployed, with each having a fixed schedule and farm locations to visit on a monthly basis. Currently, the workload is not evenly spread between the mobile clinics, where some mobile clinics are serving larger farming communities than others (and hence more patients), and some mobile clinics are covering longer distances but serving smaller communities. In this talk, an overview of the problem will be presented, with a specific focus on the Witzenberg region of the South Africa. Objectives and constraints considered will be discussed, as well as practical considerations that are unique to the context, compared to solutions found in literature. Our process of working with the healthcare staff to get buy-in will also be discussed, along with results from focus group sessions with healthcare staff to understand staff preferences better, and how to incorporate this in the model developed.

■ ME-03

Monday, 15:30-16:30 - Room C

Blood Logistics

Stream: Talks
Contributed session
Chair: *John Blake*

1 - Reducing platelet wastage with a machine learning-based allocation policy
Joseph Farrington, *Kezhi Li*, *Wai Keong Wong*, *Martin Utley*

Managing perishable products such as platelets requires policies for replenishment and allocation. It is common to use an OUFO (oldest-unit first-out) allocation policy when deciding which unit of platelets to issue to meet demand. This policy may not be optimal if, as in our partner hospital, approximately 10% of issued platelets are not transfused and are returned to the hospital blood bank. We hypothesized that a simple data-driven allocation policy could help to reduce wastage: issue the youngest unit if a model predicts it will not be transfused, and the oldest unit otherwise. With a sufficiently good predictive model, this policy should increase the likelihood that, when a unit is returned, there is sufficient time to reissue it to another patient before it expires. We simulated the impact of this data-driven policy for different assumed levels of predictive model performance and identified a target region of sensitivity and specificity combinations required to reduce wastage and shortage compared to an OUFO policy. We then developed a supervised learning model to predict whether a requested unit would be transfused based on two years of data including requesting specialty, patient location, and platelet count, which satisfied target performance. In this talk we will discuss our simulation-first approach to this potential use case for machine learning and our work with the hospital to understand whether the proposed policy could be used in practice.

2 - Optimised extended red blood cell matching for transfusion dependent sickle cell patients
Folarin Oyebolu

People with sickle cell disorder (SCD) are heavily dependent on blood for prevention/treatment of complications. Current matching practices for red blood cell (RBC) transfusion cause avoidable harm to patients in the form of alloimmunisation to non-self RBC antigens. Alloimmunisation increases the risk of inadequate blood availability and life-threatening transfusion reactions. This disproportionately affects those with SCD - who have no other treatment options. Recently, a cost-effective DNA test has been developed, allowing the complete antigen profile of donors to be determined at scale. This should allow provision of routine extended matching to reduce alloimmunisation, and reduce the occurrence of shortages. Currently blood is matched manually which limits the feasibility of more extended blood matching. In this work, we build upon previous models for matching extensively typed RBC units to extensively typed patients where the objective is to minimise the costs associated with allocating available RBC units to patients requiring RBC transfusions. These costs include the risk of alloimmunisation and wastage of expired units. We carry out simulations of daily RBC stock and patient demand, and solve a series of daily transportation problems over an extended time horizon. Novel to previous work, we focus on simulating demand from patients with SCD who are already alloimmunised. Our results demonstrate that extended antigen matching reduces the incidence of alloimmunisation.

3 - The Operational Impact of Introducing Cold Stored Platelets
John Blake

BACKGROUND: Cold stored platelets (CSP), largely abandoned in the 1970's due to their rapid clearance from the body, undergo physical changes that make them better at initiating a clot. An active literature into cold stored platelets has recently emerged. However, many of the clinical and operational aspects of re-introducing cold stored platelets remain to be resolved.

STUDY DESIGN AND METHODS: A simulation model of a regional blood supply chain was built. Two scenarios were considered: "No-CSP" conditions, in which the hospital issues only RTP, and "CSP" conditions, in which hospitals issue both RTP and CSP. Within the CSP scenarios, conditions were tested under which the hospital receives only RTP and converts some to cold stored platelets and a second strategy where the hospital receives CSP from the regional supplier.

RESULTS: A centralized supply of CSP is necessary to meet patient needs, since on-site conversion is limited by platelet age restrictions. It was also determined that, because relatively few RTP units can be converted on-site, that RTP wastage is not decreased with the introduction of CSP.

CONCLUSION: Given the clinical benefits for treatment of trauma, CSP is a desirable addition to a blood formulary. However, it is unlikely that significant RTP wastage savings will occur because of the introduction of cold stored platelets.

Tuesday, 9:00-10:00

■ TA-01

Tuesday, 9:00-10:00 - Room A

Keynote Talk II

Stream: Plenaries
Keynote session
Chair: *Michael O'Sullivan*

1 - The Future is Now - Digital Twins for Healthcare
Michael O'Sullivan

Digital twins are digital copies of (existing or proposed) physical systems that are used to both better understand and also support decision making about those systems. In healthcare the use of digital twins can range from physically accurate representations of organs to support diagnosis and treatment to logically accurate representations of an entire healthcare system to support policy design and development. This talk will present a vision of a futuristic healthcare system that utilises digital twins to deliver healthcare services effectively and efficiently. It will then give case studies from existing Operations Research work by the ORUA research group (orua.auckland.ac.nz) that already prototype the digital twin models needed for the future.

Tuesday, 10:00-10:30

■ TB-01

Tuesday, 10:00-10:30 - Room A

Poster Pitch Session

Stream: Posters
Contributed session

Tuesday, 11:00-12:30

■ TC-01

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

Poster Session

Stream: Posters
Invited session
Chair: *Laura Boyle*

1 - Interconnections between critical blood tests and prescribed medication in IBD patients
Thomas Xenos, Ioannis Drygiannakis, Ioannis Koutroubakis, Nikolaos Matsatsinis

Keywords: IBD, multifactorial, CRP, correlation, medication

Hereby we analyse clinical data and laboratory tests of Inflammatory Bowel Disease (IBD) patients to highlight the correlation between critical values of the latter with the adjusted prescribed medication, emphasising on optimal monitoring of disease activity.

We aim to optimise treatment by revealing complex interconnections between laboratory test values and physician's proposed optimal medication. This is of importance as IBD is a complex multifactorial disease with variable symptoms, signs and an added uncertainty caused by the great variability in laboratory biomarkers of inflammation such as CRP (the golden standard), ESR, Alb, Hgb and PLT.

To deal with such a complexity we separated IBD patients by disease phenotype and by physician's decision for advanced treatment with biological agents. We correlated each of these clusters to CRP and/or the rest of the aforementioned blood tests.

To carry out this task, we use analytics methods such as data analysis and machine learning methods.

2 - Orthopaedic Care Pathway Modelling Using Hybrid Simulation
Matthew Howells, Paul Harper, Daniel Gartner, Geraint Palmer

Disruptions caused by COVID-19 still cause backlogs in many countries' elective patients waiting lists. In this research, we focus on Orthopaedics, which is a specialty that faces extraordinary pressures driven not just by current elective care backlogs, but also the phenomenon of an ageing population. We present the results of a systematic literature review into operational research methods applied to orthopaedic settings and treatments. Our analysis of 492 papers reveals that there is limited modelling of holistic care pathways, few applications of mixed-methodologies, and the potential need for increased resource and capacity planning. Having identified gaps in the literature, we are developing a hybrid simulation model that combines the paradigms of discrete-event simulation (DES) and system dynamics. The DES component models patient flows through a holistic orthopaedic surgical pathway. This interacts with a system dynamics component, which considers the musculoskeletal health of the general population and how this affects Secondary Care demand through referrals from Primary Care and emergency demand. Our model will enable hospital staff to make more informed decisions on demand and capacity planning, to help find strategies to alleviate the treatment backlog and improve care outcomes.

3 - Triage of injured persons at mass casualty incidents with algorithms and/or drones
Franziska B. Metz, Melanie Reuter-Oppermann

Traffic accidents, terrorist attacks or natural disasters regularly lead to mass casualty incidents (MCI), which significantly exceed the supply capacities of the rescue service. In order to ensure the survival of as many patients as possible, it is particularly important to classify the injured persons according to urgency of treatment. Various algorithms are available for this triage. These algorithms suggest a sequence of defined questions and processes (e.g. checking vital signs), at the end of which each patient is assigned to one of these triage categories. Thereby a fast and reliable identification of vital threatened persons is crucial in order to treat them as quickly as possible. The aim of the work is to analyse and compare triage done by paramedics with common triage algorithms and triage done by drones with e.g. imaging techniques and thermal cameras. These techniques should be used to detect the number of injured patients, their vital signs, injuries, body temperature etc. to use for triage algorithms or direct for a classification to triage categories. In the future, a simulation will be used to analyse the time required and the accuracy of patient classification.

4 - Optimising Patient Transport and Medical Resource Allocation in Mass-Casualty Incidents
Florentina Hager, Melanie Reuter-Oppermann

Providing adequate medical treatments in a mass-casualty incident with a sudden increase in demand poses a complex logistical problem. With time being a crucial factor influencing the chance of survival, one of the main goals in a disaster's response phase is to transfer casualties to medical centres quickly. Especially in disasters resulting in major damages, local capacities may be overwhelmed and not capable of providing treatment to all casualties. Thus, considering opening temporary medical centres or transporting casualties to more distant permanent medical centres may be inevitable. While temporary medical centres may relieve permanent medical centres and avoid long transportation distances for casualties, they may require some lead time before being able to operate and be limited in treatment options. On the other side, with many casualties needing transfers, mass-transportation vehicles may provide useful alternatives to conventional vehicles such as ambulances and reduce overall transportation times. However, those mass-transportation vehicles should arrive at the disaster site quickly. Thus, coordinating the stationing of mass-transportation vehicles with patient-to-hospital allocation and routing is a necessary task. With both decisions influencing each other, we will present a model that considers both tasks simultaneously such that waiting and transportation times for casualties are minimised.

5 - Health Flow Optimizer for Surgery
Kjartan Kastet Klyve

We present the Health Flow Optimizer for Surgery, a comprehensive software developed in an innovation partnership with Oslo University Hospital, which leverages selected Operations Research methods. Two key features of the product are 1) algorithmic planning of surgeries and 2) A digital twin that combines automized planning with discrete event simulation to enable forecasting and advanced analyses. Furthermore, the product includes numerous other capabilities, e.g. a patient portal where patients can communicate their availability, a calendar view reflecting different patients' risk of no-show, a re-planning module for planning of emergency cases, real time surveillance of surgical activity etc. In our session, we will tell the story of how the innovation partnership in less than 9 months produced a functional Operations Research-based software customized to the Hospital's needs and demonstrate the use of our product.

6 - A decision-making tool for the location, districting and dimensioning of Community Houses in Lombardy, Italy
Martina Doneda, Ettore Lanzarone, Angelo Barbato, Carlotta Franchi, Sara Mandelli, Alessandro Nobili, Giuliana Carello

This work presents a decision-making tool for the location, districting and dimensioning of Community Houses (CHs) in Lombardy, Italy. CHs are new entities in the Italian Healthcare Service, envisaged to provide proximity care to citizens. CHs are part of the Italian National Recovery and Resilience Plan, within the NextGenerationEU scheme. The presented tool provides a systematic approach to their planning, and is based on a Mixed Integer Linear Programming (MILP) model that considers various factors such as demand, accessibility, and equity to identify the optimal location, dimensioning and districting of CHs. The tool uses a data-driven approach that leverages on information on healthcare service provision, enriched with demographic and geographic data. The MILP can optimize all decisions simultaneously, but it can also be deployed to solve only one decision at a time

(i.e. only districting). The tool provides stakeholders with a decision-support platform, enabling them to understand the trade-offs between different options and make informed decisions. It is adaptable and can be updated as new data becomes available, or whenever a change is imposed on the system, ensuring that decisions remain relevant. The tool was tested on real data of a representative area, the Province of Brescia. It was chosen because it spans over a variety of typically Italian environments, including urban, rural, and alpine ones. The results validated the adequacy of the proposed solutions.

7 - Multi-level Hierarchical Location-Allocation Model for a Healthcare Facility Network Problem
Maria Lopes, Daniel Santos, Ana Paula Barbosa-Póvoa

Providing good and equitable healthcare services is the strategic objective and ultimate challenge in NHS-based countries. One key factor that directly impacts the provision of healthcare is the definition of a referral network of medical specialties, that can be provided at different levels of care, according to patient demand and capacity limitations associated with each facility. Such decisions impact the daily operation of hospitals and the quality of services provided. In this study a mixedinteger, multi-objective, multi-period hierarchical optimization model is developed to aid in planning a hospital network with multiple specialties provided at different levels of specialization with decisions regarding the location of facilities and allocation of demand, based on the combination of medical specialties and specialization levels. Constraints concerning the stability of the network, continuity of care and the flow of referred patients are included, together with the more commonly found ones regarding demand allocation and facility location. Two objective functions are minimized: the travel distance weighted by demand and the operational and investment costs of such network, corresponding respectively to accessibility and efficiency measures. The epsilon-constraint method is used to attain the Pareto front and the model is applied to a case-study based in the Lisbon and Vale do Tejo area of Portugal. The results of the model are evaluated against the current network.

Tuesday, 13:30-15:00

■ TD-01

Tuesday, 13:30-15:00 - Room A

Emergency Medical Services I

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

1 - Joint planning of drones and volunteers in emergency response to out-of-hospital cardiac arrest
Henrik Andersson, Tobias Andersson Granberg

Various initiatives are in place worldwide to reduce the time from the occurrence of an out-of-hospital cardiac arrest to the start of cardiopulmonary resuscitation (CPR) and defibrillation using an Automated External Defibrillator (AED). In addition to optimizing the management of emergency medical services and other professional emergency response resources, these include utilizing close-by volunteers using mobile phone dispatching, and delivering AEDs using Unmanned Aerial Vehicles (UAVs), commonly known as drones. The latter two examples have previously been studied separately, and it has been proved that the time to administer CPR and AED delivery can be reduced. In this presentation, the potential of joint planning and dispatching of volunteers and AED delivering drones is investigated. Optimization models are used to determine good locations for drones. These are then evaluated, together with new, adapted dispatch strategies for the volunteers, using a simulation model. Results of a case study, with data for the county of Västra Götaland in Sweden, show that drones can help reduce the time to defibrillation, and, by adaptive dispatching, the time to CPR can be reduced as well. Thus, it is shown that by joint planning of drones and volunteers, it may be possible to improve the survival probability from out-of-hospital cardiac arrest.

2 - A clinical complexity- and acuity-based model to improve efficiency of emergency department operations
Chiara Morlotti, Benny Mantin, Mattia Cattaneo, Stefano Paleari

Traditional streaming processes in emergency departments (EDs) ground on the evaluation of the so-called Emergency Severity Index (ESI), usually represented by discrete levels. However, severity is recognized to be the synthesis of two main components, namely clinical complexity and acuity. This study explores the potential benefits of utilizing distinct measures of clinical complexity and acuity for operational decision-making. To pursue this objective, we rely on a 10-year dataset of 1.4 million ED accesses to a large multi-hospital network located in the North of Italy. The dataset contains extensive triage information, including details on patients' demographic characteristics, assigned ESI level, anamnesis, and vital parameters. First, we apply a factor analysis on triage data to estimate the two distinct components. Second, we develop a model grounded on these two factors to predict the severity level and ED resource consumption. Finally, we compare traditional and model-derived evaluations and performances for simulated ED operations, demonstrating efficiency gains in queue and resource management.

3 - A hybrid simulation model for analyzing the impact of police intervention in out-of-hospital cardiac arrests
Miguel Baigorri, Ángel Martín del Rey, Fermin Mallor

This paper focuses on analysing the impact of equipping local police with Automated External Defibrillators (AEDs) to attend out-of-hospital cardiac arrests. (OHCAs). To do so an innovative simulation model is developed, which combines agent-based and discrete event simulation. Each police officer is described by his/her motivation, which affects the willingness to attend training lessons, learning rate, and training level. Each officer is unique, and their attributes change depending on the outcome of the OHCAs that the officer has attended,

while at the same time, this outcome is affected by the training level of the officer. The outcome of the OHCAs is measured in terms of the survival probability of the patient, which is considered a function of the time to cardiopulmonary resuscitation and the training level of the first responder. The model developed is applied to analyse the benefit that training and equipping police officers with AED have in the survival probability of OHCAs under different scenarios defined by frequency of formative programs, patrol areas, participation of other responders, among others.

4 - Ambulance Location-Allocation Optimization: a case study in the Basque Emergency Medical Services.
Maria Merino, *Imanol Gago*, *Unai Aldasoro*

The precision of the response given to health emergencies is crucial. A rapid response can mean the difference between a patient's life and death in serious situations such as a heart attack. The optimal location of ambulances can determine the efficiency of emergency services, as it is responsible for the quick allocation of ambulances to emergency calls. For about half a century, healthcare experts started tackling the location-allocation problems. Nowadays, operational research plays a key role in helping decision-making. This work approaches the ambulance location-allocation problem in the geographical area of the Basque Country (Spain). To that end, a two-stage stochastic 0-1 integer linear programming model and its variations are analyzed.

Concerning the satisfaction of the decision-makers and the quality of the Emergency Medical Services, the objectives to be pursued and the indicators to be met are numerous. We consider two alternative objective functions: (1) to maximize the number of emergencies responded to in target time and (2) to minimize the average response time. Additionally, we also consider equity and risk-averse measures to balance the efficiency between rural and urban areas and minimize worst-case scenarios, respectively. Some computational results are shown and compared.

■ TD-02

Tuesday, 13:30-15:00 - Room B

Integrated Planning of Care Networks

Stream: Talks
Contributed session
Chair: *Ettore Lanzarone*

1 - A decision-making tool for the location, districting and dimensioning of Community Houses in Lombardy, Italy
Martina Doneda, *Ettore Lanzarone*, *Angelo Barbato*, *Carlotta Franchi*, *Sara Mandelli*, *Alessandro Nobili*, *Giuliana Carello*

This work presents a decision-making tool for the location, districting and dimensioning of Community Houses (CHs) in Lombardy, Italy. CHs are new entities in the Italian Healthcare Service, envisaged to provide proximity care to citizens. CHs are part of the Italian National Recovery and Resilience Plan, within the NextGenerationEU scheme. The presented tool provides a systematic approach to their planning, and is based on a Mixed Integer Linear Programming (MILP) model that considers various factors such as demand, accessibility, and equity to identify the optimal location, dimensioning and districting of CHs. The tool uses a data-driven approach that leverages on information on healthcare service provision, enriched with demographic and geographic data. The MILP can optimize all decisions simultaneously, but it can also be deployed to solve only one decision at a time (i.e. only districting). The tool provides stakeholders with a decision-support platform, enabling them to understand the trade-offs between different options and make informed decisions. It is adaptable and can be updated as new data becomes available, or whenever a change is imposed on the system, ensuring that decisions remain relevant. The tool was tested on real data of a representative area, the Province of Brescia. It was chosen because it spans over a variety of typically Italian environments, including urban, rural, and alpine ones. The results validated the adequacy of the proposed solutions.

2 - A ward occupancy forecasting model as an integrated planning tool to increase patient transfers and elective surgeries
Felipe Rodrigues, *Mehmet Begen*, *Greg Zaric*

An essential component of the pandemic response in Ontario, Canada, was the transfer of patients from overcrowded Toronto hospitals to other facilities. One of these facilities is The London Health Sciences Centre (LHSC) in London, Ontario. Starting in April 2021 (due to the pandemic surge) and continuing in 2023 as part of the plan to clear the backlog of 1 million elective surgeries in Ontario, Toronto hospitals continue to transfer patients, and more recently, surgeries, to LHSC. The requests created a challenge for managers at LHSC: accepting more patients would increase the utilization of their wards and thus potentially reduce the ability of the hospital to care for patients from within their normal catchment area. However, denying those requests could have serious health consequences for patients needing transfer or elective surgeries delayed by the pandemic. To help managers at LHSC make decisions about accepting regional transfers and increasing elective surgery loads, we developed a stochastic model to help forecast capacity utilizations of their ICUs and medicine wards from seven to twenty-eight days into the future. The model uses knowledge of current ward capacity utilization, patient length of stay, and assumptions about the future arrival of patients from outside the region or increases in the scheduling of elective surgeries. The model implementation was a success and became the base point for short-term integrated planning at LHSC.

3 - Optimal Demand Allocation and Service Configuration of Care Facilities During a Pandemic
Navid Izady, *Reza Zanjirani Farahani*

We investigate the trade-off between flexibility and specialization in the context of demand allocation among hospitals during a pandemic. Using a heavy-traffic queueing approximation, we develop an optimization model minimizing the average waiting time of pandemic and non-pandemic patients in a network of two facilities with equal capacities. Justified by the critical care data from English hospitals during the Covid-19 pandemic, the model captures the conflicting impacts of pooling and mix-variability. We provide full analytical characterization of the optimal solution for our optimization model, which identifies the optimal configuration of facilities and the corresponding demand allocation. Our results show that the optimal configuration is a partially flexible configuration for a wide range of pandemic and non-pandemic arrival rates. We provide closed-form expressions for the value of partial flexibility as compared to full and no flexibility. This suggests that implementing the optimal partial flexible configurations would have made maximum savings of about 6.6% and 1.9% in the first and second waves of the pandemic in England, respectively, as compared to the flexible configuration with a balanced demand allocation.

4 - Muti-level Hierarchical Location-Allocation Model for a Healthcare Facility Network Problem
Maria Lopes, *Daniel Santos*, *Ana Paula Barbosa-Póvoa*

Providing good and equitable healthcare services is the strategic objective and ultimate challenge in NHS-based countries. One key factor that directly impacts the provision of healthcare is the definition of a referral network of medical specialties, that can be provided at different levels of care, according to patient demand and capacity limitations associated with each facility. Such decisions impact the daily operation of hospitals and the quality of services provided. In this study a mixed-integer, multi-objective, multi-period hierarchical optimization model is developed to aid in planning a hospital network with multiple specialties provided at different levels of specialization with decisions regarding the location of facilities and allocation of demand, based on the combination of medical specialties and specialization levels. Constraints concerning the stability of the network, continuity of care and the flow of referred patients are included, together with the more commonly found ones regarding demand allocation and facility location.

Two objective functions are minimized: the travel distance weighted by demand and the operational and investment costs of such network, corresponding respectively to accessibility and efficiency measures. The epsilon-constraint method is used to attain the Pareto front and the model is applied to a case-study based in the Lisbon and Vale do Tejo area of Portugal. The results of the model are evaluated against the current network.

■ TD-03

Tuesday, 13:30-15:00 - Room C

Staffing and Capacity Planning

Stream: Talks
Contributed session
Chair: *Ana María Anaya-Arenas*

1 - Developing and implementing capacity demand models for short, medium and long term healthcare planning at a regional/national level.
Mark Tuson

Whether it's identifying the resources needed to address patient backlogs built up during the covid lock-downs, supporting the production of clinical strategic plans for the next decade or forecasting the demand and capacity needs for a new hospital build, Capacity and Demand models form an integral part of the planning processes for publicly funded healthcare organisations.

The presenter has a long-term collaborative relationship with a regional/national healthcare provider. For each of the three applications above, the issues and challenges they present are described and the forecasting/simulation models developed for short (c. 2 years) and medium-term (c. 10 years) planning are presented along with strategies to engage stakeholders in their use. Models in development for longer planning over longer time frames (hospital new build) are also discussed.

2 - Linking Predictive and Prescriptive Analytics for Healthcare Services: The Case of Frail and Elderly Patients
Elizabeth Williams, *Daniel Gartner*, *Paul Harper*

Ageing is one of the most common and well-known risk factors for most chronic diseases putting increased pressure on healthcare resources. As patients get older their severity of frailty increases and as a result, so does their dependency on healthcare resources. Planning for the frail and elderly can be difficult since these patients often suffer with multi-morbidity and can take longer to recover in hospital with more care required. This often leads to difficulty in clustering these patients for prediction as there are many different factors which cause longer lengths of stay (LOS). Previous literature has highlighted the importance of holistic planning across hospital services, rather than single hospital settings. Patient attributes that have similar LOS groupings within hospital were determined via CART with ten different variables included. By incorporating the associated LOS groupings into deterministic and two-stage stochastic models, we provide novel insights for capacity planning of hospital beds and staffing requirements. We apply this to a case study of 11 hospitals in South East Wales across 29 specialties for elderly and frail patient admissions. Results show planning upfront reduces the additional costs associated with opening new wards and deploying agency nursing staff. Our approach highlights how linking two analytical paradigms can be useful for decision makers to capture the stochastic nature of healthcare and make more robust strategic planning decisions.

3 - Improving performance in acute care by introducing an Enhanced Care Unit
Luca Grieco, *David Egan*, *Palmira Mathurdas*

An Enhanced Care Unit (ECU) was introduced at a hospital in London to relieve pressures on their Intensive Care Unit (ICU) during the COVID-19 crisis. ECU's role is to provide detailed monitoring and observation for severely ill patients in addition to non-invasive respiratory support and therefore to host patients who do not require (yet) intensive care. Given its smaller staff-to-patient ratio and cost per bed, hospital managers have been considering the use of ECU in non-COVID settings for a better management of patient flow in acute care areas. We developed a discrete-event simulation model of the flow of patients into ECU and/or ICU from other hospital areas. We implemented it into a user-friendly R application to support scenario analysis. The tool enables assessment of patient waiting times and staff needs depending on the configuration of bed capacities in ECU and ICU. We handed the tool over to analysts at the hospital who parameterised it using routinely collected data on patient types and needs, and used it to conduct scenario analyses, particularly comparing waiting times and capacities in presence or absence of the ECU. We will present the features of our simulation model as well as the insights generated by the analyses undergone at the collaborating hospital. We will also highlight the challenges of introducing the ECU in day-to-day operations and the prospects on extending this assessment by considering the interplay of ECU with other hospital units.

4 - Perinatal mental health plan in Ile de France (IDF): allocations distribution among maternities
Catherine Crenn-Hebert

Multidisciplinary psycho-socio-medical meetings take part in national objective to improve perinatal health with vulnerable pregnant women support and in the fields of action in perinatal mental health plan. How to allocate part of regional budget among the 77 maternities with wide activity and patient recruitment gaps ? How to take into account territorial health inequalities? How to consider the different organizations in resources, territorial relationships with other providers? We used our regional Perinatal health Information System data to measure patient pool in each maternity with their district of residence and a composite indicator called deprivation index built at a district level. We opened a call for proposals asking to describe local organizations with a special attention to integration of ambulatory and hospital partnership in medical, social and mental care. The candidates had to ask for a budget for necessary but available resources in terms of staffing and expertise. We were granted with a regional budget of 1 816 000 euros in 2021 then supplement of 800 000 euros in 2022. 42 maternities answered to the first call and 18 at the second one, covering 91% of the 166 000 births. A theorical grant was attributed for each maternity according to their activity and deprivation patient recruitment. Studying each file, we have made matchings with demands and grants. A first assessment is scheduled in june 2023 to check how resources staffing is set up.

Tuesday, 15:30-17:00

■ TE-01

Tuesday, 15:30-17:00 - Room A

Emergency Medical Services II

Stream: Talks
Contributed session
Chair: *Roberto Aringhieri*

1 - Evaluating Heterogeneous Ambulance Fleet Allocations in Jakarta
Geraint Palmer, Mark Tuson, Sarie Brice, Paul Harper, Vincent Knight, Daniel Gartner

Ambulance services have a duty of care to the clinical outcomes of the population they serve, and so aim to maximise the chances of survival and improve patient outcomes following a medical emergency. Although the ambulance location-allocation problem has been widely studied, it has mainly focused on minimising response times or maximising coverage, and not explicitly considering patient outcomes. Here we propose a modelling approach to optimally locate different types of emergency response vehicles to maximise patient survival, and to evaluate such allocations. We develop a heuristic algorithm to find allocations that maximises the expected survival, and a discrete-event simulation to evaluate a given allocation. Key features of both models include dispatching heterogeneous vehicles (emergency ambulances and rapid response motorbikes) to a heterogeneous population of patients. The simulation models each vehicle type sequentially, considering synchronicity between the models, combining the results to give a range of KPIs such as response time and percentage of abandoned calls. We apply our approach to the case of Jakarta, Indonesia, collaborating with a non-government organisation in the city. Models are parametrised on real-world data, and various demand scenarios are explored informed by surveys of ambulance usage. These give decision makers tools to better understand ambulance fleet capacity needs, locations, and their impact on patient outcomes.

2 - Patient transport planning as part of the German EMS system
Melanie Reuter-Oppermann, Andrea Raith

EMS systems in Germany are not only responsible for emergency services but also for the transport of patients if the attendance of an emergency medical assistant is necessary. Even if many of the transportation demands are known in advance, trips are usually not planned at present, if anything then they are planned manually. Due to cost increases and cost pressure which are typical for the healthcare sector efficient planning methods become more and more important. As in Germany, emergency medical services transport thousands of patients each day, electrifying ambulances could make a significant contribution to reducing the carbon footprint. While first ambulances exist, practitioners are doubting whether currently existing vehicles offer a sufficient range. In this talk, we present a mathematical model and an algorithm for solving the patient transportation problem. We test these using data from German EMS regions. In addition, we use the transport data from a German coordination centre to analyse the number and distribution of patient transports that could have been performed by an e-ambulance and determine locations for potential charging stations.

3 - Emergency Medicine System Real-time simulation decision support tool
Joe Viana, Navonil Mustafee, Alison Harper

We present a Real-time simulation (RtS) framework and model for short-term decision-support in healthcare. RtS enables an interaction between a real system and a simulation model using real-time or near-real time system data as simulation model inputs. Short-term decisions based on simulation outputs will affect the real system and be reflected in the real-time system data. A conventional discrete event simulation model developed to improve Emergency Department patient flow, using secondary operational data provided by our case hospital is extended to update its state based on real-time data streams. We present how the internal model state and current system state are synchronised, and, how to control the execution of the RtS to ensure it is ready for experimentation when subsequent real-time data updates. Thus the "closed-loop process," actions taken in the previous iterations of 1) receiving data, 2) model initialisation, 3) model experimentation, and 4) decision making, are manifest in subsequent real-time data feeds. Illustrative scenarios will be presented to demonstrate the implementation of our RtS framework in our case model. Our proposed framework captures the closed-loop process. In implementing our framework, we address key challenges. Our proof-of-concept RtS model, demonstrates considerable progress toward the real-world application of RtS in the health and social care domain for short-term decision-support.

4 - Planning for the Patients - Towards New Objectives in Emergency Medical Service Logistics
Sven Watzinger, Stefan Nickel

Emergency Medical Services (EMS) provide first aid and transportation to a hospital for patients in the case of an emergency. The main objective for logistical planning in EMS currently is to reach as many patients as possible within a set response time target (RTT). It is an on-going discussion, whether a RTT is a suitable planning objective for EMS. One of the main arguments is, that there is no evidence, that reaching a patient within the RTT is actually beneficial for the medical outcome of the patient. For critical conditions, such as cardiac arrest, the RTTs are usually too long. For others, such as strokes, the time until arrival at a suitable hospital is more important than the response time. For less critical patients a breach of the current RTT is not indicative of a worse medical outcome. To gain a better understanding of how different time intervals affect different patients, we have organized a sequence of workshops with medical doctors and practitioners from EMS to investigate, how we can categorise patients and quantify the development of the patient's condition over time with utility functions. The utility functions map the utility from a patient's perspective continuously over time and can be used to inform analytical models, e.g. for station location planning or ambulance dispatching. In our talk, we will present the preliminary findings of the workshops and discuss how they can be used to look at logistical problems in EMS with a different perspective.

■ TE-02

Tuesday, 15:30-17:00 - Room B

Healthcare Policies and Systems

Stream: Talks
Contributed session
Chair: *Christos Vasilakis*

1 - System Dynamics in healthcare: a new approach to generic modelling
Sally Brailsford

One of the well-known barriers to the widespread use of modelling in healthcare is the 'not invented here' problem. Managers and clinicians trust models that they were actively involved in developing, but do not necessarily trust models developed for other settings. Unfortunately, generic models designed to be applicable anywhere face their own challenges. Potential users may distrust this one-size-fits-all approach, and tailoring a generic model to a specific site may require technical modelling skills and the purchase of software. This talk presents a new approach to tackling these challenges: initially developing a user-friendly, cloud-based, 'semi-generic' model based on a set of hospitals in one particular UK region, and then adapting the model to make it fully generic. The approach is illustrated by a system dynamics model that allows a novice user to test the system-wide impact, in their own

locality, of five Emergency Department based interventions targeted at older people. The talk briefly describes the model, but focuses mainly on the processes of model development, piloting, and dissemination. We discuss whether this new approach to generic modelling is likely to improve the chances of wider adoption.

2 - Evaluating policy changes to Eurotransplant's liver allocation rules with Discrete Event Simulation
Hans de Ferrante, Bart Smeulders, Frits Spieksma

Eurotransplant (ET) prioritizes liver transplant candidates with a complex match algorithm. The most important factor used by the algorithm is the patient's MELD score, which quantifies their 90-day waitlist mortality risk based on blood biomarkers. To help quantitatively map the impact of policy changes to ET's match algorithm, we developed a discrete event simulator based on real-world data, which we call the ET Liver Allocation System Simulator (ETLASS). Simulating allocation between 2016 and 2020 based on actual allocation rules, we find that ETLASS accurately describes average patient wait times, waitlist mortality rates, transplantation rates, and median MELD scores at transplantation in all ET member countries.

To demonstrate utility of ETLASS for policy evaluation, we study the impact of changes to ET's exception point system. Such exception points are awarded to patients whose MELD scores do not accurately reflect their urgency. Concerns exist exception patients are currently overprioritized, and crowd non-exception patients out of transplantation. Changes we evaluate are capping the number of exception points received, reducing the 90-day point increments exception patients receive, and awarding a fixed number of exception points set relative to the median MELD at transplantation (as done in the U.S.). Results suggest that these simple changes can prevent up to 30 waitlist deaths per year without substantially increasing adverse event rates for exception patients

3 - Modelling long-term changes in population health state and associated healthcare resource requirements
Zehra Önen-Dumlu, Richard Wood, Christos Vasilakis

Healthcare policy makers face regular challenges on how to allocate healthcare resources with limited budget. Mathematical and computer modelling tools can capture these interacting factors in estimating the long-term trajectory as well as the implications of different mitigatory measures. Our aim is to develop a mathematical model to support decisions around long-term commissioning needs for a large healthcare system in the Southwest of England.The model is a finite horizon discrete-time Markov chain where the state space is based on population segmentation using Cambridge multimorbidity score. Individuals' transitions are extrapolated using observations from 2019 to 2022 and demographic projections from the ONS. Data were obtained from the System Wide Dataset, a patient-level linkable dataset for the 1.05 million local population. Our modelled results show that Core Segment 1 (lowest morbidity score) population size decreases slightly over the 20-year time horizon while the size of all other segments increase. Ultimately, while the population is expected to increase by 14%, the total cost is expected to increase by 41%, indicating the scale of the challenge required to reduce the increasing multimorbidity of the population and/or improve technical efficiency in terms of reducing the spend on addressing given health needs. We also consider mitigations to these 'do nothing' trajectories to support health leaders weigh up the value of implementing different policies.

4 - Combining Optimization and Simulation for the Targeted Immunization of a Population under Epidemic Outbreak
Rowan Hoogervorst, Guðmundur Óskar Halldórsson, Rakel Guðrún Óladóttir, Evelien van der Hurk, David Pisinger, Niels-Christian Bagger

Targeted immunization of a population focuses on selecting a subset of the individuals to immunize in such a way that the spread of an epidemic disease is minimized. In our approach, we model the spread of the disease using simulation based on an SEIR compartmental model and a contact graph that represents the contacts between individuals in the population. This simulation approach allows us to take into account the effect of contact tracing and a limited willingness to test and quarantine. We propose the use of a genetic algorithm to solve the immunization problem, where we use simulations of reduced size to quickly identify promising solutions within the algorithm. Moreover, we look at a stochastic programming approach based on sampling the disease spread that occurs during simulation runs. We perform an extensive numerical study on data from a major university in Denmark and for disease characteristics representing those of the COVID-19 pandemic. In our numerical analysis, we compare the solutions found by both algorithms to those found by applying well-known centrality measures. Moreover, we compare the impact of immunization to the impact we found of minimizing distinct contacts while scheduling classes in an earlier study.

■ TE-03

Tuesday, 15:30-17:00 - Room C

Capacity and Network Planning

Stream: Talks
Contributed session
Chair: *Felipe Rodrigues*

1 - Layout planning and reassignment of spaces for outpatients' clinics for a specialized hospital
Ana María Anaya-Arenas

The increase in chronic disease and the need of long-term care for the patients has caused a significant increase in the demand for the healthcare systems and its outpatient services. Therefore, hospitals are challenged to replan and expand the physical space to meet the needs of the population. This research shows a decision support system proposed and implemented to support the managers of the University Institute of Cardiology and Penology of Quebec (IUCPQ) in their process of reorganizing the outpatients' clinics services. The proposed approach includes qualitative and quantitative aspects to optimize the space allocation, inspired by the facility layout planning methodology. The assignment model and analysis performed to provide a useful tool to healthcare managers will be presented. The challenges of implementation will also be discussed.

2 - Exploring the interactions between private surgery numbers and Nhs waiting lists
Marion Penn

As a result of reduced capacity through the COVID-19 pandemic UK hospitals were able to carry out fewer planned operations and waiting lists have increased. This is a significant concern for patients and the issue has been raised in the media many times over the last year The media coverage included the issue of some patients deciding to pay to have their treatment privately as the waiting time for Nhs treatment is unacceptable to them. This project explores the historical data on Nhs waiting times and private surgery numbers to explore how they interact and how this might be used to project numbers following the impact of the pandemic. Causal loop diagrams develop understanding the factors influencing waiting time and analysis of feedback loops allows us to explore the factors to control waiting time from both demand and supply perspectives. This allows us to include a wide range of considerations, which is particularly important where we don't have access to full data. From this understanding of the wider healthcare system in the UK a simplified quantitative model was developed allowing us to explore different scenarios and test the extent to which patients would need to go to private treatment before the effect on the Nhs waiting lists became significant.

3 - 3D Printing at Point of Care: From Strategy to Operation - Insights from a real-world case
Philipp Url, Siegfried Voessner, Wolfgang Vorraber

3D printing at point of care is a growing business and many hospitals are dealing with the challenge to design and setup a 3D printing center at the clinic for daily operational use beyond research activities. This work presents the necessary steps to establish such a 3D printing center from strategy to daily operational use. For this purpose, a simulation model was created to support decision making concerning its configuration and the evaluation of its economic feasibility. It is capable of simulating various scenarios of current and future demand. Its output, representing the operational performance, can then be used for estimating required resources such as number of 3D printers, number of employees and work shifts. We present the model itself, its creation steps based on the business model and business processes of a real-world case as well as several scenarios and their results. Furthermore, an outlook on an economical evaluation based on the simulation output will also be presented.

4 - A simulation-based optimization model for non-acute patients re-allocation in multi hospital networks
Mattia Cattaneo

Non-acute patients have been acknowledged to play a major role in congesting emergency departments, being responsible of more than 80% of accesses. Abnormal non-acute patient rates indeed contribute to a deterioration of the service, leading to increased waiting times, patient dissatisfaction, medical errors and ED re-admissions or abandonments. As an effective strategy to alleviate ED overcrowding, we investigate non-acute patients' re-allocation decisions towards other EDs belonging to the same multi hospital network. To this aim, the model addresses a strategic focus, determining the potential of deploying a fleet of equipped vehicles to re-balancing flows and mitigate congestion at EDs. In detail, we propose a simulation-optimization approach to appropriately account for both the presence of different emergency level queues before ED boarding and the impact of adding/dropping new re-allocated patients. We leveraged an extensive dataset comprising 4 EDs and 1.4 million patient accesses of a medium-large Italian regional hospital network in the period 2010-2022. Results show that under specific conditions (e.g., time of the day) the re-allocation of non-acute patients can be a valid strategy to improve the efficiency of emergency care services within a multi hospital network.

Thursday, 9:30-10:30

■ HA-01

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

Podium Discussion

Stream: Plenaries
Invited session
Chair: *Siegfried Voessner*

1 - The role of integrated planning in mastering current and future challenges in managing healthcare - adding practioner's perspectives
Siegfried Voessner

The panel will discuss the current and future challenges seen by healthcare managers and assess the role that integrated planning along with modeling and quantitative methods plays in mastering these challenges. The panel consists of one health care manager, one health care planner, one investigative Journalist and one academic host with operations research background, who will facilitate the discussion and the link to the audience.

Thursday, 11:00-12:30

■ HB-01

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

World Café Session

Stream: Plenaries
Invited session
Chair: *Sebastian Rachuba*

1 - Serious Games in OR for Healthcare
Sebastian Rachuba, *Marion Rauner*, *Wolfgang Vorraber*

Successfully implemented research findings in the field of healthcare operational research depend on buy-in from decision-makers and managers. If this buy-in is missing, valuable results and insights might not inform current practice at the various organisations. Serious games could potentially offer a bridging element towards an interactive and engaging platform for decision-makers, researchers, and practitioners in healthcare operational research. This World Café session aims to explore the applications, methodologies, and impacts of serious games in the field of healthcare operational research operations research/management. Through interactive roundtable discussions, participants share their experiences focusing on (1) teaching healthcare OR/OM at universities, (2) teaching healthcare OR/OM to practitioners, and (3) make research findings accessible to stakeholders. Through the exchange of best practices, sharing of lessons learned, and exploration of new avenues, this session explores potential contributions of serious games as a valuable tool to foster successful implementation of research findings. Participants of this session collectively envision future directions, and promote wider adoption of serious games in healthcare OR/OM.

Thursday, 13:30-14:00

■ HC-01

Thursday, 13:30-14:00 - Room A

World Cafe Session Results

Stream: Plenaries
Invited session
Chair: *Wolfgang Vorraber*

1 - World Café Result Presentation
Wolfgang Vorraber

Results will be presented by the participants

Thursday, 14:00-15:00

■ HD-01

Thursday, 14:00-15:00 - Room A

Business Meeting

Stream: Plenaries
Invited session

Thursday, 15:30-17:00

■ HE-01

Thursday, 15:30-17:00 - Room A

Integrated Planning of Home Care

Stream: Talks
Contributed session
Chair: *Gréanne Leeftink*

1 - Integrated decision-making for medium-term home health care planning
Arne Delaet, Kris Braekers, Yves Molenbruch, Katrien Ramaekers

Home health care (HHC) may be defined as care workers visiting patients following predefined schedules in order to provide medical services in their homes. Maintaining a sustainable and effective health care system is a major challenge, so HHC providers must discover new ways to decrease costs and enhance productivity by optimizing the use of resources.

First, the findings of a literature review on OR models applied in HHC will be discussed. It was found that a key opportunity for improvement is the optimization of medium-term (4-week) decision-making by integrating different decisions (e.g., rostering, assignment, scheduling, routing) while considering numerous realistic problem aspects (e.g., continuity of care and working time regulations). Second, the specific problem setting we focus on is defined, and a matheuristic solution algorithm for the problem is proposed. This integrated algorithm first finds a feasible initial solution using a tailored k-means heuristic and a binary integer linear programming model. In the second phase of the solution algorithm, the initial solution is improved by a tailored large neighbourhood search heuristic while periodically solving a mathematical model. Finally, the efficiency gains of tackling the medium-term HHC planning problem in an integrated manner instead of sequentially will be demonstrated, after which the results of some experiments conducted to derive insights for the practical organization of HHC will be discussed.

2 - Optimizing Home Health Care Services through Integrated Districting and Nurse Allocation under Stochastic Demand
Nadia Lahrichi, Dai Nguyen, Soumen Atta, Maria I. Restrepo

This paper presents a comprehensive study of the joint districting and staffing problems in Home Health Care services, taking into account the uncertainty in demand. The objective is to optimize the compactness and workload balance measures of both districts and nurses. The problem is formulated as a two-stage stochastic program, where the contiguity requirements are explicitly defined for both districts and basic territorial units assigned to nurses. To address the need for stability in districting for several years, the model includes the uncertainty in demand. The problem is analyzed in various settings encountered in practice. Extensive computational experiments are conducted to investigate the impact of problem characteristics. Overall, the study provides insights into optimizing resource allocation in home healthcare services and offers useful methods for decision-makers to improve the efficiency and quality of patient care.

3 - Integrated nurse routing and rerostering in hospital-at-home
Anisha Maharani, Véronique François, Yasemin Arda

Hospital-at-home is an emerging trend that provides treatments to patients at their own homes for conditions that would otherwise require admission to hospital wards. The expected benefits of such systems range from improved patient quality of life to reduced healthcare costs. This study focuses on the operational planning decisions in hospital-at-home services. Indeed, a precise scheduling plan is required to meet the acute care needs of a fluctuating patient mix, using resources whose availability varies over time. Given the baseline roster of the nurses and the patient's requirements, several decisions are taken simultaneously over the planning horizon: select which patients to treat at home, assign nurses to those admitted patients, sequence and schedule the care visits to build the daily tour of each nurse, and decide whether and to what extent the baseline nurse roster should be updated. The objective is first to maximize the number of patients treated at home, and second to minimize the change in the baseline roster. A heuristic solution method is currently being developed to solve the problem, oscillating between re-rostering and routing moves, and allowing infeasible solutions to be visited. Preliminary results of the computational experiments are presented, and challenges encountered in tackling the integrated problem are discussed.

4 - Nurse scheduling and routing with uncertainties for home health care
Paul Fleurance, Olivier Péton, Maria I. Restrepo

In this work we present a problem of routing and scheduling nurses in a home health care context under uncertainty. We consider two types of uncertainties, never studied together to the best of our knowledge: service time and nurse availability. We model the problem as a two-stage stochastic programming model. The first stage decisions allocate work schedules (over one week or more days) to regular nurses. The second stage is in charge of finding the routes for the regular nurses, as well as deciding which tasks will be performed by external nurses (i.e. one of the recourse actions). We empirically show that this problem is too difficult to solve with direct methods. Therefore, we propose to solve problem with a the decomposition method dedicated to stochastic models, the well known L-shaped algorithm.

■ HE-02

Thursday, 15:30-17:00 - Room B

Transportation, Routing and Logistics

Stream: Talks
Contributed session
Chair: *Yannick Kergosien*

1 - Optimising Patient Transport and Medical Resource Allocation in Mass-Casualty Incidents
Florentina Hager, Melanie Reuter-Oppermann

Providing adequate medical treatments in a mass-casualty incident with a sudden increase in demand poses a complex logistical problem. With time being a crucial factor influencing the chance of survival, one of the main goals in a disaster's response phase is to transfer casualties to medical centres quickly. Especially in disasters resulting in major damages, local capacities may be overwhelmed and not capable of providing treatment to all casualties. Thus, considering opening temporary medical centres or transporting casualties to more distant permanent medical centres may be inevitable. While temporary medical centres may relieve permanent medical centres and avoid long transportation distances for casualties, they may require some lead time before being able to operate and be limited in treatment options. On the other side, with many casualties needing transfers, mass-transportation vehicles may provide useful alternatives to conventional vehicles such as ambulances and reduce overall transportation times. However, those mass-transportation vehicles should arrive at the disaster site quickly. Thus, coordinating the stationing of mass-transportation vehicles with patient-to-hospital allocation and routing is a necessary task. With both decisions influencing each other, we will present a model that considers both tasks simultaneously such that waiting and transportation times for casualties are minimised.

2 - Routing and Scheduling for Mobile Vaccination Services Aiming Fairness for the Vulnerable Populations
Sibel Salman, Betul Kayisoglu, Eda Yücel, İlker Kayi, Muhittin Hakan Demir

In a pandemic, the effective distribution of vaccines is crucial to avoid an explosive increase in infections. In this study, we focus on providing services to people that have difficulty accessing vaccination services, such as those living in rural areas, disabled or elderly people that are immobile, and refugees. We plan the logistics of delivering vaccination services with mobile facilities having adequate personnel and vaccine supply of different types over a planning horizon such as 12 weeks. We form groups of people that are in the same location, have the same ideal vaccination schedule, belong to the same vulnerability group, and prefer the same type of vaccine. We minimize the number of people who are not vaccinated, the amount of lateness in vaccination, and the total distance traveled by the mobile facilities. We also aim to provide an equitable service with two alternative approaches, namely Gini Index and Rawlsian Maximin criterion. We develop a mixed integer program and a hierarchical matheuristic to solve large instances of the problem. Computational experiments are conducted on the case of COVID-19 vaccination of Syrian refugees and Turkish citizens having difficulty accessing vaccination services and living in different neighborhoods in the city of Gaziantep in Turkey. The performance of the models solved by the CPLEX solver and the proposed heuristic solution approach. Are compared and several insights are derived.

3 - Simulation in complex environments: an incremental approach
Sarie Brice, Mark Tuson, Elizabeth Williams, Paul Harper, Geraint Palmer, Daniel Gartner

The demand for genetic testing is growing rapidly, fuelled by new research and by a expanding portfolio of test processes. This in turn makes for extremely complex processes with a wide range of shared resources, both technological and people's skill sets. This is made more so by rigid KPI's relating both to the high-quality standards required and the tight service times. The utility of a DES simulation to identify bottlenecks, assess the impact of new technology and increased workload is obvious. In addition, the simulation is intended to forecast issues in achieving service times, in time to take remedial action to address them. The presenter describes such a project situated within a national genetics testing service, which in addition to the aims described above is also looking to support a planned move to new premises. The approach used for mapping the system, incremental implementation of the simulation and results so far are described, and the current iteration of the model is presented.

4 - Promoting resilience within the pharmaceutical supply chain: A hybrid simulation approach
Fatemeh Alidoost

The pharmaceutical supply chain (PSC) is a complex network, spanning multiple stakeholders and global systems. Medicine shortages have risen worldwide due to multi-factorial causes including supply-related and demand-related factors. Extraordinary geopolitical events (sanctions) and different disruptions (pandemic) can also affect medicines' availability and PSC resilience. COVID-19 exacerbated these challenges and has had consequences on the healthcare system including delays in treatment and cancellation of care. Insufficient or postponed care can lead to unfavorable consequences for patients and considering the NHS in the UK (funded publicly), a greater system cost might be incurred. Advances in computing power have potentially increased the possibility of developing more realistic models through M&S techniques. While healthcare problems are challenging to capture through a single M&S method due to their complexities, hybrid simulation allows for more comprehensive models that can capture complex interactions, and exploration of different scenarios, and enables the model to be more flexible and adaptable. In this study, a hybrid simulation modelling framework of the PSC is proposed to investigate the interrelation between different levels of the PSC during a disruption. The proposed model investigates the critical bottlenecks of the PSC during a crisis and aids the evaluation of the cost-effectiveness of different interventions to support decision-making processes.

■ HE-03

Thursday, 15:30-17:00 - Room C

Staff and Resource Scheduling

Stream: Talks
Contributed session
Chair: *Theresia van Essen*

1 - Two-stage physician scheduling at a health prevention department
Eugenia Zanazzo, Sara Ceschia, Laura Deroma, Andrea Schaerf, Francesca Valent

The physician scheduling problem under consideration concerns the medical staff of the Public Health Unit of the Health Prevention Department of Udine (Italy). Physicians have different qualifications and are involved in different services, each one carried out on a specific day and location. A peculiarity of our problem is that, under some specific circumstances, a physician can cover two services at the same time. All services but one (necropsy) are delivered during the daylight hours from Monday to Friday and share the same locations. Necropsy occurs every day (including weekends and public holidays) and its locations are different from the other services. Physicians have compatibilities and preferences concerning services and locations.

Constraints regard coverage, workload, compatibilities, complete weekend, minimum and maximum working days, service continuity, and teamwork. The objective is to minimize the penalty for unsatisfied preferences about locations and services and the deviation from the optimal working time.

Our problem is modeled using a two-stage approach, where we first allocate weekend tasks for a long-term period of six months and then schedule the weekday activities one week at a time taking into consideration the previously assigned weekend tasks. Stage I is solved through a greedy heuristic taking into account the border data, whereas for Stage II, the most complex one, a mathematical model is designed and solved using CPLEX.

2 - A scheduler for in-hospital production of 3D-printed devices for medical use
Ettore Lanzarone, Stefania Marconi, Davide Duma

3D-printed anatomical models and medical devices support surgery planning, surgeon training and other important activities. Nowadays, outsourced companies supply these devices to hospitals, while only a few services have been insourced within the hospital worldwide. But, this configuration will be exploited more and more in the future because it involves physicians more directly in the process, thus reducing production times and costs. Properly managing in-hospital 3D factories is a difficult task, due to the complex requirements to be considered when scheduling the operations. An order involves two pre-processing activities (segmentation of patient-specific medical images and device design), the 3D printing itself, and a post-processing activity (cleaning and finishing). Each order requires a specific set of materials on the printer, and changing materials could be wasteful (expensive) and time consuming. Moreover, each order has a due date, usually quite strict, which is set according to the scheduled procedures. We developed a scheduler suited for in-hospital 3D factories, with the goals of maximizing production, starting from the models with highest priority and closest due date, and minimizing production costs related to material consumption and wastage. A linear programming model and a matheuristic approach to solve real-size instances were implemented. The developed tool was tested on real instances from the 3D4Med Lab of IRCCS Policlinico San Matteo, Pavia, Italy.

3 - Cyclic shift scheduling for hospital nurses. a real case.
Marta Cildoz, *Fermin Mallor*

In this paper, we present a mathematical programming model that solves the problem of assigning shifts to nurses in a private hospital. This problem has been extensively studied in operational research literature, considering different types of constraints and objectives. Our problem differs from those already studied in that the solution must be cyclical to achieve a completely fair distribution of shifts among nurses, and include the objectives and real constraints of both hospital managers and nurses' unions. In fact, the ultimate purpose of the mathematical model is to become an important element in the negotiation between the hospital management and the nursing staff. Thus, the model must consider the demands of the nursing unions and work schedules that are attractive for both nurses with permanent contracts (established employees) and newly hired workers (in order to avoid excessive turnover in the job). The developed mathematical model creates a cyclical shift assignment system differently from how this problem has been dealt with in previous studies.

4 - Integrated hospital case mix and medical resident planning
Sebastian Kraul

The case mix planning problem deals with selecting the ideal mix and volume of patients in a hospital and is an important tool for strategic and tactical hospital planning. Case mix planning aims to match patients with the appropriate level of care and resources to improve the quality of care, reduce costs, and increase the overall efficiency of hospitals. The choice of the patient mix directly impacts the potential number of medical residents to be trained by a hospital because the patient mix is related to the content relevant to residents' training (specific number of procedures). In order to take a holistic view of the medical resident training in the hospital, it is necessary to consider case mix planning and analyze it from the perspective of medical resident planning. In this research, we will formulate the integrated problem as a mixed integer program and analyze different settings.

Friday, 9:30-11:00

■ FA-01

Friday, 9:30-11:00 - Room A

ÖGOR Health & Disaster I

Stream: Talks
Contributed session
Chair: *Marion Rauner*

1 - The potential of the community parametric strategy for the ambulance rescue system in the City of Hamburg, Germany
Marion Rauner, Benjamin Swyter

The demand for the ambulance rescue system of the City of Hamburg, Germany, which is executed by the firebrigade, rose by more than 10% from 2019 to 2021. To cope with this situation, fire security staff has often undertaken ambulance rescue system's duties since then.

This increase in demand can be attributed mainly to the increase in non-critical ambulance rescue operations (raise of more than 20%), while the critical ambulance rescue service operations even dropped. This trend is caused by demographic change, long waiting times in primary care, and worsening of the extramural health care services provided.

A potential solution would be the introduction of community parametrics who treat and counsel patients at home before ambulance rescue services might be required subsequently. Therefore, the ambulance rescue system could be released.

In this study, the stations and their operations of the ambulance rescue system of Hamburg are analyzed in detail from a statistical point of view to identify the potential for a community parametric strategy. Full data from the representative year 2021 were gathered. We identify certain stations with high potential as well as best mission times (time of day, day of week, calender weeks) for being supported by community parametrics. Finally, we conclude with some predictions of the managerial and economic potential for such a community parametric strategy in the City of Hamburg.

2 - Appointment Scheduling under Patient Choices with Walk-in Behavior and Cancellations
E. Lerzan Ormeci, Feray Tuncalp, Erhun Ozkan

We consider an outpatient clinic with regular and walk-in patients. Regular patients may belong to different classes that may bring different revenues to the hospital based on the insurance type. The clinic dynamically decides on the daily number of appointment slots allocated for walk-in patients and the set of appointment days offered to a patient. Patients' choices are represented through multinomial logit models. Given the offered set, patients may select to make an appointment for one of the offered days or walk in on a day that is not included in the set. It is also possible that they leave the system without making an appointment or walking in. Walk-in patients have a risk of not receiving service, which we call "blockage" and patients take the blockage cost of the walk-in option into account while making their choices. We assume that patients may cancel their appointments or not show up. The clinic may resort to overbooking to compensate for the effect of cancellations and no-shows. Furthermore, physicians may work overtime to satisfy the excess demand from appointment patients. The objective is to maximize the expected net profit. We first formulate the problem with a static model which does not take the current system state into consideration. We characterize the structure of the optimal solution under the static model and establish its asymptotic optimality for the stochastic model.

3 - Automated Medical Resident Scheduling in Austria
Wolfgang Dummer, Alexander Gaal

The Resident Scheduling Problem (RSP) deals with the assignment of medical residents to training facilities during their postgraduate training. In Austria, there are about 8000 residents in training across 148 hospitals. Achieving fair schedules that minimize and evenly distribute negative aspects among residents is crucial. Today's manual scheduling process is costly and time-consuming, while the quality of scheduling is highly dependent on the skills and methods of individual schedulers, which can lead to fairness issues. Considering the social and economic aspects of RSP, we propose a novel hybrid approach to solve real problems in Austria using rule-based scheduling and metaheuristic optimization. None of the existing approaches meet the requirements of the Austrian framework and realistically sized problems. In most cases, the number of residents and time periods are small, and only a few constraints and objectives are considered, thus, no automatic planning solution is available. We address both the planning effort and the fairness aspect by applying a hybrid method consisting of an evolutionary metaheuristic combined with a rule-based heuristic. The method finds feasible rotation schedules for all residents, considering trade-offs between the ethical and social issues involved and the quality of education that can be achieved. The results show that the approach can produce high-quality solutions that consistently outperform a human decision maker.

■ FA-02

Friday, 9:30-11:00 - Room B

Discussion Session

Stream: Discussion Session
Contributed session
Chair: *Laura Boyle*

1 - Triage of injured persons at mass casualty incidents with algorithms and/or drones
Franziska B. Metz, Melanie Reuter-Oppermann

Traffic accidents, terrorist attacks or natural disasters regularly lead to mass casualty incidents (MCI), which significantly exceed the supply capacities of the rescue service. In order to ensure the survival of as many patients as possible, it is particularly important to classify the injured persons according to urgency of treatment. Various algorithms are available for this triage. These algorithms suggest a sequence of defined questions and processes (e.g. checking vital signs), at the end of which each patient is assigned to one of these triage categories. Thereby a fast and reliable identification of vital threatened persons is crucial in order to treat them as quickly as possible. The aim of the work is to analyse and compare triage done by paramedics with common triage algorithms and triage done by drones with e.g. imaging techniques and thermal cameras. These techniques should be used to detect the number of injured patients, their vital signs, injuries, body temperature etc. to use for triage algorithms or direct for a classification to triage categories. In the future, a simulation will be used to analyse the time required and the accuracy of patient classification.

2 - Towards a hospital-wide simulation framework
Melanie Reuter-Oppermann, Ilze Ziedins, Cameron Walker, Michael O'Sullivan

In a hospital, there are many dependencies between different resources, processes and departments. When changes are made to one resource or in one department, it is often very difficult to estimate the consequences for the rest of the hospital and it is unclear how far they actually stretch. While there is a tendency towards more integrated planning in hospitals, analysing the effects and benefits, especially for the whole hospital, is often still not possible. The aim of our research project is to design and build a simulation for a complete hospital including all departments, processes, resources and care provision that allows for a hospital-wide analysis. In order to achieve that, we first derive a conceptual model as a basis for the implementation. By using a container-based approach, we allow the integration of various

simulation models for different departments and their interactions. A simulation-wide event calendar and clock align the events and makes sure that the interaction between the individual sub-models is well-coordinated and stable.

3 - A New Fairness Oriented Algorithm for the Assignment and Scheduling Problems of the Home Health Care Service Systems
Roberto Aringhieri, Matteo Di Cunzolo, Alberto Guastalla, Semih Yalçındağ

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 (I) to assign patients to medical teams, and (ii) to decide their weekly visiting plans, both under fairness considerations. Including fairness within an optimization approach could be a challenging task both 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 main steps. In the initialization phase a set of patients have been assigned to set of teams according to visit requirements, skill compatibilities and daily team capacities. In the second phase, according to new patient arrivals and/or discharging of existing patients, a newly developed post-assignment algorithm is used to meet patients needs and fairly manage team workloads.

We provide some preliminary results on real data provided by Molinette Hospital in Turin, partner of the Circular Health for Industry project.

4 - Challenges in Simulation Modelling of Critical Care Networks
Alexander Rutherford

The COVID-19 pandemic highlighted the vulnerability of the critical care system in many countries to a public health crisis. I will introduce our simulation model of the critical care system in British Columbia, Canada that was developed to inform capacity planning for seasonal influenza and COVID-19, as well as future pandemics. Simulation modelling of critical care systems poses several challenges. Many systems incorporate two levels of care: the intensive care unit (ICU) and the high acuity unit (HAU). ICUs frequently utilize overflow beds in either the post anesthesia care unit or the emergency department, and it is important to capture this in simulation models. The critical care system should be modeled as a network because patients are often transferred due to changes in the level of care or to alleviate capacity limitations. If the ICU is full, then patients may be discharged early (or "bumped") to an HAU or the ward, if it is medically safe to do so. Although difficult to model, bumping is an important aspect of patient flow in critical care systems, especially when under stress. I will describe our approaches to incorporating these features into our simulation model of the critical care system of British Columbia. We will discuss stresses faced by other critical care systems, how simulation modelling can be used to help address them, and challenges with incorporating into simulation models those aspects of patient flow that are unique to critical care.

■ FA-03

Friday, 9:30-11:00 - Room C

Patient Flow and Care Pathways

Stream: Talks
Contributed session
Chair: *Leonid Churilov*

1 - A flexible Discrete Event Simulation model to analyse patient flow along cancer pathways
Amalia Gjerloev, Luca Grieco, Yogini Jani, Christina Pagel, Sonya Crowe

Since the Covid-19 pandemic, healthcare systems have seen a strain on hospital resources and increased pressure to operate efficiently in order to save patient lives. Cancer services have been particularly impacted and face long waiting times following a dramatic fall in referrals at the start of the pandemic. Understanding the pandemic's impact on patient care and addressing current bottlenecks is crucial for clearing the accumulated backlog and satisfying the national performance targets. We developed a configurable discrete-event simulation model of cancer pathways and implemented it into a tool for use in collaboration with hospital analysts. Our approach involves strong engagement with clinicians and operational managers to identify the right model configuration and parameter values for the pathway of interest. We will present our simulation tool and discuss two case studies in which we collaborated with two different London-based hospitals to inform operational decisions for cancer services.

2 - Discrete event simulation model to improve the appointment process and the patient flow of an MRI department.
Marie Petit, Erik Demeulemeester

Additionally to operating rooms, diagnostic equipment belongs to the most crucial resources in many hospitals. The number and the repartition of scanners throughout the Belgian hospitals are fixed by the government, while the demand for imaging diagnostics continues to increase. This leads to sizable access times, especially in university hospitals like UZ Leuven offering all types of imaging research, including the most complicated ones. Depending on the type of examination, the waiting time to get an appointment can last several months, which is detrimental to patient satisfaction, but above all can have adverse medical consequences.

In this research, a detailed discrete-event simulation model that mimics the Magnetic Resonance Imaging (MRI) scanning process at UZ Leuven is designed. By modeling both the appointment process and the patient flow, direct and indirect waiting times are taken into account. Moreover, multiple heterogenous scanners, patient characteristics, unpunctuality and no-show probabilities are also integrated into the model. After testing different scenarios and performing a thorough sensitivity analysis, recommendations for improvement are provided, including for example the organization of the flows or the allocation of the scanners' capacity.

3 - The effect of time preferences on adherence to therapy: Policy monotonicity in discounting parameters of a Markov decision process with present bias
Hakan Kılıç, Pelin Canbolat, Evrim Didem Gunes

Patient adherence is important as nonadherence to therapy is likely to lead to worse patient health outcomes, which increase healthcare costs. Adherence is associated with many determinants. One such factor is the perceived benefits of the therapy, which is also affected by how much the patient discounts the future, i.e., his time preferences. In this work, we model the patient as a decision-maker who chooses a level of adherence based on his health status and time preferences. We use a discrete-time finite-horizon Markov decision process, where the time preferences are modeled by a quasi-hyperbolic discounting function, which models the present bias and is more realistic than the standard exponential discounting. We examine how adherence behavior is affected by discounting parameters. This is the first study to investigate the effects of quasi-hyperbolic discounting parameters on the optimal policy for such a general problem. We present the sufficient conditions under which the optimal policy is monotone in the discounting parameters. We observe that adherence is higher for an individual who discounts the future less when the ratio between the benefit of health and the cost of adherence is sufficiently large. We also present numerical examples. These conclusions offer insights to identify the patients who are more at-risk of nonadherence and to plan interventions accordingly.

4 - A modelling and simulation study of the burden of ovarian cancer treatment in France
Julia Fleck, Denis Koala, Vincent Augusto, Lionel Perrier

Ovarian cancer is the eighth most common cause of female cancer worldwide and one of the deadliest gynecological cancers. In this study, a three-state Markov model was developed to compare, in the French context, the efficiency of managing patients with advanced epithelial ovarian cancer in an expert center (high volume hospital - HVL) as opposed to a low volume hospital (LVH). The model included stable, progression and death states to account for a patient's care trajectory and chosen treatment strategy with a 10-year time horizon and cycles of one month. The inventory of resources and cost estimates were defined based on the recommendations of the French High Authority for Health. A simulation model was implemented in Anylogic to optimize patient pathway and capacity planning. Metrics computed for HVH and LVH included the total burden of advanced epithelial ovarian cancer over a 10-year time horizon, average progression-free survival per patient, and the number of Quality Adjusted Life-Years (QALY). In addition, the incremental cost effectiveness ratios (ICERs) per progression free year gained and per QALY gained were also determined. Without prejudice to its acceptability in terms of the willingness of the French public decision-maker to pay for treatment, we identified a threshold value such that the cost of managing advanced epithelial ovarian cancer patients in expert centers is cost-effective.

Friday, 11:30-13:00

■ FB-01

Friday, 11:30-13:00 - Room A

ÖGOR Health & Disaster II

Stream: Talks
Contributed session
Chair: *Patrick Hirsch*

1 - Consequences of an Extensive and Prolonged Internet Blackout on selected areas of the Healthcare Sector: A System Dynamics Analysis
Larissa Schachenhofer, Manfred Gronalt, Patrick Hirsch

The healthcare sector has become increasingly reliant on the Internet to maintain its operations, with vital systems and processes dependent on continuous connectivity. This presentation uses System Dynamics to explore the potential consequences of an extensive and prolonged internet blackout on patient transport and intramural care. The health sector relies on the Internet, from electronic health records and telemedicine to remote monitoring and supply chain management. The potential consequences of an extended outage, including system-wide failures, lead to a sharply rising workload for healthcare professionals and, with increasing duration, possibly to compromised access to health services. Utilizing a System Dynamics approach, we analyze how an internet blackout can lead to cascading consequences on patient transport and intramural care. A causal loop diagram (CLD) is introduced to enhance the understanding of complex interrelations. The CLD visualizes relevant cause-effect relationships and feedback loops that shape the behaviour of the selected healthcare sector areas during an internet outage. By analyzing the system's behaviour, we discuss potential points of vulnerability and opportunities for mitigation. This presentation provides valuable insights for researchers in disaster management and healthcare, enabling them to deepen their understanding of the challenges posed by prolonged internet disruptions and strategies for increasing resilience.

2 - Modelling of Opportunistic Salpingectomy to Prevent Ovarian Cancer in Austria
Florian Schierlinger-Brandmayr, Heidrun Sagmeister, Diether Kramer, Philipp Url, Elisa Sieghartsleitner, Mario Mauberger, Sigurd Lax, Karl Tamussino, Siegfried Voessner

Ovarian cancer is the most common cause of gynecologic cancer death and the fifth most common cause of cancer-related death overall in women in developed countries, including Austria. There is no reliable modality for early detection or screening so that primary prevention is key. Most ovarian cancers arise in the fallopian tubes. Removal of the tubes (salpingectomy) is associated with robust risk reduction for the development of ovarian cancer. Accordingly, salpingectomy at the time of gynecologic surgery in appropriate women is recommended, established and effective. Looking beyond gynecology there are multiple potential opportunities at non-gynecologic surgery (e.g., cholecystectomy) where salpingectomy could be accomplished. We use modeling and simulation (M&S) to assess the potential of salpingectomy at non-gynecologic procedures in the Austrian population. In a sensitive domain such as healthcare, M&S can explore complex dynamics, evaluate scenarios, derive conclusions about the real system and be used to design improvements. Especially for an intervention that affects women's reproductive capacity, M&S is an attractive approach to identify the potential of opportunistic salpingectomy without the need for invasive studies in the population. The model, built upon multiple data sources, will address whether and to what extent opportunistic salpingectomy at the time of non-gynecologic surgery could reduce the incidence of and mortality from ovarian cancer in Austria.

3 - P&L sharing for Primary Healthcare Centers
Raimund Kovacevic, Doris Behrens

Primary Healthcare Centers (PHC) are an important part of the healthcare systems in many countries. In Austria they started to develop only in recent years and the aim of the government is to increase the number of units in the future. Usually, the potential owners have alternatives like founding their own doctor's office or working together in smaller groups. Sometimes PHC projects fail to start because the participating persons have difficulties to define rules for sharing profits and losses that are acceptable to all of them in view of these alternatives. One reason is the fact that contributions in terms of capital investment, working time and other resources can be very different for the participating persons. We analyze the economic properties of PHC as a production unit, using optimization and game theoretic approaches (bargaining and coalitions), in order to find fair distributions of profit and losses.

■ FB-02

Friday, 11:30-13:00 - Room B

Decision Support Systems

Stream: Talks
Contributed session
Chair: *Mónica Oliveira*

1 - Aligning continuous monitoring with value-based remote care services assessment: an integrated approach for building a multidimensional management dashboard
Rafael Miranda, Mónica Oliveira, Filipa Baptista, Isabel Albuquerque

Remote patient monitoring (RPM) can be an efficient, sustainable and equitable alternative for improving access and care quality in chronic disease management. Successfully implementing RPM requires close monitoring and ongoing evaluation of initiatives to introduce improvements and ensure value creation. Aiming to contribute to the health technology assessment field - which lacks tools for day-to-day assessment - this study proposes an integrative approach combining business intelligence and multicriteria decision analysis to build a multidimensional management dashboard (MMD) to assist decision-makers in continuously monitoring and evaluating RPM programs. Making use of a collaborative value modelling framework, the proposed integrative approach combines participatory methods and decision-aiding tools to (a) involve stakeholders in selecting key performance indicators that are aligned with producing RPM value and with achieving managerial targets; (b) build a flexible multicriteria value model allowing the user a customised analysis, and a multicriteria classification model to help decision-makers understanding which RPM areas need corrective actions; and (c) integrate indicators and value model information into a user-friendly MMD that incorporates stakeholders preferences. We show how the proposed approach can be used in the context of a heart failure RPM program through the collaboration of providers, technology suppliers, payers, health professionals, and patients.

2 - Promoting health systems' sustainability and resilience in the PHSSR-Portugal initiative: Enhancing OR techniques and tools within a novel policy dialogue
Monica Oliveira, Aida Tavares, Rosário Trindade, Ana Vieira

Health policymakers increasingly pay attention to sustainability and resilience policy objectives when reforming healthcare systems. Pursuing these objectives requires an engagement of health stakeholders and experts to identify and select high-value policies. Developed within the scope of the Partnership for Health Systems Sustainability and Resilience in Portugal (PHSSR-Portugal), in this study, we propose a novel policy dialogue that combines Workshops and a Web-Delphi process with Dialogue Mapping and Analysis of Interconnected Decision Areas (AIDA) tools to promote agreement and help health stakeholders and experts to identify and discuss policy recommendations with high potential to improve sustainability and resilience. We describe how we have implemented the proposed policy dialogue in PHSSR-Portugal, in which 40 top-level health stakeholders and experts successfully collaborated to generate 69 policy recommendations, out of which 43 were selected as having gathered a high agreement on its high potential to improve sustainability and resilience. Finally, based on the PHSSR results and experience, we discuss how we are adapting the desirability-doability multicriteria framework (2xD) to move from policy recommendations towards the design, analysis and selection of policy actions according to their desirability and doability.

3 - Rejection-Proof Mechanisms for Multi-Agent Kidney Exchange
Bart Smeulders, Danny Blom, Frits Spieksma

Kidney exchange programs increase kidney transplantation by facilitating the exchange of incompatible donors. Increasing the scale of kidney exchange programs leads to more opportunities for transplants, and collaboration between transplant organizations (agents) is thus desirable. As agents are primarily interested in providing transplants for their own patients, collaboration requires balancing individual and common objectives. In this talk, we consider a setting where an independent party proposes an initial set of exchanges, including "shared" exchanges involving multiple agents. Next, individual agents can reoptimize within their own pool of patients and donors, potentially rejecting proposed shared exchanges with other agents. Our goal is to develop mechanisms which propose initial solutions such no agent has incentive to reject any shared exchanges. We call such mechanisms rejection-proof. We provide an exact mechanism, which maximizes social welfare given rejection-proofness. The underlying optimization problem can be modelled as a bilevel problem. While we establish that this problem is Sigma-2-p-hard, we develop a solution method capable of solving medium size instances. We also propose two heuristic rejection-proof mechanisms. Finally, we show that while requiring rejection-proofness can in theory lead to large losses in numbers of transplants compared to overall optimal solutions, this is typically not the case for realistic instances.

4 - Decision Support Systems (DSS) for services in both elective and emergency regime: two examples applied to the University Polyclinic Hospital of Bologna
Luca Zattoni, Andrea Eusebi, Cristiano Fabbri, Marco Leonessi, Enrico Malaguti, Paolo Tubertini

As a collateral effect of COVID19 pandemic, traditional management models in healthcare have been questioned: the sentence "we have always done so" has never turned out to be so fallacious and shortsighted. On one hand, this represents a challenge for health structures management and clinical staff, as they must deal with the considerable inertia that such complex systems often take along. On the other hand, this represents an opportunity to reveal the great capabilities of an advanced quantitative-based decision making in such contexts. In this talk we present two models that aim to overcome traditional operational schemas: both studies have been conducted on real cases at the IRCCS AOU Bologna Sant'Orsola, a research-oriented hospital. The first one is a DSS for a weekly agenda rearrangement in an endoscopic context, managing both time slots assignment to a set of operational units, and exams assignment to the designed slots. The problem is addressed using a two-step lexicographic integer programming approach. In our second study we propose a DSS tool for the Emergency Department. The proposed model, using a hybrid optimization and artificial intelligence approach integrated in an online discrete-event simulation, aims to prevent critical issues such as overcrowding and excessive waiting times before they manifest. This is made possible through a dynamic reorganization of patients' queues, performed while considering each patient's priority and required services.

STREAMS

Discussion Session

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Track(s): 2

Plenaries

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Track(s): 1

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Track(s): 1

Talks

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Track(s): 1 2 3

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