

# **ORAHS 2015**

**41th Annual Meeting  
EURO Working Group on Operational  
Research Applied to Health Services**

**Networking Health: Facing the  
Challenges in Health Services  
Management**

**July 19 - 24, 2015**

**HEC Montréal, Canada**





## Welcome from the Conference Chairs

Dear participant,

Welcome to ORAHS 2015. The EURO Working Group on Operational Research Applied to Health Services crosses the Atlantic this year to hold its 41<sup>st</sup> annual meeting in the welcoming setting of Montréal, renowned for its Old World charm infused with North American energy but also for the plurality of cultures of its inhabitants.

The theme of the conference is “Networking Health: Facing the Challenges in Health Services Management”. The scientific program comprises two plenary talks, by Professors Martin Puterman (UBC, Canada) and Andrea Lodi (Polytechnique, Canada), a discussion panel on the challenges of education in ORAHS and Health Systems Engineering with the participation of academics from both sides of the Atlantic, and 24 parallel sessions where a total of 68 papers will be presented as well as a poster session with 6 posters. As was the case in Istanbul two years ago, this year there will be no Hospital visit, but instead two very interesting tutorials have been programmed into the schedule, from Professors Erik Demeulemeester (KUL, Belgium) and Ettore Lanzarone (IMATI, Italy). Regular visitors to the ORAHS meetings will find the familiar format in which the sessions include plenty of time not only for the presentations themselves, but also for the discussions at the end of each presentation.

In addition to the scientific program, we also have prepared an attractive social program, including: a day excursion to explore some of the main attractions of Montréal, namely the Biodome, the Montreal Tower and the Botanical garden, and concluded by a boat tour in the Old Port on Le Bateau Mouche; a gala dinner at the Cabaret du Roy, in Old Montréal, for an evening that will bring us back in time to the taverns of Nouvelle France; a first day cocktail in HEC on Monday; and a welcoming get together on Sunday afternoon.

A novelty this year, in this era of green/sustainable economy, we have decided to forgo the use of charter buses. Instead, all participants will be provided with a Public transport prepaid card (Hebdo OPUS card) valid from Monday morning 5:00 until Sunday July 26, at 23:59. This card provides unlimited access for one week to the subway (Metro) and all city buses, as well as the bus connecting the downtown area to the P.-E. Trudeau airport (Bus 747). You are encouraged to use this card and Montreal's extensive public transport network to get from your hotel to HEC Montréal and back, to explore the city, etc. We will use public transport for the Wednesday excursion as well as for the Gala dinner Thursday since in both cases the locations are easily accessible via the Metro.

It is the second time that ORAHS crosses the Atlantic to come to Canada, after Toronto in 2008, but this will be the first time it is held in the French speaking part of the country, giving the chance to 2008 participants to sample this other side of the Canadian identity. We are very glad that Michael Carter, ORAHS 2008 organizer, will be among us and we hope that the 2015 meeting will leave fond memories to all participants, as did the 2008 edition.

Finally, we would like to express our gratitude for the hard work performed by our colleagues in the organizing committee without whose contribution we would not be here today.

We wish you all a stimulating and fruitful meeting and a wonderful time in Montréal!

Angel Ruiz Bartolomé and Patrick Soriano

## Organizing committee

- Valérie BÉLANGER (HEC Montréal and CIRRELT)
- Yannick KERGOSIEN (POLYTECH Tours, France)
- Nadia LAHRICHI (MAGI, POLYTECHNIQUE Montréal and CIRRELT)
- Angel RUIZ BARTOLOMÉ (Université LAVAL and CIRRELT)
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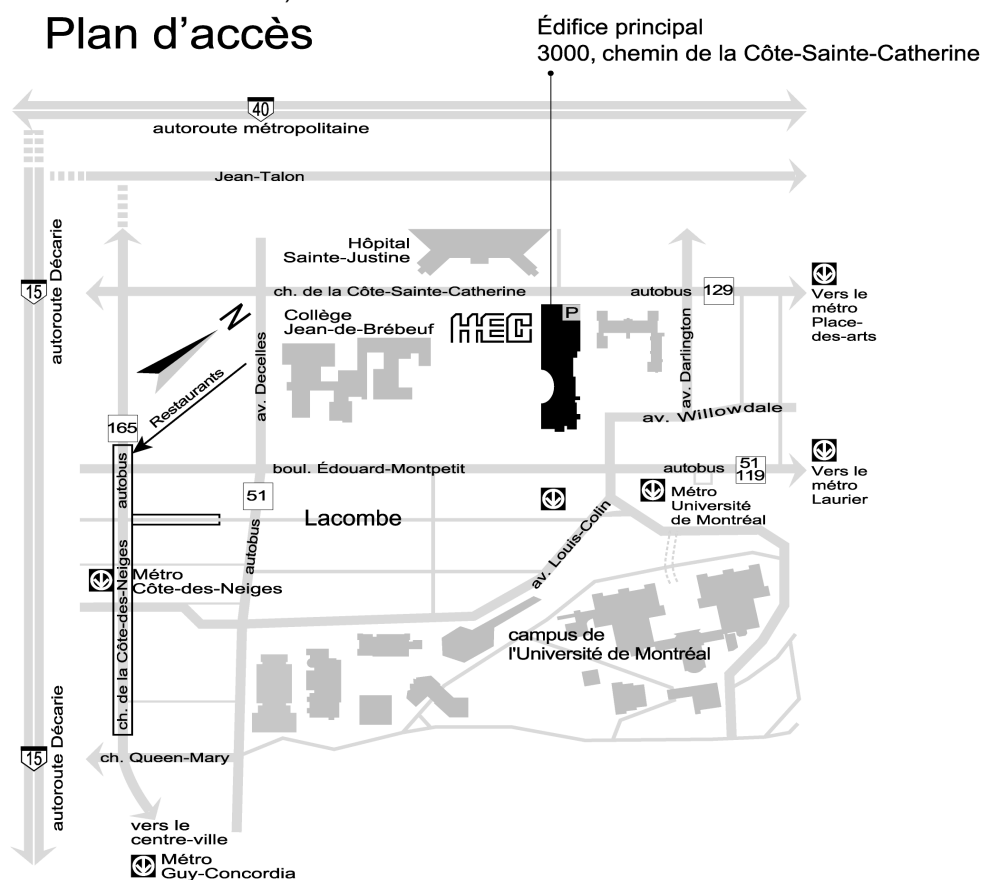


## Practical information

### Conference Venue

The ORAHS 2015 Conference will take place at HEC Montréal, in the Côte-Sainte-Catherine (CSC) building located at 3000 chemin de la Côte-Sainte-Catherine. The venue is accessible by metro and bus lines as shown in the map below.

- The closest and easiest access is via Université de Montréal metro station, taking the exit towards avenue Louis-Colin and then walking across avenue Édouard-Montpetit to the Louis-Colin entrance of HEC (100 meters).
- HEC is also accessible by bus lines 51 and 119 (exit at corner of Louis-Colin and Édouard-Montpetit), 129 (main entrance on Côte-Sainte-Catherine), and 165 that runs on Côte-des-Neiges (exit at Côte-Sainte-Catherine and walk east to the main entrance – 10 min).



- All scientific activities, lunches, coffee breaks and Monday cocktail take place at HEC Montréal at the locations specified in the following table. The specific location of the rooms can be found on the maps of the Rez de jardin level and 1<sup>st</sup> floor reproduced in the following pages.

<b>Registration</b>	Tata Communications Room (Garden level – Rez de jardin)
<b>Coffee breaks / Lunches</b>	Investissement Québec Room (Garden level – Rez de jardin)
<b>Plenaries/Tutorials</b>	Banque de développement du Canada (BDC) (1 <sup>st</sup> floor, blue section)
<b>All other sessions</b>	BDC / Ernst Young / Banque Scotia (1 <sup>st</sup> floor, blue section)
<b>Cocktail (Monday)</b>	Salon National (Garden level – Rez de jardin)

## OPUS card

Along with your participant tag and conference material, you are provided with a one week prepaid Public transport card (OPUS card) with unlimited access. Take care of it and use it to board the Metro (subway) or city buses to get around Montréal.

## Registration Desk

The registration desk will be located in the Tata Room, on the Rez de jardin level (ground floor w/r to Louis-Colin entrance). It will be open Monday, Tuesday, Thursday (8:30 – 17:00) and Friday (8:30-12:30). Note that no registration will be possible on Sunday.

## Internet Access

Internet connection is available throughout HEC either via WiFi or the many Ethernet plugs available (bring your own cable). Eduroam is available. A limited number of computers will be available next to the registration desk in the Tata Room.

## Poster Display Session

Posters will be displayed in the Investissement Québec Room on Tuesday.

## Instructions to Speakers and Session Chairs

- Each talk is allotted 30 minutes total. We ask speakers to prepare for a 25 minutes presentation. Chairpersons will allow questions from the audience for the remainder 5 minutes.
- All session rooms are equipped with a video projector, VGA connectors and a computer. Please make sure you arrive early enough before your session begins in order to copy your presentation on the computer or check the connection to the projector if you use your own computer.
- If you act as chairperson, we ask you to adhere to the schedule strictly:
  - periodically inform each author of the time remaining to complete his (her) talk;
  - in case of no show, take a 30 minute-break before moving to the next talk.

These measures will allow people to move freely between sessions.

## Share your ORAHS 2015 Photos

We have created a Picasa Web Album so we can all share the photos made during the conference. Below are the details:

Website: <https://picasaweb.google.com>

Username: [orahs2015@gmail.com](mailto:orahs2015@gmail.com)

Password: montreal2015

## Emergency Contacts

You can contact the local organizing committee as follows:

Patrick Soriano : +1 514 928 7611

Semih Yalcindag : +1 514 709 8243

Valérie Bélanger : [Valerie.Belanger@cirrelt.ca](mailto:Valerie.Belanger@cirrelt.ca)

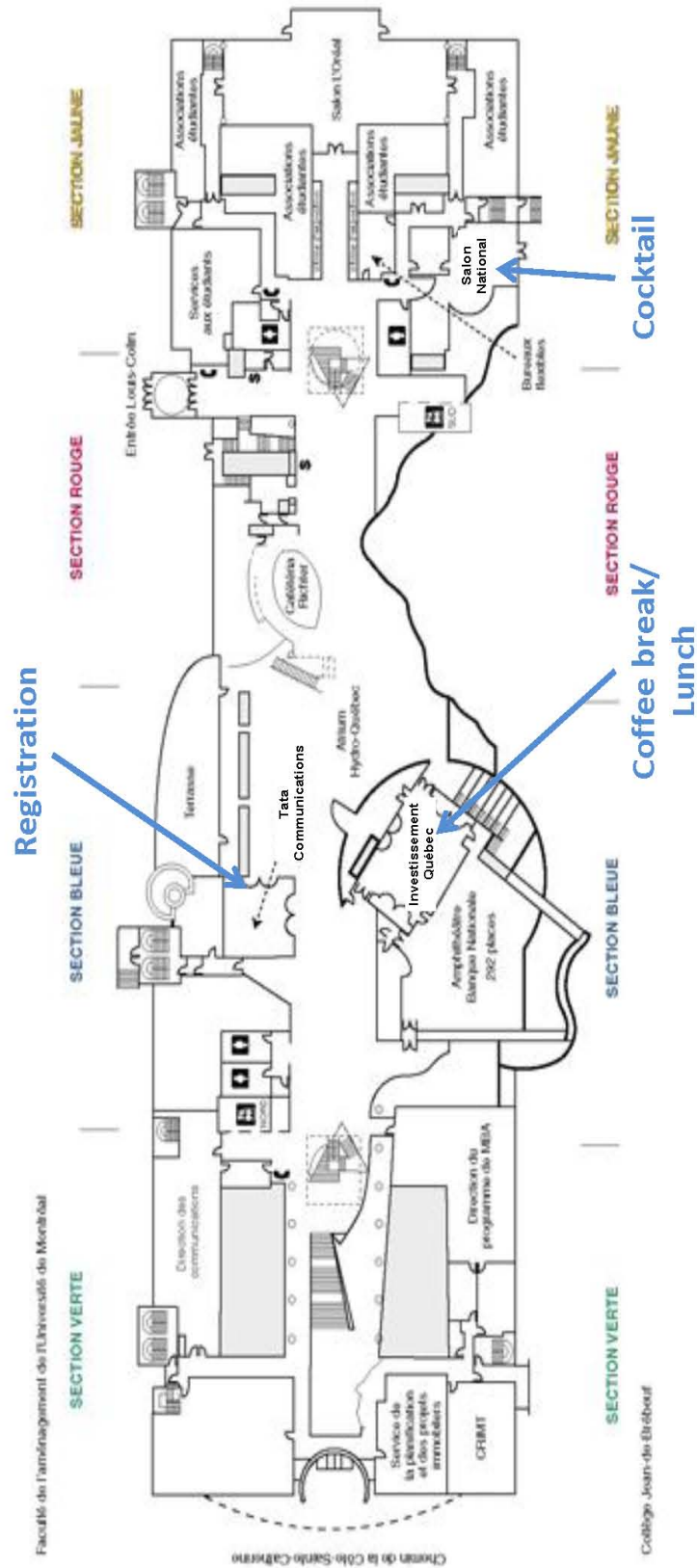
Nadia Lahrichi : [nadia.lahrichi@polymtl.ca](mailto:nadia.lahrichi@polymtl.ca)

### ***In Memory of Angela Kelly Blake***

*Angela Kelly Blake, age 45, died suddenly last April. Dear wife of our colleague John Blake and mother of James, Angela was a regular and soothing presence at the ORAHS conferences for as long as I remember. Always smiling, always a kind word, always helpful, always caring for the others. That is the image that comes to my mind when I think of her... And her pushing James in a stroller in the streets of Genoa, and other ORAHS host cities. I am sure that all who knew her share similar fond memories. We are deeply saddened by this tragic and untimely loss, and all our thoughts are with John, James and Family.*  
*P. Soriano*

HEC Montréal  
3000, chemin de la Côte-Sainte-Catherine  
Montréal (Québec) H3T 2A7

Garden Level







## Social Program

### **Sunday : Get Together (16:00 – 19:00)**

HEC Montréal being closed and inaccessible on Sunday, an informal Get Together will take place at the Rôtisserie St-Hubert restaurant located close by, on Côte-des-Neiges street (at 5235, chemin de la Côte-des-Neiges), where we will be able to enjoy a glass of wine or beer and nibble on finger food. Registered participants will be able to pick up their badges and conference material. Note that no registration will be possible at this activity. Participants not yet registered are of course welcome to the get together but will need to proceed with their registration at the registration desk, starting on Monday morning.

### **Monday : Cocktail (17:00 – 18:30)**

A welcoming cocktail will take place in Salon National, on Rez de jardin level at HEC Montréal, after the end of the sessions.

### **Tuesday: Optional Dinner (not included)**

Enjoy a dinner (Dutch treat = pay yourself) in one of the many restaurants in Montréal. See the list of suggested restaurants provided at the registration and the maps for their locations. Transportation to the restaurants and back to your hotel is not provided.

### **Wednesday : Excursion and Boat tour (9:00 – 18:30)**

The activities of the excursion day being all easily accessible by public transport, we will not be using charter buses to get to them. The meeting point is in front of the VIAU Metro station (green line) at 9:00 ( Pierre-de-Coubertin ave., north side). We will visit the Biodome (<http://espacepurlavie.ca/en/biodome>), in the Olympic parc, which showcases the four main ecosystems found on the American continent (self-guided tours, approximately 90 min). We will then climb up the Montreal Tower (Olympic stadium mast) to get a birds eye view of the city. We will then walk (15 min) to the Botanical Garden (<http://espacepurlavie.ca/en>) where we will have lunch and then a guided visit. At 16:00, we will take the Metro (and bus) to the Old port where we will embark on Le Bateau-Mouche (<http://www.bateaumouche.ca>) for a one hour cruise on the Saint-Lawrence River on a Paris style bateau-mouche (boarding will be at 17:15 on Quai Jacques-Cartier). Both activities can be reached from your Hotels directly via Public transport (or by Taxi). Directions will be available at the registration desk.

### **Thursday: Gala Dinner (20:00-end)**

The Conference Gala Dinner will be held at the restaurant Le Cabaret du Roy, in Old Montreal (363 Rue de la Commune East,), where we will travel back in time to an 18's Century Tavern of Nouvelle-France to live an experience ... Out of the ordinary! While tasting a succulent feast inspired by the early colony times and featuring local Québec terroir produce, musicians and lively staff will make you sing and laugh. The restaurant is easily accessible by Public transport. Directions will be available at the registration desk.

## Scientific Program

### Plenary Speakers

#### Martin L. Puterman

Martin L. Puterman is Professor Emeritus at UBC's Sauder School of Business. He regularly communicates with professional audiences through his numerous consultancies, and his regular interactions with senior health care managers. For the past 5 years he has taught a highly regarded course on health care operations to Executive and full time MBA students. Moreover, he was founder and director of the UBC Centre for Health Care Management, the Centre for Operations Excellence at UBC, a recent winner of the INFORMS UPS Smith Prize, and the Biostatistical Consulting Service at BC Children's Hospital. His research focuses on using operations research methods to improve health system access and performance. He has consulted widely on health care operations and planning, statistical modeling, logistics, inventory control, forecasting, operations management, program evaluation and management strategy. He received the prestigious INFORMS Lanchester Prize for his book Markov Decision Processes. He is an INFORMS Fellow and recipient of the Canadian Operations Research Society (CORS) Award of Merit, the CORS Practice Prize and the INFORMS case prize. He has been an editorial board member of Mathematics of Operations Research, Operations Research, Management Science, Production and Operations Management, Manufacturing and Service Operations Management and The Journal of the American Statistical Association. He received his PhD in Operations Research and an MS in Statistics from Stanford University and AB in Mathematics from Cornell.



#### Andrea Lodi

Andrea Lodi is a leading international researcher in mixed linear and nonlinear programming. As Canada Excellence Research Chair in Data Science for Real-Time Decision-Making at Polytechnique Montréal, he holds Canada's main chair in operations research. Before joining the Polytechnique, he was a professor in operations research in the faculty of electrical and information engineering at Italy's University of Bologna. He earned his doctorate in systems engineering from this same university in 2000. He is interested in developing new models and algorithms that would make it possible to process a large quantity of data from multiple sources both rapidly and effectively. Through his research, he is looking for solutions designed to improve the electricity market, rail transport logistics, and health-care planning. His innovative work has earned him several awards, including the Google Faculty Research Award in 2010 and the IBM Faculty Award in 2011. In 2005 and 2006, he was a fellow in the prestigious Herman Goldstine program at the IBM Thomas J. Watson Research Center in New York. In addition to co-ordinating several large-scale European projects in operations research, He has also acted as a consultant for the IBM CPLEX research and development team since 2006. He has authored more than 70 publications in top mathematical programming journals; and has served as associate editor for several of these journals.



## Tutorial Speakers

### Erik Demeulemeester

Erik Demeulemeester is Professor in the Research Center for Operations Management at the KU Leuven. He earned the degree of commercial engineer (field of Management Informatics) in 1987, the degree of Master of Business Administration in 1988 and a PhD in 1992, all from the KU Leuven. The title of the PhD was 'Optimal algorithms for various classes of multiple resource-constrained project scheduling problems'. From 2001 on, he is Full Professor and he currently teaches a course on quality management, a course on project and production scheduling as well as a seminar on production and logistics. His main research interests are situated in the field of project scheduling and health care planning and he has published many papers on these topics. He currently belongs to the editorial board of the European Journal of Operational Research, the Journal of Scheduling and the European Journal of Industrial Engineering. He also is appointed as a member of the Program Committee for the EURO XXVIII Conference in Poznan (July 3-6, 2016). Additionally, he became a core jury member for the EURO Excellence in Practice Award (EEPA) that will be awarded at the EURO-k conferences in 2016, 2018 and 2019. In the past, he has twice organized a PMS workshop in Leuven and once an ORAHS meeting. These are workshops of around 120 researchers from around the world that presented their newest research results in Leuven. Moreover, he is currently the chair of the Decision Sciences and Management Informatics department at the Faculty of Economics and Business of the KU Leuven.



### Ettore Lanzarone

Ettore Lanzarone was born in 1979, and he obtained the Master Degree in Biomedical Engineering and the Ph.D. in Bioengineering from Politecnico di Milano in 2004 and 2008, respectively. He is currently Researcher at the Institute of Applied Mathematics and Information Technology (IMATI) of the National Research Council of Italy (CNR), and Professor of Mathematical Analysis at the Politecnico di Milano. Moreover, he is co-founder and member of the  $\beta$ -Lab, joint laboratory among Università degli Studi di Pavia, CNR-IMATI and Policlinico San Donato. His main research interests include: optimization and resource planning of healthcare facilities, with particular attention to the robustness of the plans; stochastic models for estimating the demand and planning the activities in healthcare structures; scheduling algorithms for the manufacturing industry; industrial bioengineering, with particular interest to the cardiovascular fluid-dynamics; parameter estimation and stochastic evolution of complex dynamic systems described by differential equations. He is co-author of about 40 papers on international journals and conference proceedings. He has been involved in several research projects, and among them he has been the Principal Investigator of the Project Fab@Hospital, funded by the Italian Ministry of Research and the National Research Council of Italy, dealing with methods and technologies for implementing prototyping services within the hospitals. He is co-founder of the Bayesian Young Statisticians Meetings (BAYSM) and co-chair of two editions, and he was member of the committee of the first International Conference on Health Care Systems Engineering (HCSE). He spent several visiting periods in international research centers, e.g., at the Jiao Tong University (Shanghai, China), at the G-SCOP Laboratory (Grenoble, France), and at the École des Hautes Études Commerciales (Montreal, Canada).



# Monday

**9:00 -10:30**    **Registration and Coffee/Tea**    Room: Tata and Investissement Québec

**10:30 -11:00**    **Conference Opening**    Room: BDC

**Patrick Soriano**, Co-chair of ORAHS 2015

**Angel Ruiz**, Co-chair of ORAHS 2015

**Sally Brailsford**, Coordinator of the EWG on ORAHS

**11:00 -12:00**    **Plenary 1**    Room: BDC

Chair: Patrick Soriano

**Martin L. Puterman**

Teaching OR to Health Care Professionals

**12:00 -13:30**    **Lunch**    Room: Investissement Québec and Atrium

**13:30 -15:00**    **Session 1**

**MB1-Operating Room  
Planning and Scheduling 1  
ORP1**

Chair: Eric Demeulemeester  
Room: BDC

**Davide Duma**

A Mixed Offline and Online  
Approach to Manage Elective  
and Non-Elective Patients

**Francisco Ballestin**

Rescheduling of Elective  
Patients

**Carla Van Riet**

Trade-Offs In Operating  
Room Planning for Electives  
And Emergencies

**MB2-Healthcare Planning 1  
HCP1**

Chair: Nadia Lahrichi  
Room: EY

**Ali Vahit Esensoy**

Whole-System Patient Flow  
Simulation Model Applied to  
Stroke Best Practices  
Evaluation

**Nazgol Niroumandrad**

Finding a scheme to maximize  
physicians' satisfaction while  
minimizing patients' pre-  
treatment phase

**Sebastian Rachuba**

Modelling the Benefits of  
Radiographer Led Discharge

**MB3-Modeling Blood Services 1  
Blood1**

Chair: Christos Vasilakis  
Room: Banque Scotia

**John Blake**

A Generic Simulation Framework  
for Modelling Blood Inventory:  
Background, Development, Uses,  
and Lessons Learned

**Sally Brailsford**

A Simulation-Optimization Model  
for Production Planning in the  
Blood Supply Chain

**Christos Vasilakis**

Development and Validation of a  
Discrete Event Simulation Model  
for Planning Hospital Based  
Provision of Blood for Mass  
Casualty Events

**15:00 -15:30**    **Coffee Break**    Room: Investissement Québec

15:30 -17:00	Session 2		
	<b>MC1-Operating Room Planning and Scheduling 2 ORP2</b> Chair: Inês Marques Room: BDC	<b>MC2-Healthcare Planning 2 HCP2</b>  Chair: Mario Jorge Ferreira de Oliveira Room: EY	<b>MC3-Modeling Blood Services 2 Blood2</b>  Chair: Semih Yalcindag Room: Banque Scotia
	<b>Paolo Tubertini</b> Tactical and operational optimization of Operating Theaters: a multi-level decision support system	<b>Saba Vahid</b> MRI Capacity Assessment in Ontario: A Wait Times Estimation Model	<b>Sem van Brummelen</b> Time Dependent Waiting Time Computation at Dutch Blood Collection Sites
	<b>Vahid Roshanaei</b> Logic-based Benders' Decomposition Approaches with Application to Operating Room Scheduling	<b>Azaz Sharif</b> A Rolling Horizon Approach to Forecast Emergency Department Patient Arrivals.	<b>Seda Bas</b> Balancing the Production of Blood Bags from Donation through Appointment Scheduling
	<b>Inês Marques</b> A Surgical Case Assignment Problem in a Block Scheduling Strategy	<b>Mario Jorge Ferreira de Oliveira</b> A Characterization of the Last 20 Years of Operations Research on Hospital Admission Systems	
17:00 -18:00	Cocktail		Room: Salon National

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**MA****Plenary 1 - Martin Puterman****Chair:** Soriano, Patrick, *HEC Montréal***Location:** BDC

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**11:00****Teaching OR to Health Care Professionals****Puterman, Martin L.**, Sauder School of Business, UBC, martin.puterman@sauder.ubc.ca

In this talk, I will share my experience developing and teaching an operations research course for health care decision makers and professionals over the past decade. I have offered this highly rated course under the heading “Managing Patient Flow” but a more apt name might be “Managing Supply and Demand”. Its goals are to provide a basic problem-solving framework and hands on experience with a set of OR tools. Moreover it communicates the importance and value of developing an OR capacity within a health care organization. All material draws on projects my colleagues and I have carried out in a wide cross-section of health care settings. These are communicated to the course participants in the form of cases, discussion problems, published research and an interactive game. The main themes are:

- The need for performance metrics and the challenges in evaluating them.
- The basic levers managers can use to improve access to services.
- The integrated nature of health care systems and the limits of local optimization.
- The limitations of lean approaches and the need for operations research methods.

The material draws from case studies and research on porter systems improvement, diagnostic imaging scheduling, reducing wait times for cancer care, reducing surgical cancellations, long term care capacity planning, workforce management and lean evaluation. OR tools emphasized include optimization, queuing and simulation. Excel add-ons and spreadsheets provide hands on experience. In addition to describing my approach to teaching OR, it will provide an overview of my health care research. <http://orincancercare.org/puterman/emba512> provides a course outline and links to a range of materials. See also <http://asg.sauder.ubc.ca/> for access to our appointment scheduling game.

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**MB1****Operation Room Planning and Scheduling 1****Chair:** Demeulemeester, Erik, *KU Leuven***Location:** BDC

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**13:30****A Mixed Offline and Online Approach to Manage Elective and Non-Elective Patients****Duma, Davide**, Dipartimento di Informatica, Università degli Studi di Torino, davide.duma@unito.it**Aringhieri, Roberto**, Dipartimento di Informatica, Università degli Studi di Torino, roberto.arinhieri@unito.it

At the operational decision level, the Operating Room (OR) management is also called “surgery process scheduling” and is generally separated into two sub-problems referred to as “advanced scheduling” and “allocation scheduling”. Usually, the two sub-problems have different and conflictual objectives, that is to maximize the OR utilization and to minimize the number of patient delayed or cancelled, respectively. The management of non-elective patients is a really complex task: actually, delaying an urgent non-elective surgery may increase the risk of postoperative complications and morbidity. Therefore, the speed at which an OR is available for that surgery, is the crucial factor to guarantee a positive final outcome. A common approach is to reserve OR capacity since it is believed to increase the responsiveness. This approach poses a question, that is if it is better to have dedicated ORs or, alternatively, to reserve capacity in the elective ORs. We discuss the problem of dealing with a joint flow of elective and non-elective patients within a surgical pathway. In literature, different solutions (dedicated operating room vs. flexible policy) have been proposed determining opposed results. Furthermore, to the best of our knowledge, online optimization is never been applied to the context of the Operating Room Planning. In this paper, we propose a mixed offline and online approach to improve the management of elective and non-elective patients. The solution framework is built on a DES methodology in order to model the patient flows and to deal with the inherent stochasticity of the problem. Further, we will address the analysis of the trade-offs between the use of dedicated operating rooms and a flexible policy.

**14:00****Rescheduling of Elective Patients****Ballestin, Francisco**, Universidad de Valencia, francisco.ballestin@uv.es**Pérez, Angeles**, Universidad de Valencia, angeles.perez@uv.es**Quintanilla, Maria**, Universidad de Valencia, maria.quintanilla@uv.es



We study in two phases how to build the schedule of elective patients in a unit of a hospital. We have to choose some patients from a waiting list and assign them a session in one of several operating rooms. The planning period is two weeks. In the first phase we study how to calculate a first schedule, two-three weeks before the actual planning period, with the goals of minimizing the percentage of late patients – operated on after their due dates – and maximising the utilisation of the operating rooms. The biggest problem in this part of the study is that the first goal is a long-term goal, not easily grasped in a two-week optimisation problem. This first schedule is built to be able to inform the chosen patients and to make any special preparations needed for the operations. Few days before the planning period, this first schedule is revisited. Usually some of the operations cannot be performed, due to unavailability of patients, doctors or necessary equipment. It is necessary to calculate a new schedule, which is done in the second phase of the study. The idea is to calculate a new schedule with the same goals as the original one, but similar to that schedule. We study how to define similarities between two schedules. Finally, we present the decision maker several possible solutions so that s/he chooses one. Some of these solutions are closer to the original one, and others are better in terms of the goals.

**14:30**

### **Trade-offs in operating room planning for electives and emergencies**

**Van Riet, Carla**, KU Leuven, carla.vanriet@kuleuven.be

**Demeulemeester, Erik**, KU Leuven, Erik.Demeulemeester@kuleuven.be

The planning of the operating rooms (ORs) is a difficult process due to the different stakeholders involved. The real complexity, however, results from various sources of variability. This variability cannot be ignored since it greatly influences the trade-offs between the hospital costs and the patient waiting times. As a result, a need for policies guiding the OR manager in handling the trade-offs arises. Therefore, researchers have investigated different possibilities to incorporate non-elective patients in the schedule with the goal of maximizing both patient- and hospital-related measures. The literature on OR planning, where both elective and non-elective patient categories are involved, shows various policies. Due to the differences in the research settings however, contradicting results on measures such as overtime and the patient waiting time are reported. Decisions on both operational policies as well as on capacity are required to assure timely access and efficiency, which are the two main drivers for the problem at hand. Through discrete event simulation, we show the impact of capacity allocation decisions on various performance measures and include patient categories with different due times, the variability in the arrival process and rescheduling actions. For this, we use data of a large OR complex of a university hospital in Belgium.

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**MB2**

## **Healthcare Planning 1**

**Chair:** Lahrichi, Nadia, *Polytechnique Montréal*

**Location:** EY

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**13:30**

### **Whole-System Patient Flow Simulation Model Applied to Stroke Best Practices Evaluation**

**Esensoy, Ali Vahit**, University of Toronto, ali.esensoy@utoronto.ca

**Carter, Michael**, University of Toronto, mike.carter@utoronto.ca

Cross-sector patient flow model is a system dynamics simulation focused on the flow rates of patients between health system sectors, and the feedback structures around them. It takes a whole-system, strategic perspective, and is designed to produce output that captures the direction and magnitude resulting from policy changes around patient pathways and service levels. We discuss our development process, highlighting the power of using multiple simple models in combination with patient-level data. We will demonstrate the model's use in policy analysis through the evaluation of the impact of Ontario's proposed stroke best practices.

**14:00**

### **Finding a scheme to maximize physicians' satisfaction while minimizing patients' pre-treatment phase**

**Niroumandrad, Nazgol**, Polytechnique Montreal, nazgol.niroumandrad@polymtl.ca

**Lahrichi, Nadia**, Polytechnique Montréal, nadia.lahrichi@polymtl.ca

A medical procedure to a patient often includes sequences of tasks performed by different individuals. Each task is in combination with equipment, supplies and specialized staff. At each step of care, waiting may be needed, which is a challenge to ensure that patient flow will be smooth from one step to the next. Due to insufficient supply and high demand, many patients experience delays in receiving treatment. Minimizing the waiting time for each stage of treatment for patient, achieving a high level of synchronization among patients, staff and resources which ensures that the services can be provided as the arrival of the patient, are some key goals that should be considered in an efficient management system. In cancer facilities and radiotherapy centers, time plays a



significant role. The sooner the disease is recognized and treatment is started, the chance of success in treatment is higher. Thus, there is not much time to waste in the pre-treatment phase. We would like to shorten this phase and make the patient ready to start the treatment in a week. In a hospital, one of the most vital and major resources is the staff. Since physicians play a significant role in providing healthcare services for patients, considerable time consuming can be obtained by focusing on physicians scheduling. The objective of this study is determining a task schedule for physicians in order to increase their satisfaction/preferences while improving the patient flow and decreasing patients pretreatment phase in a radiotherapy center with considering all possible constraints. To reach this objective, we developed an Integer Linear Programming which was a pattern based. In addition, a meta-heuristic approach (Tabu Search) was developed based on physicians' tasks to evaluate the quality of patterns.

14:30

### **Modelling the Benefits of Radiographer Led Discharge**

**Rachuba, Sebastian**, University of Exeter, s.rachuba@exeter.ac.uk

**Pitt, Martin**, University of Exeter, m.pitt@exeter.ac.uk

**Knapp, Karen**, University of Exeter, K.M.Knapp@exeter.ac.uk

Diagnostic imaging services are an essential part of the diagnosis pathway for many patients arriving at hospital emergency departments. Commonly, patients need to be seen again by a doctor or emergency nurse practitioner after radiographic imaging has been conducted to finalise their diagnosis and determine the next stage in their pathway (e.g. admission to hospital, fracture clinic or discharge). Depending on the workload of the doctors and the general activity levels the emergency department, significant waiting times can accrue for this follow-up consultation following imaging. There is evidence that a significant number of patients with appendicular injuries could be discharged by the radiographer directly after imaging, without the need to be seen again by a doctor if no fracture is detected. This could potentially both reduce load on the emergency department and also lessen wait times for patients. Dedicated training for radiographers to improve image interpretation skills could therefore enable earlier discharge for a significant proportion of patients with specific diagnoses. In this study, we model patient pathways through a hospital's accident and emergency department in order to analyse current practice and the resulting wait times and workload. In terms of a what-if analysis we evaluate the possible impact of introducing early discharge by radiographers directly after imaging. Based on a conceptual model we build up a simulation model which has been developed in order to evaluate current practice at a hospital in the SW of the UK. We conduct a simulation study using Simul8 and demonstrate the benefits of a radiographer led discharge in terms of changes in consultants' workloads and reduced waiting times.

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**MB3**

### **Modeling Blood Services 1**

**Chair:** Vasilakis, Christos, *University of Bath*

**Location:** Banque Scotia

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13:30

### **A Generic Simulation Framework for Modelling Blood Inventory: Background, Development, Uses, and Lessons Learned**

**Blake, John**, Dalhousie University, john.blake@dal.ca

Since 2010 we have created simulation models to analyze logistics and inventory questions for Canadian Blood Services and Héma-Québec, Canada's two blood agencies. The original genesis of the framework was a model to evaluate the impact of a shorter shelf-life for red blood cells in Québec. A set of similar models was then developed for each of the distribution regions serviced by Canadian Blood Services (CBS). The size of the task led to the adoption of a generic modelling framework that could be easily ported from location to location. While designed to evaluate the amount and distribution of inventory at the different regions in the CBS network, the generic framework and its use has evolved over time – sometimes in unexpected ways. The models have been used to draw general conclusions about shorter shelf life for red blood cells, to evaluate site-to-site inventory transfers between production centres, and even as a basic framework for short term decision making around platelet production ahead of statutory holidays. While generic or reusable models are often considered the “holy grail” of modelling efforts, examples of their application in health care are rare. In this presentation we discuss a generic approach to modelling a set of similar problems in the blood supply chain. We discuss the good and the bad of a generic approach. Our experience suggests that the issues that influence the usability of “one-off” models – data availability, ownership and on-going maintenance, and linkage with decision makers – also influences the usefulness of generic models. However, the effort to make a generic model portable serendipitously provides an inherent extensibility to respond to new and unforeseen questions and can thus provide unexpected benefits.

14:00

### **A Simulation-Optimization Model for Production Planning in the Blood Supply Chain**

**Osorio, Andres**, University of Southampton, afo1e13@soton.ac.uk

**Brailsford, Sally**, University of Southampton, S.C.Brailsford@soton.ac.uk

**Smith, Honora**, University of Southampton, Honora.Smith@soton.ac.uk

Production planning in the blood supply chain is a complex task. Multiple aspects such as proportionalities of blood groups, shelf life constraints, multiple collection and fractionation alternatives and capacity constraints must be considered. This complexity requires advanced decision-making methodologies. This article presents an integrated simulation-optimisation model to support decisions in production planning. The simulation model is used to represent the flows throughout the supply chain considering collection, production, storing and distribution. On the other hand, an integer linear optimization model running over a rolling horizon planning scheme is proposed to support daily decisions about number of donors required, including blood groups, collection and fractionation methods. The integration of simulation and optimization methodologies enhance the decisions making processes in the studied system. The proposed methodology is evaluated using real information from a blood centre in Colombia. Results show that applying the developed rolling horizon optimization model, a reduction of 16%, 40% and 100% is obtained in the stockout rate for red blood cells, platelets and plasma and cryoprecipitate respectively. In addition, the expired number of units is also reduced by 93% for red blood cells and 45% in the case of platelets. Finally, the number of donors required and the production cost are reduced by about 1.3% using the optimization model proposed.

14:30

### **Development and Validation of a Discrete Event Simulation Model for Planning Hospital Based Provision of Blood for Mass Casualty Events**

**Glasgow, Simon**, Centre for Trauma Sciences, Blizard Institute, Queen Mary University of London, UK

**Vasilakis, Christos**, Centre for Healthcare Innovation & Improvement (CHI2), University of Bath School of Management, UK, c.vasilakis@bath.ac.uk

**Perkins, Zane**, Centre for Trauma Sciences, Blizard Institute, Queen Mary University of London, UK

**Tai, Nigel**, Trauma Clinical and Academic Unit, The Royal London Hospital, Barts Health NHS Trust, London, UK; Academic Department of Military Surgery and Trauma, Royal Centre for Defence Medicine, Birmingham, UK

**Brohi, Karim**, Centre for Trauma Sciences, Blizard Institute, Queen Mary University of London, UK; Trauma Clinical and Academic Unit, The Royal London Hospital, Barts Health NHS Trust, London, UK

Mass casualty events (MCEs) create a surge in severely injured casualties amongst which haemorrhage is a leading cause of preventable mortality. Minimising in-hospital mortality therefore demands adequate blood provision. MCE planning through live or tabletop exercises is disruptive, costly and limited in terms of experimentation. A simulation model offers potential as a practical planning tool for understanding and improving outcomes from these events. For this study we developed a discrete event simulation model of casualty blood provision at a UK major trauma centre following a generic MCE. The model incorporated the delivery of emergency red cells to different cohorts of casualties of varied priority and blood demands. Both treatment and laboratory-based blood group processing systems were modelled. The model was validated using real-life data from the experience at the main responding major trauma centre during the London bombings of 2005. Nearly half of all the transfused casualties on the day of the bombings received their transfusion requirement within one hour. Similarly, our simulation experiments incorporated this same amount within the interquartile range (IQR) of results across all 100 replications performed. Furthermore, there was no significant difference identified between the real world values and the model output for all individual red cell treatment times on paired t-test analysis ( $p$  value = 0.35). The other principal output of interest was individual red cell group stock levels and their rate of consumption following an event, especially in terms of emergency universal donor group O red cells. All post event real world red cell stock levels were found to fall within the IQR produced by the simulation model for each corresponding group. In conclusion, we have designed a simulation model to aid in understanding the transfusion system levers, which potentially have the greatest impact on improving bleeding casualty outcomes following these challenging events.

**MC1****Operation Room Planning and Scheduling 2**Chair: Marques, Inês, *FCUL / ULHT / CMAF-CIO*

Location: BDC

**15:30****Tactical and operational optimization of Operating Theaters: a multi-level decision support system****Buccioli, Matteo**, ORMresearch, [matteo.buccioli@gmail.com](mailto:matteo.buccioli@gmail.com)**Lodi, Andrea**, Università di Bologna, [andrea.lodi@unibo.it](mailto:andrea.lodi@unibo.it)**Tubertini, Paolo**, Università di Bologna, [paolo.tubertini@unibo.it](mailto:paolo.tubertini@unibo.it)

The high costs of health care push national and regional health services as well as local authorities to constantly improve management performances in order to obtain more efficient organization of hospitals activities and provide patients with the best possible care. Tactical and operational planning decisions in Italy are classified as separate problems both in terms of time frame and in terms of decision makers. The tactical planning process is performed, on a monthly or quarterly basis, by the hospital management board and defines the assignment of operating room time slots to medical specialties. The operational planning process is performed, on a weekly basis, by the specialty head physician and defines the scheduling of patients in the assigned operating room time slots. We present a multi-level decision support approach focused on a multispecialty Operating Theater for Emilia-Romagna region. First, we present a tactical optimization model that calculates, on a monthly or quarterly basis, the assignment of operating room time slots to medical specialties in order to minimize: (i) the length of specialties waiting lists weighted by their relative importance for patients safety, (ii) the cost overrun, and (iii) the gap between the negotiated case mix and the final one. The final objective is a tradeoff between (i) and (ii), (iii). Second, we present an operational optimization model that calculates, on a weekly basis, the subset of patients in the waiting list that will be scheduled for surgery treatment in order to: (a) comply with the regional guidelines related to maximum waiting time per pathology, and (b) significantly reduce the violation of time slots (overtime) and the misuse of surgical time (under-utilization). Finally, we present a simulation model that integrates the tactical and the operational optimization models evaluating their effectiveness on a monthly or quarterly planning horizon.

**16:00****Logic-based Benders' Decomposition Approaches with Application to Operating Room Scheduling****Roshanaei, Vahid**, University of Toronto, [vroshana@mie.utoronto.ca](mailto:vroshana@mie.utoronto.ca)**Aleman, Dionne M.**, University of Toronto, [aleman@mie.utoronto.ca](mailto:aleman@mie.utoronto.ca)**Urbach, David**, Toronto General Hospital, [david.urbach@uhn.on.ca](mailto:david.urbach@uhn.on.ca)

We develop three novel logic-based Benders' decomposition (LBBD) cut generation approaches and a cut propagation technique to solve large-scale location-allocation integer programs (IPs). We show that each LBBD can be implemented in four different possible ways, giving rise to 24 distinct LBBD variants with completely different computational performances. LBBDs decompose the IP model into a location- and knapsack-based allocation master problem and multiple packing sub-problems. We illustrate the performance of our LBBDs on the distributed operating room scheduling problem, where patients and operating rooms are collaboratively scheduled across a group of hospitals, and the goal is to select patients with the highest priority scores and schedule them in the current planning horizon, while determining the number of surgical suites and operating rooms required to accommodate the schedule at minimum cost. We quantitatively demonstrate that the new Benders' cuts, cut propagation, and implementation can individually or collectively yield a computational time impact of at least one order of magnitude. We also demonstrate that our LBBDs are faster than IP+Gurobi and can find optimal solutions when IP+Gurobi cannot.

**16:30****A surgical case assignment problem in a block scheduling strategy****Marques, Inês**, FCUL / ULHT / CMAF-CIO, [ines.marques@fc.ul.pt](mailto:ines.marques@fc.ul.pt)**Captivo, M. Eugénia**, FCUL / CMAF-CIO, [mecaptivo@fc.ul.pt](mailto:mecaptivo@fc.ul.pt)

An adequate access to healthcare is one of the strategic axes considered in the Portuguese National Health Plan (PNHP). The strategic integration of the PNHP seeks to ensure the best performance and adequacy of care which maximize the use of resources, quality, equity and access. The demand for surgical care in Portugal tends to grow continuously ever since a systematic measurement was introduced. Hospitals are forced to make the most appropriate use of available resources in order to provide timely care to surgical requests. This work emerges from a close collaboration with the Administration of a publicly funded Portuguese hospital. This hospital has a central operating theatre with a large number of operating rooms shared by several specialties. The operating room time is pre-allocated to specialties (master surgery schedule) and each specialty schedules surgeries to its allocated time block and day (block scheduling strategy). In advance scheduling, also referred to as surgical case

assignment problem (SCAP), patients waiting for surgery (elective patients) are assigned to an operating room and a day in a weekly planning horizon. Several versions for this particular SCAP are formulated in (mixed) integer programming: from the Administration's intention up to the surgeon's current practice. In preliminary results using hospital data, Cplex provided a feasible solution with a gap smaller than 1% in negligible time.

## MC2

### Healthcare Planning 2

**Chair:** Ferreira de Oliveira, Mario Jorge, *Federal University of Rio de Janeiro* **Location:** EY

15:30

#### MRI Capacity Assessment in Ontario: A Wait Times Estimation Model

**Vahid, Saba**, Cancer Care Ontario, saba.vahid@cancercare.on.ca

**Esensoy, Ali Vahit**, Cancer Care Ontario, alivahit.esensoy@cancercare.on.ca

**Norton, Jonathan**, Cancer Care Ontario, jonathan.norton@cancercare.on.ca

**Mujtaba, Zain**, Ontario Ministry of Health and Long Term Care, zain.mujtaba@ontario.ca

**Dang, Jason**, Cancer Care Ontario, jason.dang@cancercare.on.ca

Saba Vahid, Methodologist, Analytics and Informatics, Cancer Care Ontario AliVahit Esensoy, Acting Senior Manager, Analytics and Informatics, Cancer Care Ontario Jonathan Norton, Senior Team Lead, Access To Care Informatics, Cancer Care Ontario Zain Mujtaba, Implementation Lead, Health System Funding and Quality, Ontario Ministry of Health and Long Term Care Jason Dang, Senior Data Analyst, Analytics and Informatics, Cancer Care Ontario Managing wait times for MRI is part of the Ontario government's strategy to transform healthcare in the province. In this project, an MRI capacity assessment model at the regional level was delivered to the Ministry of Health and Long term Care (MOHLTC). The tool provides MRI demand forecasts based on historical data from the Wait Times Information System (WTIS) in Ontario. Time series forecasting was used to produce regional level demand forecasts. In addition, a wait times estimation module was developed using multivariate linear regression to support the MOHLTC in assessing incoming funding requests based on their estimated impact on regional wait times. Finally, non-linear programming was used to recommend optimal regional funding levels to reach provincial wait time targets. This interactive model allows MOHLTC to investigate different funding policies, such as the wait times impact of blitz versus sustained funding.

16:00

#### A Rolling Horizon Approach to Forecast Emergency Department Patient Arrivals

**Sharif, Azaz**, Western University, asharif9@uwo.ca

**Stanford, David**, Statistical & Actuarial Sciences, Western University, stanford@stats.uwo.ca

**Zaric, Gregory**, Management Science, Ivey School of Business, Western University, gzaric@ivey.uwo.ca

The mismatch between the demand for ED services and the available resources have direct and indirect negative consequences, such as long wait times, overcrowding, poor patient outcomes, and productivity loss. Moreover, ED physician pay in some jurisdictions reflects pay-for-performance contracts based on operational benchmarks. To assist in capacity planning and meeting these benchmarks, we built a forecasting model to produce short-term forecasts of ED arrivals. The variability in patient presentation rates and relative allocation of resources require the need for separate models for high and low acuity patients. We used regression and time series techniques to model total ED arrivals as well as separate forecasts for high (resuscitation, emergent) and low (urgent, less-urgent, non-urgent) acuity patients. Several accuracy measures have been calculated and compared to validate our forecasting models. We advocate the use of the rolling horizon approach to accurately forecast ED patient arrivals. Our analysis provides ED managers with valuable insight to efficiently allocate ED resources.

16:30

#### A characterization of the last 20 years of Operations Research on Hospital Admission Systems

**Ferreira de Oliveira, Mario Jorge**, Federal University of Rio de Janeiro, mario\_jo@po.coppe.ufrj.br

**Teixeira, Ana Paula B.**, University of Trás-os-Montes e Alto Douro, ateixeir@utad.pt

This paper uses a collaborative platform, produced by the authors that enables one to show an updated review of Hospital Admission Systems (HAS) and outline an overview of the subject, based upon articles published in the last six decades. The main characteristics of Operational Research (OR) as applied to HAS within the 1995–2015 period are described and analysed. The information contained in relevant publications on this theme is catalogued in accordance with specific key elements previously chosen; a database containing this information is built. Moreover, the progresses on OR technics applied to HAS on the period under concern are evaluated, chiefly in terms of the related applications and their practical implementation. The goal is to provide an insight on the developments of OR technics applied to HAS over the last years and point out new pathways for the near future.

**MC3****Modeling Blood Services (Blood) - 2****Chair:** Yalcindag, Semih , *HEC Montreal***Location:** Banque Scotia**15:30****Time Dependent Waiting Time Computation at Dutch Blood Collection Sites****van Brummelen, Sem**, University of Twente, s.p.j.vanbrummelen@utwente.nl**de Kort, Wim**, Sanquin Research, w.dekort@sanquin.nl**van Dijk, Nico**, University of Twente, n.m.vandijk@utwente.nl

The Dutch blood bank, Sanquin, collects blood from donors on a non-remunerated basis. It is therefore important to keep waiting times as short as possible. Standard analytic models to calculate waiting times use some form of steady state distribution. If arrivals are nicely spread out over the day, this would be reasonably justified. But, as Dutch blood collection sites allow free walk-ins, the arrival process of donors is highly time dependent. Peaks in arrival patterns show up early in the morning, around noon and just before dinner time. Accurately approximating waiting times is especially important during these peak times. A transient rather than steady state approach is therefore required. To closely approximate the waiting times and queue length distributions in time dependent tandem queues, a method that splits the opening hours of the collection sites into short intervals is proposed. Within these intervals we assume arrival and service rates to be constant. An iterative algorithm is developed based on Continuous Time Markov Chains. The algorithm starts with some probability distribution of donors when the collection session starts, i.e. donors that arrived before the collection session started. The approximate algorithm computes the probability distribution of the donors at each phase of the collection process at any given time during the collection session. This enables us to compute various performance measures that are of interest to Sanquin, including queue length distributions, average waiting time and probability of no queue upon arrival of a donor.

**16:00****Balancing the Production of Blood Bags from Donation through Appointment Scheduling****Baş, Seda**, Yeditepe University, seda.bas@yeditepe.edu.tr**Carello, Giuliana**, Politecnico di Milano, carello@elet.polimi.it**Lanzarone, Ettore**, CNR-IMATI, etторе@mi.imati.cnr.it**Ocak, Zeynep**, Yeditepe University, zocak@yeditepe.edu.tr**Yalçındağ, Semih**, HEC Montréal and CIRRELT, semih.yalcindag@cirrelt.net

Blood is fundamental in several care treatments and surgeries, and plays a crucial role in the healthcare system. It is a limited resource as it can be produced only by donors and its shelf life is short. Blood Donation (BD) system aims at providing an adequate supply of blood bags to transfusion centers and hospitals. Its main phases are blood collection, screening, storage, distribution and utilization. An effective collection of blood bags from donors, through a suitable scheduling of donations, is fundamental for adequately feeding the entire BD system and optimizing blood usage. Indeed, blood collection may represent the bottleneck of the whole BD. Despite its relevance, to the best of our knowledge, donor scheduling is only marginally addressed in the literature, whereas a high number of papers deal with blood storage and distribution. We address an appointment scheduling problem for the donations in a blood collection center, with the goal of balancing the production of the different blood products among days, in order to provide a quite constant feeding of the BD system. We consider both booking donors and donors arriving at the center without reservation. The proposed approach consists of pre-allocating donation slots for booking donors, which are then used by the call center for scheduling real donation appointments. The pre-allocation is then refreshed at fixed frequency to account for the newly scheduled appointments. The pre-allocation problem is modeled as an integer linear programming model. The approach has been applied to the real case of the Milan Department of the Associazione Volontari Italiani Sangue (AVIS), one of the main BD associations in Italy. Results on small examples based on this real case validate the approach and confirm its applicability and effectiveness. Keywords: Blood Donation System; Donor Appointment Scheduling; Balancing Blood Production; Integer Linear Programming Model.

## Tuesday

<b>09:00 -10:00</b>	<b>Tutorial 1</b>	Room: BDC
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Chair: Sally Brailsford

**Eric Demeulemeester**

Scheduling Patients at the UZ Leuven

<b>10:00 -10:30</b>	<b>Coffee Break</b>	Room: Investissement Québec
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<b>10:30 -12:00</b>	<b>Session 3</b>
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**TuB1-Operating Room Planning and Scheduling 3 ORP3**

Chair: Bernardetta Addis  
Room: BDC

**Saeedeh Ketabi**

Surgical Scheduling to Smooth Demand for Resources

**Michael Samudra**

Is Overtime Always a Relevant Performance Measure in Healthcare?

**Bernardetta Addis**

Medium term surgery scheduling with patient release dates

**TuB2-Healthcare Planning 3 HCP3**

Chair: Roberto Aringhieri  
Room: EY

**Henni Tenhunen**

Disruptive Opportunities of Non-Invasive Prenatal Testing (NIPT) in Maternal and Natal Health Services Management

**Luca Grieco**

Informing Decisions on the Provision of Protective Suits For Use in Decontaminating Patients Exposed to Hazardous Substances

**Emmanuel Ochola**

Operations research in the eyes of a Subsaharan African faith based hospital

**TuB3-Patient Scheduling 1 PSch1**

Chair: Ettore Lanzarone  
Room: Banque Scotia

**Maartje van de Vrugt**

Static and Dynamic Appointment Scheduling to Meet Access Time Norms

**Lara Wiesche**

Strategies for Interday Appointment Scheduling

**Nardo Borgman**

Appointment Scheduling at a Radiology Department with Unscheduled arrivals and reprioritization

<b>12:00 -13:30</b>	<b>Lunch</b>	Room: Investissement Québec and Atrium
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<b>13:30-15:00</b>	<b>Panel Discussion</b>	Room: BDC
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**Education Challenges in ORAHS/Health Systems Engineering**

**Michael W. Carter (chair)**, University of Toronto

**Sharon Johnson (moderator)**, Worcester Polytechnic Institute

**Erwin Hans**, University of Twente

**Nadia Lahrichi (moderator)**, Polytechnique Montréal

**Christos Vasilakis**, University of Bath

<b>15:00 -16:00</b>	<b>Poster Session</b>	Room: Investissement Québec
	<b>Poster Display</b>	

**Inês Marques**

An Efficient Decomposition Approach for Operating Room Scheduling

**Marianna Frangeskou**

Combining Organizational Routine Theory with Simulation Modelling: Applications to Healthcare Quality Improvement

**Antoine Legrain**

Online Stochastic Optimization of Radiotherapy Patient Scheduling

**Nadia Lahrichi**

Analysis and optimization of nursing assignment for homecare services delivery

**Mehdi Mahnam**

A novel heuristic algorithm to Volumetric Modulated Arc Therapy (VMAT) treatment planning problem

**Dorval, Valérie**

Planning and scheduling of surgical activities taking post-surgical capacity into account

<b>16:00 -17:30</b>	<b>Session 4</b>		
	<b>TuD1-Operation Room Planning and Scheduling 4 ORP4</b>	<b>TuD2-Healthcare Planning 4 HCP4</b>	<b>TuD3-Disease Modeling and Policy 1 DMP1</b>
	Chair: Erwin Hans Room: BDC	Chair: Franklin Dexter Room: EY	Chair: Martin L. Puterman Room: Banque Scotia
	<b>Nara Barros</b> A Master Surgery Scheduling Problem in a Private Hospital	<b>Sally Brailsford</b> Understanding Care Pathways for Frail Older People: From Mapping to Modelling	<b>Hootan Kamran Habibkhani</b> Predictive Capabilities in Hierarchical Node-Based Clustering of Flu Time Series
	<b>Paolo Landa</b> Bed leveling of a surgery Department using Variable Neighborhood Search	<b>Katariina Silander</b> Core Capabilities Related to Modularization in Health Care Service Design	<b>Leslie Anne Campbell</b> Managing the Additional Demand for Colonoscopy Services following the Introduction of Average Risk Colorectal Cancer Screening: A Comparison of Two Strategies
	<b>Erwin Hans</b> Development of a Benchmark Set and Instance Classification System for Surgery Scheduling	<b>Franklin Dexter</b> E-mail as Appropriate Method of Communication for Decision-Maker Obtaining Advice from Expert for Operational Research Implementation	<b>Martin L. Puterman</b> Improving Access to Cancer Treatment

**TuA**

**Tutorial 1 - Eric Demeulemeester**

**Chair:** Brailsford, Sally, *University of Southampton*

**Location:** BDC

**09:00**

**Scheduling patients at the UZ Leuven**

**Demeulemeester, Erik**, KU Leuven, Erik.Demeulemeester@kuleuven.be

In many hospitals there are patients who receive surgery later than what is medically advised. In one of Europe's largest hospitals, the UZ Leuven, this is the case for approximately every third patient. Serving patients late is a problem as they might consequently be exposed to an increased health risk. In order to improve the current situation, the lateness of patients had to be quantified and the responsible mechanism, the patient scheduling process, better understood. Drawing from this understanding, we implemented and tested different patient scheduling methods using a discrete event simulation model. In order to get a realistic test environment, we tried to avoid making any assumptions. Instead we investigated and modeled all the mechanisms that we found to have an important impact on the way patients are scheduled and served at the hospital in reality. We found that it is important to model the non-elective to OR allocation mechanisms in place and, additionally, also to include elective rescheduling. Modeling rescheduling ensures that OR related performance metrics, such as overtime, will only loosely depend on the chosen patient scheduling method. We also found that capacity considerations should guide both patient scheduling and replanning related decision making. This is the case as those scheduling strategies that ensure that OR capacity is efficiently used will also result in a high number of patients served within their medically advised time limit. An efficient use of OR capacity can be achieved, for instance, by serving patients first come, first served. As applying first come, first serve might not always be possible in a real setting, it is important to allow for patient replanning.

**TuB1**

**Operating Room Planning and Scheduling 3**

**Chair:** Addis, Bernardetta, *Université de Lorraine*

**Location:** BDC

**10:30**

**Surgical Scheduling to Smooth Demand for Resources**

**Ketabi, Saeedeh**, University of Isfahan, sketabi@yahoo.com

**Carter, Michael**, University of Toronto, mike.carter@utoronto.ca

**Liu, Tian Mu**, , liutianmu@gmail.com

With growing demand for healthcare resources, pressure on efficient usage of available bed capacity is increasing. Peaks in bed demand are due to variability in admissions and lengths-of-stay. With a balanced schedule in elective surgeries, peak traffic is levelled across the week, hence, reducing overcrowding without turning away any patients or increasing bed capacity. This study presents a two phase approach for scheduling the surgeries which has been implemented in Hamilton Health Sciences in Ontario, Canada. In the first phase, a Monte Carlo simulation type model is applied to estimate the patient demand for beds in the hospital during a typical week. The second phase involves running an integer programming model to minimize the required beds for elective inpatients admitted for surgery to the hospital, by changing the day of surgery blocks. This demonstrates the opportunities for smoothing the expected patient demand for beds by adjusting OR schedule. This decision is made at the tactical level. The demands for different surgeries have been estimated based on a two year historical data and the integer programming model has been solved using GAMS/CoinBonmin MINLP Solver. The optimal schedule reduces the demand for beds between 7% on Fridays and 69% on Mondays. The model can be extended to cover the demand for other resources such ICU beds, too.

**11:00**

**Is overtime always a relevant performance measure in healthcare?**

**Samudra, Michael**, KU Leuven, samudra@kuleuven.be

**Demeulemeester, Erik**, KU Leuven, Erik.Demeulemeester@kuleuven.be

**Cardoen, Brecht**, Vlerick Business School, Brecht.Cardoen@vlerick.com

Overtime is in the inpatient scheduling literature one of the most frequently used performance measurements. This is the case as: (1) it is in reality an important cost factor in hospitals and (2) as a performance measure it easily works together with many operations research methods. In this research, we are trying to determine whether there are cases when overtime, and other operating room related performance measures, may not be



entirely applicable to real inpatient scheduling problems. This is an important question for both researchers and practitioners working on inpatient scheduling. For researchers it is important to understand whether overtime, given their setting, can be included into the objective of their method. Also for practitioners it is important as they try to identify methods from the literature that apply to their setting. In order to tackle this question we use: (1) a very detailed simulation model of a real hospital operating room department and (2) the results of an analysis of a real setting. Using simulation, we found that the patient scheduling methods we tested did not significantly affect overtime. Using data analysis, at this stage of our research, we think that the strongest determinant of overtime is the surgery duration estimation error whereas other relevant factors are emergency arrivals and surgery rescheduling. Those results suggest that, in an inpatient surgery scheduling setting, caution should be applied whenever overtime is used as an optimization criteria.

11:30

### Medium term surgery scheduling with patient release dates

**Addis, Bernardetta**, LORIA - Universite de Lorraine, bernardetta.addis@univ-lorraine.fr

**Carello, Giuliana**, Dipartimento di Elettronica, Informatica e Bioingegneria - Politecnico di Milano, giuliana.carello@polimi.it

**Tanfani, Elena**, Department of Economics and Quantitative Methods University of Genova, etanfani@economia.unige.it

This work deals with the Advance Scheduling Problem, which is a key problem in operating theatre planning and in surgery wards managing. The problem consists in determining the set of patients to be operated on and their scheduling over a given planning horizon. We consider an elective waiting list: each patient in the waiting list is characterized by a waiting time, a surgery duration and an urgency level. Based on his/her urgency level, a maximum waiting time before treatment is computed for each patient (deadline). We consider a medium term planning horizon up to three months. Therefore, we also consider new elective patients who join the waiting list during the planning horizon. New patients are characterized, as those already in the list, by an urgency level, a surgery duration and a deadline. Furthermore, a release date is given, i.e. the date in which the patient is registered in the waiting list. The set of operating blocks available in the planning horizon is given, each characterized by a surgery time capacity. The aim is to provide the best possible quality of service from the patient point of view. This means that the surgery must be performed before deteriorating patient clinical condition and possibly keeping the waiting time as small as possible. Thus the objective function accounts for waiting time and tardiness of patients. Different MILP formulations and MILP based heuristics are proposed. All the proposed methods are tested and compared on a set of real-life based instances. Their behavior, with respect to both computational time and quality of the obtained solutions, is evaluated. The impact of planning horizon length and number of blocks is analyzed.

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TuB2

## Healthcare Planning 3

**Chair:** Aringhieri, Roberto, *Università degli Studi di Torino*

**Location:** EY

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10:30

### Disruptive Opportunities of Non-Invasive Prenatal Testing (NIPT) in Maternal and Natal Health Services Management

**Tenhunen, Henni**, Aalto University, henni.tenhunen@aalto.fi

**Reijonsaari, Karita**, Aalto University, karita.reijonsaari@aalto.fi

Background: Non-invasive prenatal testing (NIPT) based on next-generation sequencing of cell-free DNA in maternal plasma has been adopted in the Hospital District of Helsinki and Uusimaa as an alternative screening method for detection of fetal chromosome aneuploidies for women with increased risk factors. Several private clinics in Finland also offer NIPT. NIPT is a prominent application of personalized medicine (PM), a field using diagnostic tools to identify specific biological markers to provide the right treatment in the right dose to the right patient at the right time. Aims: The purpose of this study is to investigate the disruptive opportunities and challenges of NIPT drawing on theories on disruptive technologies and business model innovation as a lens. The focus is on public and private maternal and natal healthcare service providers. The research problem builds on whether NIPT can disrupt the prenatal testing market and what are the implications regarding e.g. value propositions, channels, and key partnerships. Methods: Literature review and interviews with service providers, NIPT specialists, maternity care nurses and midwives are carried out. Results: Disruptive opportunities of NIPT can be categorized based on, inter alia, the new risk profiles and skill sets required. Examples include increased counseling by geneticists, advanced sample logistics, and the effect of fewer invasive operations. Conclusions: The research provides new insights into utilizing the business opportunities of NIPT and similar PM technologies. The results can also be employed to handle management challenges, as there is a new level of costs and

complexity. Further studies are needed for evaluating potentially disruptive genomic innovations in other healthcare areas.

**11:00**

**Informing decisions on the provision of protective suits for use in decontaminating patients exposed to hazardous substances.**

**Grieco, Luca**, University College London, l.grieco@ucl.ac.uk

**Utley, Martin**, University College London, m.utley@ucl.ac.uk

Events involving release of chemical, biological, radiological or nuclear (CBRN) substances may prompt the need for decontamination procedures in aid of exposed casualties prior to further treatment. Powered Respirator Protective Suits are needed by healthcare workers to perform such procedures in order to avoid direct contact with contaminants. In collaboration with representatives of the UK Government Department of Health and NHS England, we developed an analytical framework to determine the provision of protective suits required by Ambulance Services and Emergency Departments across England if they are to have an accepted degree of resilience to locally identified hazards. Given the different nature of the processes characterising decontamination procedures, the two types of healthcare services were treated separately. Ambulance Services reach the scene of an event and face a group of contaminated people needing treatment, thus a simpler multiplicative clearing model linking the expected number of casualties to the needed number of protective suits was built. Emergency Departments receive contaminated people at a certain rate (varying with time), usually upon manifestation of symptoms, therefore requiring a more complex model based on queueing theory results and assuming a time-varying patient arrival rate. We will describe the framework and how it has been used in conjunction with information in the public domain and expert opinion to inform recommendations on Emergency Department and Ambulance Service holdings.

**11:30**

**Operations research in the eyes of a Sub-Saharan African faith based hospital**

**Ochola, Emmanuel**, St-Mary's Lacor Hospital, ayiga33@hotmail.com

**Ogwang, Martin**, St-Mary's Lacor Hospital

**Odong, Emintone**

**Corti, Dominique**

**Opira, Cyprian**

Many health units, particularly faith based hospitals in Sub-Saharan Africa tend to be engulfed in patient care with minimal time for reflective work, given the high burden of infectious and non infectious diseases, generally poor and underfunded health care system, difficult working conditions and limited community reach. We present the case of St. Mary's Hospital Lacor, a faith based Hospital that started in 1959, and importantly founded by an Italian doctor and his Canadian wife. It underwent tumultuous times of wars with its effects, epidemics like HIV, TB and Ebola, death of founders, and reducing funding. It also underwent formation of local capacity in care, leadership and research. We cite a few recent examples of research in the hospital and its context, showing particularly one focused on health trends in post conflict Northern Uganda that informed the strategic plan and the potential increase of user fees, and an operations research into the analysing the health care processes for the management of Tuberculosis starting from the time the patient arrives in the hospital until they are followed up in the community, with the purpose of improving the process. The need for research in the context of busy African hospital contexts, the opportunities, and the challenges of conducting locally relevant and informative research in such contexts is discussed, stressing the need for increased funding and collaboration.

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**TuB3**

**Patient Scheduling 1**

**Chair:** Lanzarone, Ettore, *CNR-IMATI*

**Location:** Banque Scotia

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**10:30**

**Static and Dynamic Appointment Scheduling to Meet Access Time Norms**

**van de Vrugt, Maartje**, University of Twente, n.m.vandevrugt@utwente.nl

**Laan, Corine**, University of Twente, c.m.laan@utwente.nl

**Boucherie, Richard J.**, University of Twente, r.j.boucherie@utwente.nl

Appointment scheduling systems for outpatient clinics have great influence on efficiency and timely access to health care services. In the Netherlands, outpatient clinics have to comply with national access time norms. The number of new patients per week typically fluctuates throughout the year, and capacity at the clinic varies because doctors have other obligations than the outpatient clinic. Most outpatient clinics use tactical appointment

schedules in which capacity is reserved for each patient type. Due to the varying supply and demand, overbooking is often unavoidable to provide patients appointments within the access time norms. Overbooking may result in doctors working in overtime, and large waiting times for patients. We optimize the tactical appointment schedule with respect to access time by invoking a Mixed Integer Program. Additionally, we introduce flexible scheduling methodologies to cope with the varying demand at the clinic, and optimally allocate the flexible capacity by means of Markov Decision Theory. We apply the methodology to a case study of the Surgical outpatient clinic of the Jeroen Bosch Hospital, a large Dutch teaching hospital facing the above mentioned problems. Numerical results from a Discrete Event Simulation provide insights to the improvements and the benefits of flexible scheduling.

**11:00**

### **Strategies for Interday Appointment Scheduling**

**Wiesche, Lara**, Ruhr University Bochum - Chair of Management, esp. Operations Research, [lara.wiesche@rub.de](mailto:lara.wiesche@rub.de)

**Schacht, Matthias**, Ruhr University Bochum - Chair of Management, esp. Operations Research, [matthias.schacht@rub.de](mailto:matthias.schacht@rub.de)

**Werners, Brigitte**, Ruhr University Bochum - Chair of Management, esp. Operations Research, [or@rub.de](mailto:or@rub.de)

**Weltermann, Birgitta**, Essen University Hospital - Institute for General Medicine, [birgitta.weltermann@uk-essen.de](mailto:birgitta.weltermann@uk-essen.de)

When faced with a medical problem, patients often contact their primary care physicians first. In primary care mainly two types of patient requests exist: urgent or same-day appointments and prescheduled appointments which are booked in advance. How many and where to schedule time slots for prescheduled appointments influence direct and indirect waiting times for patients, the number of urgent overflow patients and the utilization of doctors. The number of patient requests differs significantly between different seasons, week days and daytime. The challenge is to match capacity with patient requests and provide as little as possible prescheduled time slots to provide as many same-day appointments as possible during regular working hours while ensuring comfortable appointments. Deciding on the amount of appointment slots has not yet been focused on in literature. We developed a multi-criteria MILP model that determines the number of prescheduled appointments a physician should plan for in a workday. Appointment schedules are regularly influenced by uncertain demands due to amount of acute patients, interarrival times and treatment durations. Consequently, the performance of an appointment system depends on various uncertain parameters. Based on an exemplary case study, we show how appointment slot allocation influences different criteria and how to find good compromise solutions.

**11:30**

### **Appointment Scheduling at a Radiology Department with Unscheduled arrivals and reprioritization**

**Borgman, Nardo**, University of Twente, [n.j.borgman@utwente.nl](mailto:n.j.borgman@utwente.nl)

**Vliegen, Ingrid M. H.**, University of Twente, [i.m.h.vliegen@utwente.nl](mailto:i.m.h.vliegen@utwente.nl)

**Boucherie, Richard J.**, University of Twente, [r.j.boucherie@utwente.nl](mailto:r.j.boucherie@utwente.nl)

**Hans, Erwin W.**, University of Twente, [e.w.hans@utwente.nl](mailto:e.w.hans@utwente.nl)

Radiology departments offer services to other hospital departments, as well as to outside health care providers (e.g., primary care physicians). Radiology resources herein are often highly utilized. One of these resource types is CT scanners, which are the focus of this study. CT scanners receive two types of patients: outpatients that arrive via appointments, and (unscheduled) inpatients from both the emergency department and wards. Of these unscheduled requests, some patients require immediate attention, and should be diagnosed as soon as possible, while others are urgent but may wait for some time. These urgent patients however must be seen within a given time frame. In this paper, we investigate the effect of an offered appointment schedule on the waiting time for scheduled patients, as well as lateness for unscheduled patients of different urgency categories. The radiology department is modelled as a discrete time (slotted) queuing model. Herein a slot corresponds to a single (appointment) slot during which patients are diagnosed. Using computer simulation we heuristically evaluate and search for appointment schedules that minimize patient waiting time. This is done using data of a Dutch hospital's radiology department. Preliminary results of this approach show that scheduled patients' waiting times may be reduced compared to currently used schedules, while unscheduled patients may still be diagnosed within the stated time windows.

**TuC**                    **Panel Discussion**  
**Location:** BDC

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**13:30**                    **Education Challenges in ORAHS/Health Systems Engineering**

**Carter, Michael W. (chair)**, University of Toronto, mike.carter@utoronto.ca

**Sharon Johnson (moderator)**, Worcester Polytechnic Institute, sharon@wpi.edu

**Hans, Erwin W.**, University of Twente, e.w.hans@utwente.nl

**Lahrichi, Nadia**, Polytechnique Montréal, nadia.lahrichi@polymtl.ca

**Vasilakis, Christos**, University of Bath, c.vasilakis@bath.ac.uk

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**Poster**                    **Poster Display**  
**Location:** Investissement Québec

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**15:00**                    **An Efficient Decomposition Approach for Operating Room Scheduling**

**Marques, Inês**, FCUL / ULHT / CMAF-CIO, ines.marques@fc.ul.pt

We address the scheduling of elective surgeries at a central university hospital. Surgeries are selected from a large waiting list being assigned intervention dates and operating rooms according to different priority levels and while meeting constraints related to room, surgeons' availability and changeover requirements. The objective is to maximize the total surgical time. In the context of operating room planning and scheduling, we follow a mixed open/block strategy in the sense that any surgery can be assigned to a room but once the daily specialty has been selected, the OR is closed for surgeries belonging to other specialties. We also tackle the strategic, tactical and some aspects of the operational level simultaneously, which has never been done to the best of our knowledge. Previous work dealing with the same problem has shown that a full-space discrete-time formulation is unable to find good quality solutions when dealing with over 2k surgeries. We now propose a two-level decomposition algorithm featuring: (i) an upper-level integer programming model that is a relaxation of a full-space continuous-time scheduling model; (ii) a lower-level, mixed-integer linear programming constrained scheduling model to synchronize surgeons operating in different rooms on a given day. Both models are derived from Generalized Disjunctive Programming using preferably the convex-hull reformulation so as to generate the most efficient set of constraints. Results from a set of real-life instances from the literature have shown that the upper level surgical assignments are rarely found infeasible by the lower level model, meaning that the detailed schedule typically features the planned surgeries. Overall, all weekly schedules with about 150 surgeries were within 1.8% global optimality. Compared to previous optimization approaches that have rounded up surgical times to multiples of 15 min, improvements of 5.1% in occupation rate and 4.6% in number of surgeries performed, were obtained.

**15:00**                    **Combining Organizational Routine Theory with Simulation Modelling: Applications to Healthcare Quality Improvement**

**Frangeskou, Marianna**, University of Bath School of Management, UK marianna.frangeskou@gmail.com

This study discusses the potential for deploying a novel approach to systems modelling and simulation in support of Quality improvement (QI). Specifically we modify Deming's seminal PDSA (Plan, Do, Study, Act) approach by incorporating computer simulation modelling, that is itself informed by the theory of organizational routines. We call this PDSimA.QI initiatives, those systematic actions and methods intended to improve care processes and health outcomes for patients, are simple in concept but in practice the substantial complexity to deal with in healthcare systems in addition to time, financial and ethical pressures can overwhelm even the most established approaches. One suggested way of overcoming these challenges is to support QI initiatives with systems modelling and computer simulation. Equally, traditional modelling methods have been criticised for being inefficient in capturing the 'reality' of those (healthcare) process they aim to improve. In our approach we draw on the theory of organizational routines to develop a richer and, hopefully, more insightful model of observed healthcare practice. Routines theory suggests that processes are generative systems that consist of both

idealised routines (i.e. how things should be, the ostensive aspect) and their actual performance (i.e. the performative aspect). The overall research design is divided in two phases. Initially, two PDSimA QI interventions will be conducted at a regional district hospital in the UK (Royal United Hospital of Bath Trust Foundation). The specific focus of these studies is the perceived lower quality of care during off-hours in (a) an acute stroke unit and (b) emergency general surgery. In the second phase, the two case studies will be evaluated in terms of practicability and efficiency from the perspective of healthcare stakeholders and modellers.

**15:00**

**Online Stochastic Optimization of Radiotherapy Patient Scheduling**

**Legrain, Antoine**, Polytechnique Montreal, antoine.legrain@cirrelt.ca

The effective management of a cancer treatment facility for radiation therapy depends mainly on optimizing the use of the linear accelerators. In this project, we schedule patients on these machines taking into account their priority for treatment, the maximum waiting time before the first treatment, and the treatment duration. We collaborate with the Centre Integre de Cancerologie de Laval to determine the best scheduling policy. Furthermore, we integrate the uncertainty related to the arrival of patients at the center. We develop a hybrid method combining stochastic optimization and online optimization to better meet the needs of central planning. We use information on the future arrivals of patients to provide an accurate picture of the expected utilization of resources. Results based on real data show that our method outperforms the policies typically used in treatment centers.

**15:00**

**Analysis and optimization of nursing assignment for homecare services delivery**

**Lahrichi, Nadia**, Polytechnique Montréal, nadia.lahrichi@polymtl.ca

Fiscal year 2015, SRSAD (Service régional de soins à domicile pour malades pulmonaires chroniques) team of Hôpital Maisonneuve-Rosemont (Montréal, Canada) received a new mandate of taking care of 400 homecare patients which requires extra visits and paperwork. To respond adequately to new needs of patients, a reorganization of the services and process of SRSAD was recommended in order to new demands without hiring new nursing professionals. This reorganization included development of new patient classification system (PCS) to calculate required workload for patients and computerized tool of assigning nursing professionals to patients specialized of SRSAD, which has been conducted manually. A 3 month-patient data collection was carried out with 4 homecare nurses and 8 homecare respiratory therapists, every day after nursing professionals came back from their daily homecare visits. New PCS is mix of prototype and scoring method and composed of 3 major criteria and 7 minor criteria. The Criteria were developed at series of meeting with nurses' manger and constantly revised from feedbacks of hands-on professionals. An integer programming optimization model was developed using the PCS' workload calculation results. The mathematical model was tested in CPLEX with actual data of 12 nursing professionals and 300 patients and minimized deviation of workload among the nursing professionals. Management tool based on EXCEL for head nurses with visualization of assignment status was also developed. New mathematical model relieved SRSAD's unequal distribution of nursing workload. Combined with management tool, it can also help nurse administrators generate nursing roster easily, which allows more time for patients care.

**15:00**

**A novel heuristic algorithm to Volumetric Modulated Arc Therapy (VMAT) treatment planning problem**

**Mahnam, Mehdi**, Polytechnique Montréal, mehdi.mahnam@cirrelt.ca

Radiotherapy works by damaging the genetic material within cancerous cells and during this process, normal cells are also affected; therefore, radiation is formed to the geometry shape of the tumor in such a way that it maximizes the dose of radiation to tumors, while simultaneously minimizing the adverse effects of radiations to healthy tissues. Volumetric-Modulated Arc Therapy (VMAT) is a new form of external radiation therapy which incorporates rotation of the beam around the patient's body, while the beam is on. Thus, the treatment planning problem consists of selecting a delivery sequence of beam shapes and determining the optimal dose rate, i.e., intensity, and rotation speed of the beam radiation. In this project, a novel optimization model for the radiation therapy treatment planning in Volumetric-Modulated Arc Therapy (VMAT) is proposed in which, the gantry speed, the dose rate, and the leaf trajectories in the treatment plan are optimized simultaneously. For that purpose, a new mixed integer programming model is proposed and then it is solved by a column-generation-based heuristic algorithm which considers both highly conformal dose distribution and computational efficiency. Moreover, a practical objective function, i.e., the total quadratic dose deviation from prescribed lower and upper bounds, is to be minimized. Finally, we evaluate the quality and efficiency of the method based on a real prostate case.

**15:00**

**Planning and scheduling of surgical activities taking post-surgical capacity into account**

**Dorval, Valérie**, Université Laval, Québec, valerie.dorval.1@ulaval.ca

Access to specialty and subspecialty services is a fundamental concern for the Health and Social Services Department of the province of Québec in order to improve the services dispensed to the population. Facing a constant increase in the demand for cares, the establishments need to: manage effectively their resources (operating theaters, human resources, beds, etc.) and analyse and anticipate the needs.

Surgery services are facing difficulties to meet demand and patients face long waiting times before being treated. In order to improve services, maximum waiting time limits have been established for certain types of surgery, however, adding a constraint to the overloaded system. Finally, the cancellation of surgeries due to lack available beds in intensive care units and wards is considered fairly common, causing a bottleneck in the flow of patients.

In this context, the aim of this project is to propose and validate a procedure for planning surgical activities that takes into account the capacity of post-surgical care units in order to improve bed utilization and thus increase the flow of patients through the system.

My poster presents an overview of how planning and scheduling surgical activities is approached in the literature when it takes the beds availability into account and what is our privileged approach considering our specific context.

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## TuD1      **Operating Room Planning and Scheduling 4**

**Chair:** Hans, Erwin, *University of Twente*

**Location:** BDC

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**16:00**

### **A master surgery scheduling problem in a private hospital**

**Barros, Nara**, FCUL, naramarquesbarros@gmail.com

**Marques, Inês**, FCUL / ULHT / CMAF-CIO, ines.marques@fc.ul.pt

**Captivo, M. Eugénia**, FCUL / CMAF-CIO, mecaptivo@fc.ul.pt

We consider the problem of optimizing the operating room schedule of a central and private hospital in Lisbon, Portugal. It performs about 8,000 surgeries per year, 2% of which are from the emergency service. The hospital has 16 surgical specialties and about 200 surgeons operate in its surgical suite. Its surgical suite has eight rooms, one of which is still closed due to the hospital's workload and capacity. Currently, the surgical suite's regular work schedule is between 8:00am and 11:00pm, from Monday to Friday but extra time is regularly used. Days are divided in two periods: Morning from 8:00am to 3:00pm, and Afternoon from 3:00pm to 11:00pm. The practice of this hospital is to assign rooms, periods and days to surgical teams and/or specialties. Therefore, a room in a period of a day can be assigned to more than one surgical team, and if that happens they should manage the time between them. We had access to the data of all inpatients and outpatients in the last two years and we were asked to study the current master surgical plan: a simple (handmade) and cyclic block schedule, with few changes from week to week. As this task is becoming even more difficult with the increasing of the workload, we proposed ourselves to find a more suitable master surgical schedule with a MILP model. In our view of the problem, an objective concerns the preferences and availability of the surgical team. As most of the surgeons work in other hospitals, some may like/need to have a fixed scheduled time per week, while others may rather have the opportunity to operate in different periods and days. In addition, we would be happy to take this work to the next stage by solving the associated sequencing problem, where surgeries are assigned to blocks.

**16:30**

### **Bed leveling of a surgery Department using Variable Neighbourhood Search**

**Landa, Paolo**, University of Genova, PAOLO.LANDA@YAHOO.IT

**Aringhieri, Roberto**, Dipartimento di Informatica, Università degli Studi di Torino, roberto.aringhieri@unito.it

**Tanfani, Elena**, Department of Economics and Quantitative Methods University of Genova, etanfani@economia.unige.it

This work here presented deals with the problem of Operating room(OR) scheduling over a given planning horizon where a set of elective surgery patients, wait for being admitted to a set of available operating room block times. The objective is to define a patient assignment able to level the post-surgery ward bed occupancies during the days, allowing a regular and smooth workload in the ward, reserving a certain quantity of beds that will be used by emergent patient (usually represented by the concurrent flow of patients from Emergency Department to hospital wards), and improving the quality of care provided to patients (e.g. reducing elective patient cancellations). In this model we exploited the flexibility of the Variable Neighbourhood Search, with the development of a solution framework that can be easily adapted to different hospital operative contexts of OR Scheduling. In order to better validate the framework, preliminary results reported are tested on a set of real based instances of a Surgery Department of a large italian public hospital. Keywords: Operating room planning, bed levelling, Variable Neighbourhood Search.

**17:00 Development of a Benchmark Set and Instance Classification System for Surgery Scheduling**

**Hans, Erwin**, University of Twente, e.w.hans@utwente.nl

**Leeftink, Greanne**, University of Twente, a.g.leeftink@utwente.nl

Numerous benchmark sets exist for combinatorial optimization problems. However, in healthcare scheduling only a few benchmark sets are known, mainly focused on nurse rostering. One of the most studied topics in the healthcare scheduling literature is surgery scheduling, for which there is no widely used benchmark set. An effective benchmark set should be diverse, reflect the real world, contain large instances, and be extendable. This paper proposes a benchmark set for surgery scheduling algorithms, which satisfies these four criteria. Surgery scheduling instances are characterized by their underlying case mix. A case mix describes the volume and properties of all relevant surgery types. For any given case mix, unlimited instances can be generated randomly. As each operating room department has its own case mix, a diverse benchmark set should contain instances based on a variety of case mixes. To identify diverse case mixes, we propose a classification based on the surgery type duration and the coefficient of variation. The case mix classification gives insight into the scheduling complexity and expected performance of algorithms. Furthermore, suitable algorithms for hospitals that have a specific case mix can be developed and evaluated using the benchmark set.

**TuD2 Healthcare Planning 4**

**Chair:** Dexter, Franklin, *University of Iowa*

**Location:** EY

**16:00 Understanding care pathways for frail older people: from mapping to modelling**

**Brailsford, Sally**, University of Southampton, s.c.brailsford@soton.ac.uk

**Taylor, Melinda**, University of Southampton, M.A.Taylor@soton.ac.uk

**Penn, Marion**, University of Southampton, M.L.Penn@soton.ac.uk

**Monks, Tom**, University of Southampton, Thomas.Monks@soton.ac.uk

**Klein, Jonathan**, University of Southampton, J.H.Klein@soton.ac.uk

**Rowley, Ian**, University of Southampton, I.T.Rowley@soton.ac.uk

**Benson, Paul**, Southampton City CCG, Paul.benson@southamptoncityccg.nhs.uk

In the English National Health Service, commissioning organisations (local Clinical Commissioning Groups and the national body NHS England) are responsible for planning and purchasing health care on behalf of their populations from primary, secondary and tertiary care providers. This project was undertaken with Southampton City Clinical Commissioning Group (CCG) and was concerned with the strategic planning of care for frail older people. In common with most developed countries, this patient group is placing increased levels of demand upon already stretched resources. The main researcher (Melinda Taylor) was an academic, but was based within - and employed by - the CCG. The project involved the development of a model of patient flows and capacity bottlenecks across the whole health and care system, including patients' own homes, residential and social care, and the hospital system. Firstly, through around 80 interviews with clinicians, care providers and managers, as well as direct observation and "job shadowing", we developed a visual pathway map of what turned out to be a massively complex system. This map was validated at several stakeholder meetings. A simplified version of this map was then developed into a system dynamics model and used to explore potential scenarios for change. In this talk, we describe the modelling process, discuss some of the challenges and positive outcomes from the project, and present the results for a couple of selected scenarios.

**16:30 Core Capabilities Related to Modularization in Health Care Service Design**

**Silander, Katariina**, Aalto University, HEMA Institute, katariina.silander@aalto.fi

**Peltokorpi, Antti**, Aalto University, antti.peltokorpi@aalto.fi

**Torkki, Paulus**, Aalto University, HEMA Institute, paulus.torkki@aalto.fi

**Kaila, Minna**, University of Helsinki, minna.kaila@helsinki.fi

Background and purpose: Health care design, development and coordination play an important role in both controlling the increasing health care expenditures and enabling more customized services to patients. Modularization and mass customization have been seen as methods to increase patient-oriented care delivery and customization of health care services. The aim of this study is to create a framework of capabilities needed in health care delivery modularization. Methods: The framework is created by systematically reviewing and analyzing previous studies related to modularization in health care delivery and comparing the findings with capabilities that arise from general modularity studies. Findings: The analysis of the identified studies shows that capabilities related to health care modularization can be divided into three categories: i) Capabilities related to categorizing of customers/patients and their needs, ii) Capabilities concerning the processes and categorization of

services and iii) Capabilities concerning organizational issues. The identified capabilities can be linked with the ability to develop and enhance both variety of services and coherence between different service modules and professionals. Conclusions: This study combines general modularity studies with health care modularity studies to identify and categorize main capabilities related to modularization in health care. Most included studies regarded elderly care, thus future research is needed to analyze whether the identified capabilities are present in other primary care areas as well as in secondary and tertiary care. Altogether, this study provides tools to both researchers and health care managers to enhance the development work of health care organizations.

17:00

**E-mail as Appropriate Method of Communication for Decision-Maker Obtaining Advice from Expert for Operational Research Implementation**

**Dexter, Franklin**, University of Iowa, franklin-dexter@uiowa.edu

**Van Swol, Lyn**, University of Wisconsin-Madison, vanswol@wisc.edu

Previously, we reviewed that the odds of a team (i.e., a small operating room management committee) making correct (optimal) decisions for many operating room management problems is very low without study. Decision-makers need to rely on experts. Literature search is the easiest approach, conceptually, to obtaining expert advice. However, we also found in our prior studies that literature search is ineffective for such problems without the decision-maker already knowing the vocabulary. Those findings, together, show that decision-makers' reliance on 1:1 communication with experts is not just typical but necessary. In our new study, we used narrative review of experimental and observational studies, including reanalysis of published data and results, to compare different communication methods between decision-maker(s) and expert(s) for applying analytical methods: e-mail (i.e., asynchronous written communication), face-to-face, video conference, telephone, live electronic chat, and discussion group (e.g., social media). Studies find e-mail to have greater or equivalent effectiveness: 1) ease-of-use across organizational boundaries; 2) convertibility to tasks; 3) asynchronicity (no appointment); 4) no expectation of immediate response; 5) expectation of a response; 6) reduced social loafing; and 7) training significantly increases productivity of use. E-mail advantages apply from decision-makers' perspectives: 1) messages can be carefully constructed (framed) to increase the likelihood of a useful response; 2) response can be read when least distracted; 3) reduced cognitive load; and 4) written text is consistently easier to understand and as effective in changing behavior for factual material. E-mail has significant advantages from experts' perspectives: 1) ability to control credibility cues; 2) titles and degrees in signature line are expected; 3) ability to focus on message construction rather than visual cues; 4) ability to include attachments with details; and 5) written expression(s) of confidence in advice (the best predictor of usage of advice in experimental studies).

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TuD3

**Disease Modeling and Policy 1**

**Chair:** Puterman, Martin L., *Sauder School of Business*

**Location:** Banque Scotia

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16:00

**Predictive capabilities in hierarchical node-based clustering of flu time series**

**Kamran Habibkhani**, Hootan, University of Toronto, hootan.kamran@gmail.com

**Aleman, Dionne M.**, University of Toronto, aleman@mie.utoronto.ca

**Carter, Michael**, University of Toronto, mike.carter@utoronto.ca

**Moore, Kieran**, Queens University, moorek@queensu.ca

Time series are sometimes expected to exhibit local behavior patterns. Depending on the features of signals, a particular clustering may yield the most significant predictive capabilities. We focus on the predictive capabilities that arise from identifying significantly lagged effects between clusters, and use a flu dataset from 103 hospitals across Ontario to identify clustering schemes with maximum predictive capabilities.

16:30

**Managing the Additional Demand for Colonoscopy Services following the Introduction of Average Risk Colorectal Cancer Screening: A Comparison of Two Strategies**

**Campbell, Leslie Anne**, Dalhousie University, leslie.anne.campbell@dal.ca

**Blake, John**, Dalhousie University, john.blake@dal.ca

**Kephart, George**, Dalhousie University, george.kephart@dal.ca

Population-level average risk colorectal cancer screening may be an important strategy for the control of colorectal cancer. However, the introduction of even two-step screening substantially increases the overall demand for colonoscopy services both to provide screening follow-up colonoscopies for positive stool tests as well as for ongoing surveillance. A discrete event simulation model, the Simulation of Cancer Outcomes for Planning Exercises (SCOPE) Model, was constructed to compare the effects of various colorectal cancer



screening decisions on demand for colonoscopy services, crude colorectal cancer incidence, and cumulative colorectal cancer mortality. Total demand for follow-up screening, diagnostic, high-risk screening and surveillance colonoscopy services increased by 33% to 54%, depending on the screening stool test and uptake rate. This additional demand was not offset by reductions in demand for diagnostic colonoscopies due to lower disease incidence with screening. Inadequate colonoscopy resources led to poor outcomes for both average- and high-risk populations. Two strategies aimed at mitigating the additional demand were compared for their effect on colonoscopy services, colorectal cancer incidence and mortality. The first scenario consisted of following up an initial positive stool test with a repeat test prior to referral for colonoscopy. The demand for screening follow-up colonoscopies was reduced by 90%. In the second scenario, selection of a stool test with a higher positivity threshold reduced the demand for screening follow-up colonoscopies by 65%. In both scenarios, many of the benefits of screening were maintained, with reductions in both crude colorectal cancer incidence and cumulative colorectal cancer mortality after 15 years of follow-up. Screening programs may therefore wish to consider strategies to mitigate the additional demand for colonoscopy services to take advantage of the potential benefits of screening without overwhelming colonoscopy services and causing unintended harm.

**17:00**

### **Improving Access to Cancer Treatment**

**Puterman, Martin L.**, Sauder School of Business, UBC, martin.puterman@sauder.ubc.ca  
**Ma, Claire, Weber, Leah, Liu, Emma, Sauré, Antoine, Tyldesley, Scott**

Operations research methods have been used extensively to address challenges facing British Columbia Cancer Agency management when striving to deliver high quality and timely care to cancer patients. Reducing wait times for initial oncologist consultations required accounting for demand variability, the multiplicity of cancer types and urgency levels, oncologist specialization mix and downstream demand generated by initial appointments. Optimization and simulation models showed the impact of managerial levers on relevant performance metrics and produced concrete capacity management recommendations to reduce wait times. A key finding was that without adequate capacity, enhanced appointment scheduling rules had little impact on wait times for first consultation.

# Thursday

**09:00 -10:00** **Tutorial 2** Room: BDC

Chair: Angel Ruiz

**Ettore Lanzarone**

Title: Addressing Uncertainty in Health Care with the Cardinality-Constrained Approach: A Trade-off between Accuracy, Computational Effort, and Interaction with Clinicians

**10:00 -10:30** **Coffee Break** Room: Investissement Québec

**10:30 -12:00** **Session 5**

**ThB1-Emergency Medical Services/Medical Transportatiton 1 EMS1**

Chair: Marion Sabine Rauner  
Room: BDC

**Peter Vanberkel**

Designing Offload Zones to reduce Offload Delay

**Melanie Reuter-Oppermann**

Multicriteria Patient Transportation Planning scheduling with patient release dates

**Marion Sabine Rauner**

A Taxonomy for Health Care Emergency Management: Interlinking Emergency Interventions, Responders, and Equipment/Materials

**ThB2-Performance Evaluation 1 Perf1**

Chair: David Stanford  
Room: EY

**Thomas Franck**

Benchmarking Hospital Geriatric Services using Discrete-Event Simulation

**Azaz Sharif**

New Developments in Minimizing Expected Excess Waiting Time in KPI-based Systems

**David Stanford**

Multi-Class Accumulating Priority Queues with Heterogeneous Servers

**ThB3-Patient Scheduling 2 PSch2**

Chair: Thierry Garaix  
Room: Banque Scotia

**Antoine Legrain**

Stochastic Optimization of the Scheduling of a Radiotherapy Center

**Ingebor Bikker**

Scheduling Appointment Series for Rehabilitation Patients, Taking Future Requests Into Account

**Thierry Garaix**

Proactive On-call Scheduling during a Seasonal Epidemic

**12:00-13:30** **Lunch** Room: Investissement Québec and Atrium

**13:30 -15:00** **Session 6**

**ThC1-Emergency Medical Services/Medical Transportatiton 2 EMS2**

Chair: Yannick Kergosien  
Room: BDC

**Caroline Jagtenberg**

Optimality of the Closest-Idle Policy in Advanced Ambulance Dispatching

**ThC2-Performance Evaluation 2 Perf2**

Chair: Andrea Raith  
Room: EY

**Leonid Churilov**

Risk Adjustment of Stroke Outcomes for Comparing Hospital Performance: A Modelling Perspective

**ThC3-Disease Modeling and Policy 2 DMP2**

Chair: Alexander Rutherford  
Room: Banque Scotia

**Izabela Komenda**

Compliance with National Guidelines for Stroke in Radiology

<b>Pieter van den Berg</b> Incorporating Coverage for Emergency Calls in Scheduling Patient Transportations	<b>Gréanne Loeffink</b> Histopathology Laboratory Operations Analysis and Improvement	<b>Steffen Bayer</b> Stroke Care Modelling in Singapore
<b>Valerie Bélanger</b> A Matheuristic Decomposition Approach to Solve the Dynamic Ambulance Relocation and Pre-Assignment Problem	<b>Andrea Raith</b> Knowledge-based Quality Assessment of Radiotherapy Treatment Plans	<b>Alexander Rutherford</b> UNAIDS 90-90-90 Targets for Reducing HIV Incidence: An Operational Analysis for Vancouver, Canada

<b>15:00 -15:30</b>	<b>Coffee Break</b>	Room: Investissement Québec
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15:30 -17:00	Session 7		
	<b>ThD1-Patient Flow PFlow</b> Chair: Martin Pitt Room: BDC	<b>ThD2-Modeling in Healthcare MoHC</b> Chair: Fermín Mallor Room: EY	<b>ThD3- Regional Health Services RegHS</b> Chair: Jan Vissers Room: Banque Scotia
	<b>Mahsa Keshtkaran</b> Hybrid Simulation Modelling of Arterial Recanalization Treatment Pathways in Acute Stroke	<b>Viviane Gascon</b> A heuristic algorithm for the Capacitated Vehicle Routing Problem with Synchronized Pick-ups and Drop-offs: a case study for medications delivery and supervision in DR Congo	<b>Roberto Aringhieri</b> Designing The Primary Care System In The City Of Turin, Italy, Using Open Data
	<b>Michele Sonnessa</b> A Hybrid Simulation Approach for Improving Patient Flows across Emergency Departments and Hospital Wards	<b>Adele Marchall</b> The Family of Discrete Conditional Phase-Type Distributions for Modelling Patient Outcome and Survival	<b>Catherine Crenn Hebert</b> Perinatal Networks And Healthcare Pathway Optimization in the Ile De France Region: A Challenge For Regional Health Authority.
	<b>Martin Pitt</b> The Visual Representation of Patient Pathways-What's the Best Way to Do It?	<b>Fermín Mallor</b> Modelling the Patient Recovery Process in an Intensive Care unit	<b>Jan Vissers</b> Generic and Specific Modelling of Health Service Provider Networks. Methodology and Application

<b>20:00</b>	<b>Gala Dinner</b>	Le Cabaret du Roy
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**ThA**                      **Tutorial 2 - Ettore Lanzarone**  
**Chair:** Ruiz, Angel, *Université Laval*

**Location:** BDC

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**09:00**                      **Addressing uncertainty in health care with the cardinality-constrained approach: a trade-off between accuracy, computational effort, and interaction with clinicians**

**Lanzarone, Ettore**, CNR-IMATI, [ettore@mi.imati.cnr.it](mailto:ettore@mi.imati.cnr.it)

Uncertainty is a fundamental aspect of several health care optimization problems, which cannot be neglected due to the significant impact it may have both on quality and feasibility of the problem solution. Indeed, high uncertainty is always related to patients' conditions and demands, and the solutions should guarantee a good quality of the service over a usually wide number of possible future realizations. Different approaches have been proposed and applied in the literature to deal with uncertainty in health care problems, which can be mainly classified into stochastic programming, distributionally robust optimization, and robust optimization. Within the robust optimization approaches, the cardinality-constrained approach, introduced by Bertsimas and Sim about 10 years ago, represents a powerful tool that allows a trade-off between the level of robustness and the computational cost of the solution. Moreover, an intuitive modeling of the uncertainty set, which can be understood and tuned by clinicians and planners without any background in operations research, is another advantage of this approach. However, despite its potentialities, this approach has been only marginally applied in the health care sector. Briefly, the cardinality-constrained approach assumes that all of the uncertain parameters belong to an interval around a nominal value, and concentrates the variability of the problem by assuming that in each constraint only a limited number of parameters deviate from the nominal to the maximum value. The tutorial deals with the discussion of the robustness concept in health care optimization and with a detailed description of the cardinality-constrained approach: the methodology is presented and some examples of application to health care are given, e.g., to the assignment problem. Finally, an extension of the approach is outlined, and some remarks and drawbacks to take into account while implementing the approach in the practice are discussed.

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**ThB1**                      **Emergency Medical Services/Medical Transportation 1**  
**Chair:** Rauner, Marion Sabine, *University of Vienna*

**Location:** BDC

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**10:30**                      **Designing Offload Zones to reduce Offload Delay**

**Vanberkel, Peter**, Dalhousie University, [peter.vanberkel@dal.ca](mailto:peter.vanberkel@dal.ca)

**Boucherie, Richard J.**, University of Twente, [r.j.boucherie@utwente.nl](mailto:r.j.boucherie@utwente.nl)

**Laan, Corine**, University of Twente, [c.m.laan@utwente.nl](mailto:c.m.laan@utwente.nl)

Offload delay occurs when the transfer of a patient from an ambulance service to an emergency department is prolonged. Offload delay negatively impacts patient care (e.g. poor pain control, delayed time to antibiotics, etc.) and ambulance coverage by delaying the return of an ambulance to service. In Nova Scotia the 90th percentile of offload delay has increased by a factor of 4 since 2002. The Halifax Infirmary and Dartmouth General Hospital have implemented Offload Zones as a solution to the offload delay problem. The Offload Zone is an area where patients can wait with a paramedic and a nurse allowing the ambulance to return to service immediately. In this talk I will present two studies related to evaluating and (re)designing Offload Zones. The first is a retrospective evaluation of the Offload Zone at the Halifax Infirmary following the Healthcare Failure Modes and Effect Analysis framework. From this study we found that when the Offload Zone was implemented staff behavior changed. In particular, patients arriving by ambulance went from "high priority to admit" to "low priority to admit", since Offload Zone patients wait with a nurse and paramedic. Patients from the waiting room, who are waiting without a health care provider, are admitted instead. This change in priority causes the Offload Zone to "fill-up", leaving nowhere for arriving ambulances to transfer their patients and, hence, the continuation of offload delay. The second study uses a continuous time Markov chain to study this effect. Specifically we identify priority thresholds which 1) ensures the Offload Zone, at a minimum, performs as well as when there is not an Offload Zone and 2) identifies when additional priority reduces offload delay by a negligible amount. Both studies are supporting policy makers in determining the future feasibility of Offload Zones at the Capital District Health Authority.

11:00

### **Multicriteria Patient Transportation Planning**

**Reuter-Oppermann, Melanie**, Karlsruhe Institute of Technology, melanie.reuter@kit.edu

**Mason, Andrew**, University of Auckland, a.mason@auckland.ac.nz

**Raith, Andrea**, University of Auckland, a.raith@auckland.ac.nz

The German Emergency Medical Service (EMS) system is responsible for executing patient transports when a patient needs to be transported in an ambulance to, from or between hospitals while the attendance of an emergency medical technician is necessary. For many EMS regions, a high percentage of transports is known in advance, but short-term requests often need to be handled immediately throughout the day. In this research we want to schedule patient transportation requests and assign them to transportation ambulances. First, we present a corresponding formulation for the patient transportation problem and extend it to a multicriteria formulation. In addition, the possibility of modeling some of the objectives as additional constraints is investigated. In order to solve larger instances in reasonable time, we propose a column-wise neighborhood search. A starting solution is determined by a best insertion heuristic. The solution is expressed as a set of columns with one column basically representing the route of one ambulance. Then, for each column several neighbors are determined by repeatedly adding/removing tasks. Finally, a small ILP is solved for choosing the columns. As sometimes only very few patient transportation requests are known in advance, an online approach is studied that assigns requests to ambulances whenever they become idle. The approach is very close to the current method used in German EMS practice. It considers the current location of the ambulance, the pick-up location as well as a possible look-ahead on future requests when assigning a patient transport to an ambulance. We test our formulations and approaches using a set of randomly generated instances that are based on real data from an EMS region in the southwest of Germany and compare the solutions for the different approaches.

11:30

### **A Taxonomy for Health Care Emergency Management: Interlinking Emergency Interventions, Responders, and Equipment/Materials**

**Rauner, Marion Sabine**, University of Vienna, Austria, marion.rauner@univie.ac.at

**Niessner, Helmut**, University of Vienna, Austria, helmut.niessner@univie.ac.at

**Sasse, Lisa**, University of Vienna, Austria, lisa.sasse@univie.ac.at

**Tomic, Kristina**, University of Vienna, Austria, kristina.tomic@univie.ac.at

For a successful emergency management (EM) it is crucial that all stakeholders, especially health care emergency responders, use the same terminology. For this reason, the team of the University of Vienna, UNIVIE, developed the S-HELP UNIVIE wiki (cf. Figure 1). This is a collaborative platform that provides main glossary terms, definitions, and standards for strategic disaster management. It was implemented for the FP7-EU S-HELP (Securing Health.Emergency. Learning.Planning) project coordinated by Dr. Karen Neville, University College Cork, Ireland which develops a Decision Support (DS) tool for EM (<http://www.fp7-shelp.eu/>). As a next step, we established a skills taxonomy template to interlink emergency interventions/tasks and emergency responders/skills (cf. Figure 2). Furthermore, we provided an overview which emergency interventions/tasks can be covered by EU Civil Protection Modules by incorporating availability, start of operation, self-sufficiency, and operation time. Next, the resource taxonomy template contained the linkage of emergency interventions/tasks and emergency responders/skills to emergency equipment/materials needed. The skills and resource taxonomy templates considered the complex and multi-disciplinary nature of health services in emergency preparedness, response, and recovery. These taxonomies are currently implemented and integrated into the S-HELP Decision Support Tool for emergency responders by University College Cork, Ireland. They are also used for health care responder training. A future improvement step of our taxonomies is the integration of special emergency equipment/materials, responders/skills, and interventions/tasks used in the disaster scenarios (flooding, chemical spill, epidemic). For the interoperability, we will investigate in detail specific main core emergency responders of selected European countries.

## ThB2

## Performance Evaluation 1

Chair: Stanford, David, *University of Western Ontario*

Location: EY

10:30

**Benchmarking Hospital Geriatric Services using Discrete-Event Simulation****Franck, Thomas**, Center for Biomedical and Healthcare Engineering, thomas.franck@emse.fr**Augusto, Vincent**, Center for Biomedical and Healthcare Engineering, CNRS UMS 6158 LIMOS/ROGI Ecole Nationale Supérieure des Mines de Saint Etienne 158 Cours Fauriel, 42023 St Etienne, France, augusto@emse.fr**Xie, Xiaolan**, Center for Biomedical and Healthcare Engineering, CNRS UMS 6158 LIMOS/ROGI Ecole Nationale Supérieure des Mines de Saint Etienne 158 Cours Fauriel, 42023 St Etienne, France. Department of Industrial Engineering and Management Shanghai Jiao Tong University, xie@emse.fr**Gonthier, Régis**, CHU de Saint-Etienne Hôpital la Charité 44 Rue Pointe Cadet 42023 Saint-Étienne, France, regis.gonthier@univ-st-etienne.fr**Achour, Emilie**, CHU de Saint-Etienne Hôpital la Charité 44 Rue Pointe Cadet 42023 Saint-Étienne, France, emilie.achour@univ-st-etienne.fr

The increasing number of geriatric patients is one of the most important problems for the next years. This kind of patients is often dependent and can have difficulties with environment changes so that hospitalization can strongly deteriorate the elderly health state. This study aims at evaluating the added value of integrated care for elderly and focuses on two services of the geriatric department: the Short Stay (Acute Care) and Rehabilitative Care (to prepare the return at home). These services are complementary and a large proportion of patients (approximately 50%) needs to be transferred to the Rehabilitative Care unit after the Short Stay. We propose a benchmark of four University Hospitals in France (Saint-Etienne, Lyon, Grenoble and Clermont-Ferrand) with different configurations of the two services (integrated and separated). In the integrated configuration (Saint-Etienne and Grenoble) both services are located in the same department and the patient keeps the same bed with the same staff (nurses, doctors...). In the separated configuration (Lyon and Clermont-Ferrand) services are independent and may be located in two different wards. According to doctors, integrated services provide the most coherent pathway for the patient but it can be difficult to implement because each hospital has constraints relevant to its territory. For example both separated case studies have a Rehabilitative Care shared with other services of the hospital and cannot be only allocated to the geriatric department. In addition the bed ratio between Short Stay and Rehabilitative Care is different in the studied hospitals. We use Discrete Event Simulation to compare the efficiency of each organization and measure the impact on indicators such as the occupancy, admissions and the length of stay. According to our results, the integrated configuration is the best solution and separated services are too dependent on other departments.

11:00

**New Developments in Minimizing Expected Excess Waiting Time in KPI-based Systems****Stanford, David**, Statistical & Actuarial Sciences, Western University, stanford@stats.uwo.ca**Caron, Richard**, Mathematics & Statistics, U. of Windsor, rcaron@unwindor.ca**Li, Na**, Statistical & Actuarial Sciences, Western U, nli66@uwo.ca**Sharif, Azaz**, Statistical & Actuarial Sciences, Western U, asharif9@uwo.ca

Key Performance Indicators (KPIs) are a measure of service system performance which comprise a delay limit and compliance probability (the chance a patient commences treatment by the delay limit). The primary flaw of a pure KPI approach is that no consideration is given for the consequences of patients whose waiting time exceeds the delay limit. We present an optimization model for such systems which seeks to minimize the weighted average of expected excess waiting time, beyond the treatment time limits, for the various classes. We test the model extensively in an Accumulating Priority Queue (APQ) setting. The Accumulating Priority Queue selects patients for treatment according to a linear priority accumulation function at a rate that depends upon the patient acuity class. It acts as a unifying patient selection discipline, which includes as its extremes the First-come, First-served (FCFS) discipline and the classical priority discipline. At ORAHS 2014, we presented our insights gained from extensive numerical testing. Most notably, when minimizing expected excess waiting time, we found the optimal accumulation rates were almost invariably close to those suggested by a rule of thumb involving accumulation rates in inverse proportion to the delay limits. We now present mathematical bounds on the optimal accumulation rates in the two class case; in particular, we establish that the rule of thumb always acts as an upper bound on the optimal accumulation rate; thereby providing a quick starting point for a recursive method to converge to the true optimal value.

### 11:30 Multi-Class Accumulating Priority Queues with Heterogeneous Servers

**Li, Na**, nli66@uwo.ca

**Stanford, David**, stanford@stats.uwo.ca

Historically, lengthy waiting time problems have been analyzed using classical priority queuing theory. Classical priority queues serve classes of customers according to their pre-assigned priority, meaning that no customer from a given class can be admitted into service when there are customers from classes with higher priority present in the queue. Kleinrock (1964) proposed a queue called "time-dependent priority queue", where customers' pre-assigned priority changes dynamically based on how long they have waited. He suggested that customers accumulate priority according to a linear function of their waiting time in the queue, and the rate at which the customer accumulates priority depends on the customer's class. Since the performance of many queues is specified in terms of tails of waiting time distributions and not only the mean waiting times, Stanford et. al. (2014) derived the waiting time distributions of different priority classes in a single server accumulating priority queue (APQ) subject to Poisson arrivals. However, in practice, often there is more than one server to handle the arriving customers in the waiting lines. Sharif et. al. (2014) obtained the waiting time distributions of different priority classes for a multi-server APQ where the service time distributions are assumed to be exponentially distributed with a common parameter for all classes. Currently, we are developing a more general multi-server model whose service times are exponentially distributed with heterogeneous service rates among different servers. Numerical investigations through simulation are carried out to validate our model.

### ThB3 Patient Scheduling 2

**Chair:** Garaix, Thierry, *Laboratoire Informatique Avignon*

**Location:** Banque Scotia

### 10:30 Stochastic optimization of the scheduling of a radiotherapy center

**Legrain, Antoine**, Polytechnique Montreal, antoine.legrain@cirrelt.ca

**Fortin, Marie-Andrée**, University of Montreal, mfortin.csssl@ssss.gouv.qc.ca

**Lahrichi, Nadia**, Polytechnique Montréal, nadia.lahrichi@polymtl.ca

**Rousseau, Louis-Martin**, Polytechnique Montréal, louis-martin.rousseau@polymtl.ca

**Widmer, Marino**, Université de Fribourg, marino.widmer@unifr.ch

Cancer treatment facilities can improve their efficiency for radiation therapy by optimizing the utilization of the linear accelerators (linacs). We propose a method to schedule patients on such machines taking into account their priority for treatment, the maximum waiting time before the first treatment, the treatment duration, and the preparation of this treatment (dosimetry). At each arrival of a patient, the future workloads of the linacs and the dosimetry are inferred. We propose a genetic algorithm, which schedules future tasks in dosimetry. This approach ensures the beginning of the treatment on time and thus avoids the cancellation of treatment sessions on linacs. Results indicate the improvements of this new procedure.

### 11:00 Scheduling Appointment Series for Rehabilitation Patients, Taking Future Requests Into Account

**Bikker, Ingeborg**, University of Twente, i.a.bikker@utwente.nl

**van der Ploeg, Rein**, Sint Maartenskliniek, r.vanderploeg@maartenskliniek.nl

**van Oosterom, Carolien**, Sint Maartenskliniek, c.vanoosterom@maartenskliniek.nl

**Boucherie, Richard**, University of Twente, r.j.boucherie@utwente.nl

We study an online appointment scheduling problem where arriving patients require a series of appointments at multiple departments that may be simultaneous, in series or both, within a certain access time. This research is motivated by a study of rehabilitation scheduling practices at the Sint Maartenskliniek (the Netherlands). In practice, the prescribed treatments and activities are typically scheduled in the first available time intervals, leaving no room for acute patients who require an appointment series on a short notice. This leads to large access times for acute patients, which has a negative effect on the quality of care and the patients' satisfaction. Our objective is to schedule the appointment series of a patient at the moment of his/her arrival, in such a way that the total number of requests scheduled within their required access time is maximized. We formulate this problem as a Markov Decision Process (MDP), that takes into account the current state of already scheduled appointments, and future arrivals. We develop heuristic policies to obtain approximate solutions. Using simulation, we compare the performance of the MDP to practical and easy-to-use heuristic decision rules.

11:30

### Proactive On-call Scheduling during a Seasonal Epidemic

**Garaix, Thierry**, École Nationale Supérieure des Mines de Saint-Étienne, garaix@emse.fr

**El-rifai, Omar**, École Nationale Supérieure des Mines de Saint-Étienne, el-rifai@emse.fr

**Xie, Xiaolan**, École Nationale Supérieure des Mines de Saint-Étienne, xie@emse.fr

Overcrowding in Emergency Departments (EDs) is particularly problematic during seasonal epidemic crises. Each year during this period, EDs set off recourse actions to cope with the increase in workload. Uncertainty in the length and amplitude of epidemics make managerial decisions difficult. We propose in this study a staff allocation model to manage the situation using on-calls. An on-call scheduling policy is proposed to best balance between demand coverage and labor cost under legal constraints of working time. The problem is modelled as a two-stage stochastic Integer Linear Program (ILP) and solved using a Sample Average Approximation (SAA) method. Several epidemic scenarios are defined with data from an ED in Lille, France.

ThC1

## Emergency Medical Services/Medical Transportation 2

**Chair:** Kergosien, Yannick, *Polytech Tours*

**Location:** BDC

13:30

### Optimality of the Closest-Idle Policy in Advanced Ambulance Dispatching

**Jagtenberg, Caroline**, CWI, jagtenbe@cwi.nl

**van der Mei, Rob**, CWI, mei@cwi.nl

**Bhulai, Sandjai**, VU, bhulai@vu.nl

We address the problem of ambulance dispatching, in which we must decide which ambulance to send to an incident in real time. In practice, it is commonly believed that the 'closest idle ambulance' rule is the best choice and it is used throughout most literature. In this paper, we present alternatives to the classical closest idle ambulance rule. We show that significant improvements can be obtained by these alternative policies. The first alternative is based on a Markov decision problem (MDP), thereby constructing the first known MDP model for ambulance dispatching. Moreover, in the broader field of Dynamic Ambulance Management, this is the first MDP that models more than just the number of idle vehicles, while remaining computationally tractable for reasonably-sized ambulance fleets. Second, we propose a heuristic for ambulance dispatching that can handle regions with large numbers of ambulances. For both alternatives, we focus on two performance metrics, namely, the fraction of late arrivals and the average response time. We evaluate our policies by simulating a large emergency medical services region in the Netherlands. For this region, we show that our heuristic reduces the fraction of late arrivals by 18% compared to the 'closest idle' benchmark policy. This sheds new light on the popular belief that deviating from the closest idle dispatch policy cannot greatly improve the objective.

14:00

### Incorporating Coverage for Emergency Calls in Scheduling Patient Transportations

**van den Berg, Pieter**, Delft University of Technology, p.l.vandenberg@tudelft.nl

**van Essen, Theresia**, Delft University of Technology, J.T.vanEssen@tudelft.nl

Many ambulance providers operate both advanced life support (ALS) and basic life support (BLS) ambulances. Typically, emergency calls can only be executed by ALS vehicles, whereas non-urgent patient transportations can either be served by an ALS or a BLS ambulance. BLS vehicle capacity does normally not suffice for all transportation requests. The remaining transportations are performed by ALS ambulances, which reduces coverage for emergency calls. Most models in literature ignore this connection between patient transportations and emergency calls. We present a model to determine routes for BLS vehicles, so as to maximize the remaining coverage by ALS ambulances. Since most transportation requests arrive during the day of execution, our model will be online to handle these incoming requests. We show that it is not necessarily optimal to execute the maximum number of patient transportations with a BLS ambulance. Executing fewer patient transportations with BLS ambulances can result in a higher coverage by carefully selecting the transportation requests that are executed by an ALS ambulance.

14:30

### A matheuristic decomposition approach to solve the dynamic ambulance relocation and pre-assignment problem

**Bélanger, Valérie**, HEC Montréal, valerie.belanger@cirrelt.ca

**Lanzarone, Ettore**, CNR-IMATI, etторе@mi.imati.cnr.it

**Ruiz, Angel**, Université Laval, Angel.Ruiz@osd.ulaval.ca

**Soriano, Patrick**, CIRRELT - HEC Montréal, patrick.soriano@hec.ca



Emergency medical services (EMS) generally deal with two real-time decisions, i.e. ambulance dispatching and relocation. Dispatching consists in selecting which ambulance to send to each emergency call, while relocation consists in relocating available ambulances throughout the day in response to changes in the state of the system. Up to now, dispatching and relocation decisions have been generally considered separately. However, they are closely related and joint strategies that consider them simultaneously could help to maintain an adequate service level together with lower relocation efforts. In this study, we address the Dynamic Ambulance Relocation and Pre-assignment Problem (DARPP) and we propose an integrated programming model to consider the dispatching and relocation decisions together. This global model determines the location of each available ambulance as well as an ordered list of available ambulances that can be dispatched to each demand zone, aiming at minimizing the expected response time as well as relocation efforts. Moreover, to ensure solving real-life instances, a matheuristic approach has been developed by decomposing the problem and exploiting the division of the territory into sub-regions. This solution approach consists of three main steps: (1) ambulances are allocated to sub-regions; (2) the DARPP is solved for each sub-region; (3) the pre-assignment lists are updated based on ambulance locations obtained from (2). Each step consists of a programming model extracted from our global model. Results obtained from a first set of instances show the benefits of simultaneously considering pre-assignment and relocation decisions, and the impact of pre-assignment decisions on relocation ones. Moreover, on a set of larger size instances representative of a real application context, the proposed decomposition approach is shown to be an effective instrument to provide good quality solutions.

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## ThC2

## Performance Evaluation 2

Chair: Raith, Andrea, *The University of Auckland*,

Location: EY

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13:30

### Risk Adjustment of Stroke Outcomes for Comparing Hospital Performance: A Modelling Perspective

**Churilov, Leonid**, Florey Institute of Neuroscience and Mental Health, [Leonid.Churilov@gmail.com](mailto:Leonid.Churilov@gmail.com)

Stroke is one of the three leading causes of death and a leading cause of long-term disability worldwide. Measuring outcomes after stroke has both major policy and operational implications. Recently the American Heart and Stroke Associations have published a joint statement on this subject. The statement provides an overview of statistical considerations for the evaluation of hospital-level outcomes after stroke and promotes the use of hierarchical or multilevel random effect regression models that use random effect terms to describe hospital-specific effects. It is argued in the joint statement that the proposed approach helps in overcoming the failure to account for variation in case numbers across hospitals and for intra-hospital clustering effects. Using mortality outcome as an example, the random effect modelling approach would generate both the population-expected hospital mortality levels and the hospital-specific predicted mortality levels by applying the regression coefficients generated from all the patients in the sample, but using different values of random intercept. The predicted-over-expected ratio is then multiplied by the unadjusted mortality rate to yield a risk-standardized mortality rate. Generating the predicted values of the hospital-specific intercepts is a non-trivial task and these are computed as a part of Bayesian framework. It is important to note that this strategy is strongly cautioned against in the random-effect regression modelling literature due to the specific technical problems arising with estimation of the cluster-specific random effects. In this talk we provide a modelling perspective on the use of random-effect regression modelling for risk-adjusted comparison of hospital performance, discuss its advantages and limitations, and compare the random-effect approach to other potential alternative approaches using Australian stroke hospital mortality data as an illustrative context.

14:00

### Histopathology Laboratory Operations Analysis and Improvement

**Leeftink, Gréanne**, University of Twente, [a.g.leeftink@utwente.nl](mailto:a.g.leeftink@utwente.nl)

**Boucherie, Richard J.**, University of Twente, [r.j.boucherie@utwente.nl](mailto:r.j.boucherie@utwente.nl)

**Hans, Erwin W.**, University of Twente, [e.w.hans@utwente.nl](mailto:e.w.hans@utwente.nl)

**Verdaasdonk, Marina**, University Medical Center Utrecht, [m.a.m.verdaasdonk@umcutrecht.nl](mailto:m.a.m.verdaasdonk@umcutrecht.nl)

**Vliegen, Ingrid M.H.**, University of Twente, [i.m.h.vliegen@utwente.nl](mailto:i.m.h.vliegen@utwente.nl)

**van Diest, Paul J.**, University Medical Center Utrecht, [p.j.vandiest@umcutrecht.nl](mailto:p.j.vandiest@umcutrecht.nl)

Histopathology laboratories aim to deliver high quality diagnoses based on patient tissue samples. Indicators for quality are the accuracy of the diagnoses and the diagnostic turnaround times. However, challenges exist regarding employee workload and turnaround times, which both impact the diagnostic quality. This paper proposes a decomposed planning and scheduling method for the histopathology laboratory using (mixed) integer linear programming to improve the spread of workload and reduce the diagnostic turnaround times. First, the

batching problem is considered, in which batch completion times are equally divided over the day to spread the workload. This reduces the peaks of physical work available in the laboratory. Thereafter, the remaining processes can be scheduled to minimize the tardiness of orders. Results show that using this decomposed method, the peaks in histopathology workload in UMC Utrecht, a large university medical center in the Netherlands, are reduced with up to 50% by better spreading the workload over the day. Furthermore, turnaround times are reduced with up to 20% compared to current practices. This approach is currently being implemented in the histopathology laboratory of UMC Utrecht.

14:30

### Knowledge-based Quality Assessment of Radiotherapy Treatment Plans

**Raith, Andrea**, Department of Engineering Science, The University of Auckland, a.raith@auckland.ac.nz  
**Ehrgott, Matthias**, Department of Management Science, Lancaster University, m.ehrgott@lancaster.ac.uk  
**Fauzi, Fariza**, Department of Engineering Science, University of Auckland, w.paizi@auckland.ac.nz  
**Lin, Kuan-Min**, Department of Management Science, Lancaster University, k.lin1@lancaster.ac.uk  
**Macann, Andrew**, Auckland City Hospital, AMacann@adhb.govt.nz  
**Manitz, Juliane**, Chairs of Statistics and Econometrics, University of Goettingen, jmanitz@uni-goettingen.de  
**Rouse, Paul**, Department of Accounting and Finance, University of Auckland, p.rouse@auckland.ac.nz  
**Sasso, Giuseppe**, Auckland City Hospital, gsasso@adhb.govt.nz  
**Simpson, John**, Calvary Mater, john.simpson@calvarymater.org.au

The aim of radiotherapy treatment (RT) for cancer is to irradiate the tumour while avoiding damage to surrounding healthy organs at risk (OARs). RT planning involves assessment of several objectives related either to the tumour or OARs, leading to multi-objective optimisation problems. The major commercial treatment planning systems use weighted sums of objectives in deriving treatment plans. RT planners iteratively modify plans by adjusting the weights of objectives until clinical planning criteria are met. This iterative trial-and-error nature of RT planning results in an inefficient planning process. At the completion of the planning phase, a plan is produced for the oncologist to review. If a plan is not deemed acceptable it takes more time to produce another plan, without knowing in advance whether the new plan will be considered preferable to previous plans. Assessing RT plan quality is a topic that is receiving attention by researchers and health practitioners. We propose to measure RT plan quality using a linear-programming-based technique called data envelopment analysis (DEA) that compares each new plan being generated to a library of previously generated clinically acceptable plans. This is not straightforward as every patient is different, the tumour and OARs will have different shapes in each case, and the relative closeness to OARs will vary. DEA assesses quality based on plan parameters such as dose delivered to the tumour and dose received by OARs while taking into account patient specific variations. We demonstrate that DEA-based plan assessment works well for prostate and head and neck cancer which can have several OARs and patient dependent volume of OAR overlap with the tumour. We thus obtain a knowledge-based plan quality assessment methodology that builds on a library of plans and captures several plan characteristics such as radiation dose received as well as the patient-specific geometry.

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ThC3

### Disease Modeling and Policy 2

**Chair:** Rutherford, Alexander, *Simon Fraser University*

**Location:** Banque Scotia

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13:30

### Compliance with National Guidelines for Stroke in Radiology

**Komenda, Izabela**, Cardiff University, komendai@cardiff.ac.uk  
**Knight, Vincent**, Cardiff University, knightva@cardiff.ac.uk  
**Harper, Paul**, Cardiff University, Harper@cardiff.ac.uk

Stroke is a medical emergency, and if patient outcomes are to be improved there should be no time delays in accessing treatment. As management and prognosis of stroke are determined by aetiology, it is vital to delineate the causality of an event as soon as it is practicable. This project focuses on the application of Operational Research methodology to investigate how the Royal Gwent Hospital can comply with revised CT scanning guidelines for stroke. Such guidelines, released by the Royal College of Physicians in December 2012, recommend a 50% reduction in maximum time from hospital admission to delivery and report of a CT head scan to just 12 hours. Statistical analyses were conducted upon historical hospital data to investigate trends in CT scan request demand. The results of this investigation were used to populate a discrete event simulation model describing patient flow through the CT scanning process in SIMUL8 software. Following successful validation and verification, the model was applied to explore a number of operational modifications to the CT scanning system through a series of scenario analyses. Each of the scenarios focused upon policies in direct relation to stroke, and were proposed during observations of key processes and through discussion with radiology staff. The results of

this investigation presented evidence of a number of strategies to support operational improvements in relation to revised stroke guidelines. A range of areas for further investigation were also proposed.

**14:00**

### **Stroke care modelling in Singapore**

**Bayer, Steffen**, Duke-NUS Graduate Medical School, [steffen.bayer@duke-nus.edu.sg](mailto:steffen.bayer@duke-nus.edu.sg)

**Eom, Kirsten**, Duke-NUS Graduate Medical School, [kirsten.eom@duke-nus.edu.sg](mailto:kirsten.eom@duke-nus.edu.sg)

**Koh, Gerald**, National University of Singapore/National University Health System, [Gerald\\_Koh@nuhs.edu.sg](mailto:Gerald_Koh@nuhs.edu.sg)

**Tan, Kelvin Bryan**, Ministry of Health Singapore, [Kelvin\\_Bryan\\_TAN@moh.gov.sg](mailto:Kelvin_Bryan_TAN@moh.gov.sg)

**Matchar, David**, Duke-NUS Graduate Medical School, [david.matchar@duke-nus.edu.sg](mailto:david.matchar@duke-nus.edu.sg)

Stroke is one of leading causes of death and the leading cause of long-term disability in Singapore as in many other countries. With the rapidly ageing population in Singapore, it is of great importance to reduce the burden of stroke on patients, their family members, as well as the health care system. In light of this, there is an urgent need to prioritize clinical interventions and pertinent policies to maximize patients' outcomes and properly allocate the available resources. As a part of the effort to address this need, we have developed a system dynamics model using Singapore-specific stroke epidemiology data, clinical practice guidelines of stroke, and cost estimates of the interventions. Targeting those with history of stroke in Singapore, the model simulates the natural history of stroke within the adult Singapore population. The stroke population in the model is categorized by time since most recent stroke and functional independence (modified Rankin Scale). Simulating the impact of different types of interventions across the wide spectrum of stroke care (incl. dysphagia screening, DVT prophylaxis, thrombolysis, rehabilitation and secondary prevention) we identify potential approaches to reduce the risk of secondary stroke, improve patient care, and help stroke survivors in Singapore reach the best possible post-stroke outcomes at acceptable costs. Comparing levels of care and projected level of care with plausible effort we estimate the impact on cumulative quality-adjusted life years, incident strokes, and stroke fatalities over a 15-year time period. As the project was designed to support policy formulation and implementation as well as programme planning for stroke care in Singapore, we reflect on the usefulness of simulation modelling in informing discussions on different ways to improve the current practice at systems-level and supporting policy makers and clinicians deciding on evidence-based recommendations related to stroke care.

**14:30**

### **UNAIDS 90-90-90 Targets for Reducing HIV Incidence: An Operational Analysis for Vancouver, Canada**

**Rutherford, Alexander**, The IRMACS Centre, Simon Fraser University, [sandyr@irmacs.sfu.ca](mailto:sandyr@irmacs.sfu.ca)

**Ahrenberg, Lukas**, The IRMACS Centre, Simon Fraser University, [ahrenberg@irmacs.sfu.ca](mailto:ahrenberg@irmacs.sfu.ca)

**Ramadanovic, Bojan**, The IRMACS Centre, Simon Fraser University, [bramadan@sfu.ca](mailto:bramadan@sfu.ca)

**Williams, Brian**, South African Centre for Epidemiological Modelling and Analysis, [williamsbg@me.com](mailto:williamsbg@me.com)

**Vasarhelyi, Krisztina**, Faculty of Health Sciences and the IRMACS Centre, Simon Fraser University, [krisztina\\_vasarhelyi@sfu.ca](mailto:krisztina_vasarhelyi@sfu.ca)

UNAIDS recently launched new targets for combating the HIV/AIDS epidemic that call for 90% of HIV-positive individuals to be diagnosed, 90% of them to be on treatment, and 90% of patients on treatment to be virally suppressed. UNAIDS anticipates that meeting this 90-90-90 target by 2020 will significantly reduce HIV incidence by 2030 and effectively end the epidemic. Utilising a differential equation model of the continuum of HIV testing, treatment, care, and disease transmission, we examine the epidemiological implications of implementing different operational approaches to reach the 90-90-90 targets in Vancouver, Canada. Our model predicts that reaching the 90-90-90 target by 2020 would reduce HIV incidence in Vancouver from 178 cases/year in 2013 to approximately 97 cases per year in 2030. HIV incidence varies only by about 3% with redistributing testing resources between targeted testing, routine testing in high prevalence settings, and routine testing in acute care. However, we find wide variation in costs of testing programmes that can meet the 90-90-90 target. Using budget units of \$1 for a routine test, simply expanding the current testing programme to meet the 90-90-90 target would cost approximately \$91,000 per year. However, through optimally re-allocating testing resources, we are able to meet the target with an annual testing budget of just \$18,000. This minimal-cost programme emphasise routine testing in high prevalence settings for gay men and injection drug users. The model predicts that reaching the 90-90-90 targets by 2020 would reduce HIV incidence to approximately 50% of baseline by 2030. This corresponds to less than 30 cases in the injection drug user and general populations, combined. However almost 70 new infections are still expected among gay men. We further examine the feasibility of a two-dimensional family of 2020 operational targets to reduce HIV incidence by 90% in 2030.

**ThD1****Patient Flow****Chair:** Pitt, Martin, *University of Exeter : Medical School***Location:** BDC**15:30****Hybrid Simulation Modelling of Arterial Recanalization Treatment Pathways in Acute Stroke****Keshtkaran, Mahsa**, RMIT University, mahsa.keshtkaran@unimelb.edu.au**Churilov, Leonid**, The Florey Institute of Neuroscience and Mental Health, leonidc@unimelb.edu.au**Hearne, John**, RMIT University, john.hearne@rmit.edu.au**Abbasi, Babak**, RMIT University, babak.abbasi@rmit.edu.au**Meretoja, Atte**, The Florey Institute of Neuroscience and Mental Health, atte.meretoja@unimelb.edu.au

The existing acute therapies for ischaemic stroke are aimed at the speediest possible arterial recanalization, where a blood clot that is obstructing a blood vessel is either removed or dissolved. Until recently, intravenous thrombolysis within 4.5 hours from stroke symptom onset was recognized as the most effective treatment for ischemic stroke. Recently published clinical trials demonstrate that intra-arterial clot removal can be successfully used to further improve the outcomes in patients with ischemic stroke. As not every hospital can perform this procedure, introducing intra-arterial clot removal intervention into stroke care systems has serious implications for both policy making and service operations. Potential treatment pathways can include either combined or individual use of available intravenous and intra-arterial clot treatments that can be delivered by different treating facilities at different stages of the acute stroke care process. These pathways are complex and require in-depth investigation prior to their deployment as a part of an efficient and effective stroke care system. In this study we discuss a hybrid multiscale simulation model aimed at investigation and improvement of the acute stroke care system focusing on the delivery of intravenous and intra-arterial clot treatment. We utilize the previously developed “Save a minute-save a day model” to develop a hybrid simulation model of acute stroke treatment pathways with the aim to investigate the potential impact of various treatment pathway configurations on the long-term patient outcomes.

**16:00****A Hybrid Simulation Approach for Improving Patient Flows across Emergency Departments and Hospital Wards****Sonnessa, Michele**, University of Genova, sonnessa@gmail.com**Landa, Paolo**, University of Genova, paolo.landa@unige.it**Tanfani, Elena**, University of Genova, etanfani@economia.unige.it**Testi, Angela**, University of Genova, testi@economia.unige.it

In many health care settings, a growing proportion of patients admitted into inpatient hospital wards comes from Emergency Departments (EDs). Moreover, due to ED overcrowding and the reduction of hospital beds it is becoming crucial to better calibrate the dynamics of these two flows in order to improve the overall ED/Hospital management as a whole system. Thanks to the collaboration with the Local Health Authority of the Liguria Region, an observational analysis was conducted based on data collected over a one-year period in a large city health district. A System Dynamics (SD) model has been developed to reproduce at a high level the whole system and the relationships and causal effects between the emergent and elective patient flows. The model can be used to evaluate the impact of exogenous variations of the flows dynamics. As an example, an increase of the rate of arrival at the Emergency Department (e.g. in winter), can trigger a reinforcing loop increasing elective waits which in turns results on further increase of the patient inter-arrival rate to ED. A Discrete Event Simulation (DES) model has also been developed which uses the elective and emergent arrival flows generated as a result of the causal effects identified by the SD model. Afterwards, the DES model can be used to evaluate corrective organizational strategies aimed at re-allocating bed capacity between emergent and elective flows. The interaction of the aforementioned models in a hybrid fashion is able to produce alternative scenarios and compare their effects with respect to a set of performance metrics. The output analysis is developed in order to capture the performance of the whole system. The main proposed metrics are: waiting times to be admitted in hospital, proportion of misallocated patients, number of trolleys in EDs, inpatient bed occupancy rates and elective waiting list length.

**16:30****The visual representation of patient pathways – what’s the best way to do it?****Pitt, Martin**, University of Exeter : Medical School, m.pitt@exeter.ac.uk

Modelling patient pathways is a key aspect of much operational research in healthcare. There are many diagramming techniques linked with established methods in OR such as rich pictures, influence diagrams, pathway maps etc. In Problem Structuring Methods, for instance, visual representations are used extensively for knowledge elicitation, user-group discussion, and presentation of pathway alternatives. In addition, diagrams and other visual representations of treatment pathways are central to a wide range of healthcare applications and commonly used by many professional groups (e.g. specifying treatment protocols, commissioning and visualising

service improvements, knowledge elicitation from clinical experts, staff training, and patient information). Within this diversity of application there are distinct user-groups each with specific skills and requirements. To date however, research focussed on the most efficient and effective way to visually represent patient pathways has been limited and many key questions remain unanswered. We need to evaluate, for example, how diagrams and visual representations are used and understood by the key stakeholder groups they are design to serve, and how they might be improved and combined. We need to assess the value of standardising diagramming methods to ensure greater accessibility and portability of representation. Here we explore patient pathway representation in the context of a case study investigation of the diagnostic pathway for chest pain drawing on a diverse set of hospital emergency departments in the south-west of the UK. We investigate what an ideal visualisation technique should provide to meet the needs of practitioners. We also assess a range of existing visualisation techniques used to model similar processes (e.g. business processes) and evaluate their ability to support modelling of clinical protocols. Based on an evaluation of practitioner need we formulate a framework outlining the criteria for the effective visualisation of patient pathways and explore some of the key issues in this area.

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## ThD2

## Modeling in Healthcare

**Chair:** Mallor, Fermín, *Public University of Navarre*

**Location:** EY

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15:30

### **A heuristic algorithm for the Capacitated Vehicle Routing Problem with Synchronized Pick-ups and Drop-offs: a case study for medications delivery and supervision in DR Congo**

**Gascon, Viviane**, UQTR, [viviane.gascon@uqtr.ca](mailto:viviane.gascon@uqtr.ca)

**Clarke, John**, Université de Montréal, [john.bradley.clarke@gmail.com](mailto:john.bradley.clarke@gmail.com)

**Ferland, Jacques**, Université de Montreal, [ferland@iro.umontreal.ca](mailto:ferland@iro.umontreal.ca)

In post-emergency contexts such as Western DR Congo, one of the crucial challenges that rural hospitals face is maintaining a pharmacy with essential medications and supplies. The cost of transporting medications and providing on-site supervision to remote hospitals is an extremely expensive endeavour and can cost as much as the medication itself. Using the province of Bandundu, DR Congo as a case study, our research attempts to determine the feasibility of a synchronized routing problem for medication delivery and on-site supervision visits. We propose a Capacitated Vehicle Routing Problem formulation that handles several requirements including activity-wise synchronization, precedence, and two activity frequencies. We implement a cluster-first, route-second heuristic with a geospatially-enabled database to solve the problem. We also present a web-based tool to visualize the solutions in a map. The preliminary results of our study suggest that a synchronized solution could offer significant savings to rural hospitals and increase the accessibility of medical services to rural populations.

16:00

### **The family of Discrete Conditional phase-type distributions for modelling patient outcome and survival**

**Marshall, Adele**, Queen's University Belfast, [a.h.marshall@qub.ac.uk](mailto:a.h.marshall@qub.ac.uk)

The discrete conditional phase-type distribution is a hybrid approach which brings together data mining approaches with a special type of Markov model that represents patient survival. The first representation of the dc-ph utilised a Bayesian network to represent patient characteristics that influenced patient length of stay in hospital. Since then, naive Bayes, decision trees, random forests and most recently support vectors have been incorporated in the model alongside the survival data. This paper presents the dc-ph distribution and its successful applications. In particular the dc-ph model utilising the support vector machines for predicting Retinopathy of Prematurity in neonatal babies will be described.

16:30

### **Modelling the Patient Recovery Process in an Intensive Care unit**

**Mallor, Fermín**, Public University of Navarre, [mallor@unavarra.es](mailto:mallor@unavarra.es)

**Azcárate, Cristina**, Public University of Navarre, [cazcarate@unavarra.es](mailto:cazcarate@unavarra.es)

**Barado, Julio**, Hospital of Navarre, [jbaradoh@navarra.es](mailto:jbaradoh@navarra.es)

**Esparza, Laida**, García Orcoyen Hospital,

**Agustín, Alba**, Public University of Navarre, [albamaria.agustin@unavarra.es](mailto:albamaria.agustin@unavarra.es)

Several methods have been used to analyze LOS data in intensive care unit (UCI). Previous studies have proved that LoS data have outliers and are usually heavily skewed to the right. Probability distributions with heavy tails and different regression models have been used for LoS modeling purposes. These models present a good performance when the primary goal is to estimate some characteristic of the LOS as its expected value or some

percentile. Nevertheless, these models fall short of modeling the recovery process of the patient and can not be used as input of a dynamic simulation model of the ICU showing the health status of the patient. In this work we model the health status evolution of an ICU patient using historical data concerning the infections gotten in the UCI, the type of illness, age, APACHE II index, etc. The purpose is to describe and understand how these covariates influence LoS and dictate the patient's recovery process. In particular, Coxian phase-type and general phase type distributions as well as semi-Markov process are considered. These distributions have been used to model LoS in hospitals, but no instances of their use in ICUs could be found in the existing literature.

## ThD3

## Regional Health Services

**Chair:** Vissers, Jan, *Erasmus University Rotterdam*

**Location:** Banque Scotia

15:30

### Designing the primary care system in the city of Turin, Italy, using open data

**Aringhieri, Roberto**, Dipartimento di Informatica, Università degli Studi di Torino, roberto.arinhieri@unito.it  
**Cerutti, Fabio**, Dipartimento di Informatica, Università degli Studi di Torino

A primary care system delivers care for most of their everyday health needs. For each citizen, it represents the first contact point with the National Health System. An efficient and effective primary care system can have a positive impact on the overall population health. To this purpose, many countries started a re-organization process to improve efficiency and effectiveness of the system. Primary care in Italy is delivered by General Practitioners (GP) in their own studio, sometimes helped by a secretary and/or by a trainee. Their studio open from 20 to 30 hours per weeks. Each GP serves about 1200 patients on average, and no more than 1500 patients. Capitation fees remunerates GPs. Same model for pediatricians but they can only serve no more than 800 patients aged from 0 to 14. In Italy, a new organizational model is introduced by a 2014 national law: the new model consists in gathering a number of GPs and pediatrician - assisted by a medical staff - in a single facility (AFT) in order to provide a 24/7 service. In this paper we discuss an optimization model to design the new 24/7 primary care system in the city of Turin, Italy. Turin is a city in the northwest of Italy with about 900000 inhabitants currently served by 843 GPs and 113 pediatricians. Several constraints are taken into account when considering different age groups. For instance, we would like to evenly distribute elderly citizens among AFT. An extended version of the model should deal with GP and pediatrician preferences. Both models are feeded by open data available at <http://www.dati.piemonte.it/> through the strategic EU MED project Homer. The use of open data aims at raising awareness and testing economic, social and political benefits of making public data open and reusable.

16:00

### Perinatal networks and healthcare pathway optimization in the Ile de France region: a challenge for regional health authority.

**Crenn Hebert, Catherine**, APHP, PERINAT-ARS-IDF, catherinecrenn2@gmail.com  
**Lebreton, Elodie**, PERINAT-ARS-IDF, elodie.lebreton@aphp.fr  
**Poulain, Chloe**, PERINAT-ARS-IDF, chloe.poulain@aphp.fr  
**Menguy, Claudie**, CHI A. Gregoire, MONTREUIL, PERINAT-ARS-IDF, claudie.menguy@chi-andre-gregoire.fr

Background Social Security financing law planed 600 millions Euros savings for Ile de France (IDF) region health budget in the next 3 years. Implementation of perinatal health networks, founded by public regional health authority, is now achieved in IDF region where one-fifth of french babies are born. 2015 is time for perinatal 5 years plan (2012-2017) half-way assessment. Which organization allows efficient and effective spendings? Material and Methods: Use of data from annual perinatal network activity reports and routine data from Perinatal health Information System which combines hospital discharge summaries with national civil registration data. Results The population of the 8 administrative districts, including Paris, is covered by 7 territorial perinatal networks (the population of a wide district is split between 2 other perinatal networks). The districts are diverse in population, number of deliveries, number and status of perinatal centers. For a total population of 11 978 363 inhabitants in IDF, 3 003 914 women are in reproductive age, and 177555 gave birth in 2013. 3 thematic networks whose geographical catchment area cover all IDF, are devoted to ambulatory voluntary pregnancy termination, vulnerable pregnant women, premature babies follow-up. Total budget is 3,8 Millions euros: 2,2 M for territorial networks, 1 M for the three thematic networks. A total of 180124 deliveries occur in the 92 maternities of IDF. 29% of the maternities have less than 1100 deliveries per year, which is defined as efficiency level, while 6 /15 public level III (with intensive neonatal care) have more than 4000 deliveries per year. Discussion-Conclusion The relevance of administrative division applied to perinatal networks area is for debate. Nevertheless, field experience and collective intelligence could help to find innovating solutions in maternity and neonatal care pathway and planning.

16:30

**Generic and Specific Modelling of Health Service Provider Networks. Methodology and Application**

**Visser, Jan**, Erasmus University Rotterdam, [visser@bmg.eur.nl](mailto:visser@bmg.eur.nl)

**Elkhuizen, Sylvia**, Erasmus University Rotterdam, [elkhuizen@bmg.eur.nl](mailto:elkhuizen@bmg.eur.nl)

**Mahdavi, Mahdi**, Erasmus University Rotterdam, [mahdavi@bmg.eur.nl](mailto:mahdavi@bmg.eur.nl)

**Van de Klundert, Joris**, Erasmus University Rotterdam, [vandeklundert@bmg.eur.nl](mailto:vandeklundert@bmg.eur.nl)

Health services are increasingly delivered by disease focused networks of service providers collaborating in regional service delivery. We had the opportunity to study regional delivery systems for three diseases (diabetes type 2, stroke, hip osteoarthritis) in six European countries (FI, GE, GR, NL, SP, UK), as part of the project Managed Outcomes which was funded by the European Union. We developed a modelling framework which enables to explore systematically the relationships between operations and outcomes. The basis of the framework is formed by a general model from which disease specific models can be derived. For specific cases, instances of regional networks can be created which include the health service users. In addition to the modelling framework we propose analysis methods to analyze how the operational models can explain outcomes. The models and analysis methods are applied to analyze networks for the three diseases in the six countries. This provided much insight into the relationship between operations and outcomes, but also on the contribution of the generic and specific models in explaining the variations in results. The presentation will concentrate on the modeling framework for describing, analyzing and comparing regional health service delivery systems. Furthermore we will present the most important findings on the relationships between operations and outcomes, and on the contribution of the generic and specific modeling. Keywords: generic and specific operational models, regional health service delivery, methodology, operations and outcomes

## Friday

<b>9:00 -10:00</b>	<b>Plenary 2</b>	Room: BDC
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Chair: Nadia Lahrichi

**Andrea Lodi**

Strategic Workforce Planning

<b>10:00 -10:30</b>	<b>Coffee Break</b>	Room: Investissement Québec
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<b>10:30 -12:00</b>	<b>Session 8</b>
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**FB1-Home Care Planning  
HoCP**

Chair: Andrea Matta

Room: BDC

**Mohamed Cisse**A General Heuristic for Home  
Health Care Routing Problem**FB2- Health Economics and  
Process Analysis/Improvement  
HEco/Proc**

Chair: Angela Testi

Room: EY

**Penelope Mullen**Should the Financing System  
Determine the Priorities and  
Objectives of a Healthcare  
System?**Jacqueline Wirnitzer**Continuity of Care in Mid-  
Term Home Care Rostering  
for a German Home Care  
Provider**Sima Ajami**Improving Emergency  
Department (ED) Processes at  
Kashani Hospital by Lean  
Management and Simulation**Andrea Matta**A Lexicographic Model to  
Optimize Workload and  
Overlapping of Visits in the  
Home Health Care  
Assignment Problem**Nicolas Seca-Masot**Improving Healthcare Delivery  
At St-Mary's Hospital Laçor  
Through OM and OR

<b>12:00-13:30</b>	<b>Business Meeting / Lunch</b>	Room: BDC
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**FA****Plenary 2 Andrea Lodi****Chair:** Lahrichi, Nadia, *Polytechnique Montréal***Location:** BDC

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**09:00****Strategic Workforce Planning****Lodi, Andrea**, University of Bologna, [andrea.lodi@unibo.it](mailto:andrea.lodi@unibo.it)

Workforce planning in Italy is a task of great complexity due to the decentralized organization of the Health Care Services. As a result of major constitutional reforms, Italian regions are in charge of determining the organization of their health services and define the amount of annual budget to be allocated to providing care to the population. The decentralized organization of national health service is yearly negotiated and regulated by agreements and pacts debated in the State-Regions Permanent Conference. Within this conference, each year the Ministry of Health collects and negotiates regional workforce requirement forecasts with regional and health professional stakeholders and in collaboration with the Ministry of Education, University and Research (MIUR), determines the total number of medical doctors that should start specialization training. The final goal of the presented study is to provide a Decision Support System for health workforce planning and forecasting so as to foresee future shortages or surpluses through a proper management of residency grant allocations under budget constraints in the Emilia-Romagna Region. In order to meet the objectives, the decision-making model that will support regional planners has to be separated in two main components. A simulation model, which describes the health workforce supply and demand behavior over time, and an optimization model that evaluates the imbalances emerging from the simulation model and suggests an optimal funding allocation in order to reduce the gap between human health resources (HHR) availability and requirements. As we are dealing with a complex dynamic system, we have opted for the development of a System Dynamics simulation model to represent Emilia-Romagna region health workforce, while an Integer Programming model computes the optimal assignments of residency grants. The proposed methodology allows a comprehensive overview of regional data availability, defines the level of accuracy that can be reached by a quantitative approach to HHR regional planning, and provides the first quantitative decision-making tool for needs forecasting and fund allocation in Italy. At the Emilia-Romagna level, the proposed approach has been included within the planning tools of “Servizio Relazioni con gli Enti del SSR, Sistemi Organizzativi e Risorse Umane in ambito sanitario e sociale, supporto giuridico” of the “Assessorato Sanità e Politiche Sociali”. In addition, the EmiliaRomagna experience and methodology has been included in the Work Package 5 of the EU “Joint Action Health Workforce Planning and Forecasting” of which the Italian Ministry of Health is responsible. (Joint work with Paolo Tubertini, Roberto Grilli, Angelina Mazzocchetti, Corrado Ruozi and Francesca Senese.)

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**FB1****Home Care Planning****Chair:** Matta, Andrea, *Shanghai Jiao Tong University***Location:** BDC

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**10:30****A general heuristic for Home Health Care Routing Problem****Cissé, Mohamed**, Université de Tours, [mohamed.cisse@univ-tours.fr](mailto:mohamed.cisse@univ-tours.fr)**Kergosien, Yannick**, Université de Tours, [yannick.kergosien@univ-tours.fr](mailto:yannick.kergosien@univ-tours.fr)**Lenté, Christophe**, Université de Tours, [christophe.lente@univ-tours.fr](mailto:christophe.lente@univ-tours.fr)**Soriano, Patrick**, CIRRELT - HEC Montréal, [patrick.soriano@hec.ca](mailto:patrick.soriano@hec.ca)

Home Health Care Routing Problem (HHCRP) consists in designing routes followed by a team of care workers to provide services needed by patients. This problem is an extension of Vehicle Routing Problem with some additional constraints stemmed from the context of home care. Based on a recent literature review, we first proposed a model as generic as possible for HHCRP. Therefore, the model can take into account many constraints such as: time windows, temporal dependencies, continuity of care, qualification requirements, breaks. To solve the problem, we developed a three phase heuristic algorithm using callbacks procedures that allow to reconsider decisions taken during a previous phase. The first phase determines the day in which each service will be provided, while guaranteeing possible delays imposed between some services. The second phase aims to assign care worker to services of each patient maintaining continuity of care and balancing workload. In the last phase, all routes of care workers is designed following the previous decisions and minimizing total routing cost while respecting temporal dependencies and qualification requirements. The proposed decomposition aims to reduce the complexity of the problem. In order to improve resulting solution, callbacks procedures are developed in order to reconsider the decisions taken before. These callbacks procedures consist in moving services from a

route to another, from a day to another or prohibiting some decisions (e.g. care worker assignments) in order to explore new solution space. Finally, computational results are presented to evaluate the efficiency of the proposed heuristic. The results will be compared to optimal solution on small instances and using CPLEX solver. Others tests will be performed in order to compare us to results of benchmarks of the literature.

11:00

### **Continuity of Care in Mid-Term Home Care Rostering for a German Home Care Provider**

**Wirnitzer, Jacqueline**, FZI Research Center for Information Technology, [wirnitzer@fzi.de](mailto:wirnitzer@fzi.de)

**Meyer, Anne**, FZI Research Center for Information Technology, [meyer@fzi.de](mailto:meyer@fzi.de)

**Nickel, Stefan**, Karlsruhe Institute of Technology, [stefan.nickel@kit.edu](mailto:stefan.nickel@kit.edu)

Continuity of care from the perspective of patients improves the quality of home care services evidentially. The nurse rostering decisions of a home care provider typically do not only include the assignment of shifts to nurses but also the assignment of nurses to patients requiring service within these shifts. Hence, it is an important goal of rostering in the context of home care to assign as few nurses as possible to each patient. In this talk we present the monthly nurse rostering planning setup of our project partner, a leading German home care provider. The planning task is currently executed manually, even though it is extremely complex: Amongst others, legal and internal working time restrictions, availabilities of full and part time nurses, different required qualification levels and a broad set of different weekly visit frequencies (1 up to 21) have to be considered. We elaborate a basic mathematical model (MIP) for the mid-term home care rostering problem (HCR) that meets all requirements of our project partner incorporating the assignment of nurses to weekly recurring tours (master tours). Based upon that basis we propose different extensions and reformulations: First, we evaluate the impact of different continuity measures and show on a real instance that continuity of care can be improved considerably compared to the manual solution. Second, we test different reformulations of the models, such as a network flow formulation, with regard to performance improvements. Finally, we show the effect of extending the models to incorporate continuity of care over a long-term horizon. All experiments are based on realistic instances derived from real planning data.

11:30

### **A Lexicographic Model to Optimize Workload and Overlapping of Visits in the Home Health Care Assignment Problem**

**Kang, Li**, Shanghai Jiao Tong University, [kangli@sjtu.edu.cn](mailto:kangli@sjtu.edu.cn)

**Matta, Andrea**, Shanghai Jiao Tong University, [matta@sjtu.edu.cn](mailto:matta@sjtu.edu.cn)

In this paper, we focus on avoid overlapping of visits under the same utilization level for assigning problem with time window in home health care services. There are two objectives solved in a lexicographic model. Firstly we balance the utilization of operators and then we avoid overlapping of visits. The operators' busy state is calculated with a probabilistic approach. Mathematical models are developed by taking into account: time window of both patients and service skills; skill compatibilities between patients and operators; multiple time planning periods; continuity of care; operators' capacity restrictions. Numerical results based on both realistic problem instances and generated test instances inspired by realistic settings are presented. Results obtained show that we can avoid overlapping of visits significantly at equal utilization level with our model.

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FB2

## **Health Economics and Process Analysis/Improvement**

**Chair:** Testi , Angela , *University of Genova*

**Location:** EY

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10:30

### **Should the financing system determine the priorities and objectives of a healthcare system?**

**Mullen, Penelope**, Independent, [penelope.mullen@btinternet.com](mailto:penelope.mullen@btinternet.com)

It is well established that the source of funding and system of financing influence the organisation and characteristics of health care, including coverage, provision and, for example, focus on preventive rather than curative approaches. However, recently there have been a number of claims that the funding and financing system should – rather than does – determine the objectives and priorities of health-care systems, with some commentators making a clear distinction in this respect between social insurance and tax-funded systems. Pursuit of this normative position could affect operational researchers as objectives and priorities are a central concern of many OR studies in health care. This paper reviews the established relationship between financing and finding methods and the provision and coverage of health care. It then moves on to explore the implications for the provision and nature of health care of the claims that the objectives and priorities should be determined, or at least influenced, by the financing system. Implications for international comparison of healthcare systems and

cross-border learning are examined. The extent to which such considerations affect analysis of health policy, systems, management and organisation and should be the concern of operational researchers will be explored.

11:00

### **Improving Emergency Department (ED) Processes at Kashani Hospital by Lean Management and Simulation**

**Ajami, Sima**, Isfahan University of Medical Sciences, [ajami@mng.mui.ac.ir](mailto:ajami@mng.mui.ac.ir)

**Ketabi, Saeedeh**, University of Isfahan, [sketabi@yahoo.com](mailto:sketabi@yahoo.com)

**Bagherian, Hosain**, Isfahan University of Medical Sciences, [h\\_bagherian1924@yahoo.com](mailto:h_bagherian1924@yahoo.com)

Introduction: A great deal of time, effort, and resources are required to provide high quality care to each of the patients in the Emergency Department (ED), whereas if one looks at the actual sequence of events, there is a tremendous amount of unnecessary activities that go on, and therefore lots of delays, repeated tests, and events not occurring in the right sequence. Lean management is a process improvement technique to identify waste actions and activities to eliminate them. So, lean management reduces the time taken by the patient to go through the processes of treatment in the ED. Simulation can show the eventual effects of alternative improvements and the outcome of the action. Aim: The aim of this study was to improve the ED processes at Kashani Hospital in Isfahan, Iran by "lean management" and "simulation". Methods: This research was applied and an analytical intervention study. Data was collected by brainstorming, observations, interview, review of work flow and documents. Data included lean team members' viewpoints, waiting and service time in all workstations related to the ED's treatment processes along with diagnostic departments (e.g. Laboratory, Radiology, Ultrasonography, and C-T Scan) during 17 days-period. To perform Lean Technique the staff of the ED was familiarized with the concept of lean management and then formed a lean management team. In the next meetings, current process was reviewed by the lean management team. Then, wastes, values and proposed ideas were identified by the team. Data was analyzed through SPSS software and simulation technique. Results: Findings showed that after applying modifications, total wait time in the system reduced from 120.83 to 107.19 minutes. Conclusion: Lean management improves quality, reliability, and productivity of the ED processes; and it does so while making work easier for the medical staff by removing waste and improving the customer experience as well. Reviewing processes of the ED services can regularly help to identify waste procedures through practical, reasonable and easy suggestions by the ED staff. Simulation technique can evaluate expensive suggestions.

11:30

### **Improving healthcare delivery at St-Mary's hospital Laçor through OM and OR**

**Seca-Masot, Nicolas Andres**, HEC Montreal and CIRRELT, [nicolas-andres.seca-masot@hec.ca](mailto:nicolas-andres.seca-masot@hec.ca)

**Bélanger, Valérie**, CIRRELT – HEC Montréal, [valerie.3.belanger@hec.ca](mailto:valerie.3.belanger@hec.ca)

**Rancourt, Marie-Ève**, Université du Québec à Montréal, [rancourt.marie-eve@uqam.ca](mailto:rancourt.marie-eve@uqam.ca)

**Soriano, Patrick**, CIRRELT - HEC Montréal, [patrick.soriano@hec.ca](mailto:patrick.soriano@hec.ca)

**Ogwang, Martin**, St-Mary's Lacor Hospital

**Ochola, Emmanuel**, St-Mary's Lacor Hospital, [ayiga33@hotmail.com](mailto:ayiga33@hotmail.com)

**Atim, Pamela**, Makers University, Gulu University Uganda

After twenty years of armed conflict in northern Uganda, St-Marys Laçor Hospital has faced a sharp rise in the number of patients presenting chronic conditions, which require longer treatments and a profound modification of the health service offer. This situation is challenging the Hospital's management team to review its practices and management tools in order to ensure the best delivery of services with it's limited resources. Tuberculosis (TB) has been identified as a critical disease for which the hospital needs new methodologies and tools to improve the current process. This project pursues two complementary objectives: 1) identify the main challenges related to the TB healthcare delivery process and propose improvements; 2) identify supports activities of the hospital which could also benefit from improved management methodologies and more sophisticated decision support tools. Since this project was initiated without any prior information on the actual TB delivery process in place at the Hospital, the initial phase consisted in a comprehensive collection of information, through a literature review and questionnaires, followed by an extensive series of interviews and observations carried out on site. The data obtained was then analyzed to produce a comprehensive process mapping which, when complemented with the interviews, would allow to identify the main challenges encountered in the TB delivery process as well in the other hospital activities supporting it. The major challenges identified were the following: patient follow-up activities, infection control risks and continuous improvement culture. Several solutions are proposed ranging from simple process adjustments, a prototype of computerized database, establishing a fast track for suspected TB patients, to a simulation tool. Finally, several challenges were identified in the hospital support activities such as: transportation planning and maintenance; nurse demand planning and scheduling. However, tackling these issues requires longer-term research efforts to develop decision tools based on operational research.

## List of participants

Surname	Name	Email	Session
Addis	Bernardetta	bernardetta.addis@univ-lorraine.fr	TuB1
Agustin	Alba	albamaria.agustin@unavarra.es	
Ajami	Sima	ajami@mng.mui.ac.ir	FB2
Aleman	Dionne M.	aleman@mie.utoronto.ca	
Aringhieri	Roberto	roberto.aringhieri@unito.it	ThD3
Augusto	Vincent	augusto@emse.fr	
Ballestin	Francisco	francisco.ballestin@uv.es	MB1
Barros	Nara	naramarquesbarros@gmail.com	TuD1
Bas	Seda	seda.bas@yeditepe.edu.tr	MC3
Bayer	Steffen	steffen.bayer@duke-nus.edu.sg	ThC3
Bélanger	Valérie	valerie.belanger@cirrelt.ca	ThC1
Bikker	Ingeborg	i.a.bikker@utwente.nl	ThB3
Blake	John	john.blake@dal.ca	MB3
Borgman	Nardo	n.j.borgman@utwente.nl	TuB3
Brailsford	Sally	s.c.brailsford@soton.ac.uk	MB3, TuD2
Campbell	Leslie Anne	leslie.anne.campbell@dal.ca	TuD3
Captivo	Maria Eugénia	mecaptivo@fc.ul.pt	
Carter	Michael	carter@mie.utoronto.ca	Panel
Churilov	Leonid	Leonid.Churilov@gmail.com	ThC2
Cissé	Mohamed	mohamed.cisse@univ-tours.fr	FB1
Crenn Hebert	Catherine	catherine.crenn-hebert@sap.aphp.fr	ThD3
Demeulemeester	Erik	erik.demeulemeester@kuleuven.be	TuA Tutorial
Dexter	Franklin	franklin-dexter@uiowa.edu	TuD2
Dorval	Valérie	valerie.dorval.1@ulaval.ca	Poster
Duma	Davide	davide.duma@unito.it	MB1
Esensoy	Ali Vahit	ali.esensoy@utoronto.ca	MB2
Ferreira de Oliveira	Mario Jorge	mario_jo@po.coppe.ufrj.br	MC2
Franck	Thomas	thomas.franck@emse.fr	ThB2
Frangeskou	Marianna	marianna.frangeskou@gmail.com	Poster
Garaix	Thierry	garaix@emse.fr	ThB3

## Participants

<b>Gascon</b>	<b>Viviane</b>	viviane.gascon@uqtr.ca	<b>ThD2</b>
<b>Grieco</b>	<b>Luca</b>	l.grieco@ucl.ac.uk	<b>TuB2</b>
<b>Hans</b>	<b>Erwin</b>	e.w.hans@utwente.nl	<b>Panel, TuD1</b>
<b>Jagtenberg</b>	<b>Caroline</b>	jagtenbe@cw.nl	<b>ThC1</b>
<b>Johnson</b>	<b>Sharon</b>	sharon@wpi.edu	<b>Panel</b>
<b>Kamran Habibkhani</b>	<b>Hootan</b>	hootan.kamran@gmail.com	<b>TuD3</b>
<b>Kazemi Zanjani</b>	<b>Masoumeh</b>	kazemi@encs.concordia.ca	
<b>Kergosien</b>	<b>Yannick</b>	yannick.kergosien@univ-tours.fr	
<b>Keshtkaran</b>	<b>Mahsa</b>	mahsa.keshtkaran@unimelb.edu.au	<b>ThD1</b>
<b>Ketabi</b>	<b>Saeedeh</b>	sketabi@yahoo.com	<b>TuB1</b>
<b>Komenda</b>	<b>Izabela</b>	komendai@cardiff.ac.uk	<b>ThC3</b>
<b>Lahrichi</b>	<b>Nadia</b>	nadia.lahrichi@polymtl.ca	<b>Panel, Poster</b>
<b>Landa</b>	<b>Paolo</b>	paolo.landa@yahoo.it	<b>TuD1</b>
<b>Lanzarone</b>	<b>Ettore</b>	ettore.lanzarone@cnr.it	<b>ThA Tutorial</b>
<b>Leeftink</b>	<b>Gréanne</b>	a.g.leeftink@utwente.nl	<b>ThC2</b>
<b>Legrain</b>	<b>Antoine</b>	antoine.legrain@cirrelt.ca	<b>ThB3, Poster</b>
<b>Lodi</b>	<b>Andrea</b>	andrea.lodi@unibo.it	<b>FA Plenary</b>
<b>Maclure</b>	<b>Malcolm</b>	malcolm.maclure@ubc.ca	
<b>Mahnam</b>	<b>Mehdi</b>	mehdi.mahnam@cirrelt.ca	<b>Poster</b>
<b>Mallor</b>	<b>Fermín</b>	mallor@unavarra.es	<b>ThD2</b>
<b>Marques</b>	<b>Inês</b>	ines.marques@fc.ul.pt	<b>MC1, Poster</b>
<b>Marshall</b>	<b>Adele</b>	a.h.marshall@qub.ac.uk	<b>ThD2</b>
<b>Matta</b>	<b>Andrea</b>	matta@sjtu.edu.cn	<b>FB1</b>
<b>Mullen</b>	<b>Penelope</b>	penelope.mullen@btinternet.com	<b>FB2</b>
<b>Niroumandrad</b>	<b>Nazgol</b>	nazgol.niroumandrad@polymtl.ca	<b>MB2</b>
<b>Ochola</b>	<b>Emmanuel</b>	ayiga33@hotmail.com	<b>TuB2</b>
<b>Pitt</b>	<b>Martin</b>	m.pitt@exeter.ac.uk	<b>ThD1</b>
<b>Puterman</b>	<b>Martin L.</b>	Martin.Puterman@sauder.ubc.ca	<b>MA Plenary, ThD3</b>
<b>Rachuba</b>	<b>Sebastian</b>	s.rachuba@exeter.ac.uk	<b>MB2</b>
<b>Raith</b>	<b>Andrea</b>	a.raith@auckland.ac.nz	<b>ThC2</b>
<b>Rauner</b>	<b>Marion Sabine</b>	marion.rauner@univie.ac.at	<b>ThB1</b>
<b>Reuter- Oppermann</b>	<b>Melanie</b>	melanie.reuter@kit.edu	<b>ThB1</b>

## Participants

<b>Roshanaei</b>	<b>Vahid</b>	vroshana@mie.utoronto.ca	<b>MC1</b>
<b>Rousseau</b>	<b>Louis-Martin</b>	louis-martin.rousseau@polymtl.ca	
<b>Ruiz</b>	<b>Angel</b>	Angel.Ruiz@fsa.ulaval.ca	
<b>Rutherford</b>	<b>Alexander</b>	sandyr@irmacs.sfu.ca	<b>ThC3</b>
<b>Samudra</b>	<b>Michael</b>	samudra@kuleuven.be	<b>TuB1</b>
<b>Savage</b>	<b>David</b>	dsavage@nosm.ca	
<b>Seca-Masot</b>	<b>Nicolas</b>	nicolas-andres.seca-masot@hec.ca	<b>FB2</b>
<b>Sharif</b>	<b>Azaz</b>	asharif9@uwo.ca	<b>MC2, ThB2</b>
<b>Silander</b>	<b>Katariina</b>	katariina.silander@aalto.fi	<b>TuD2</b>
<b>Sonnessa</b>	<b>Michele</b>	sonnessa@gmail.com	<b>ThD1</b>
<b>Soriano</b>	<b>Patrick</b>	patrick.soriano@hec.ca	
<b>Stanford</b>	<b>David</b>	stanford@stats.uwo.ca	<b>ThB2</b>
<b>Tenhunen</b>	<b>Henni</b>	henni.tenhunen@aalto.fi	<b>TuB2</b>
<b>Testi</b>	<b>Angela</b>	testi@economia.unige.it	
<b>Tihani</b>	<b>Ilias</b>	ilias.tihani@hec.ca	
<b>Tohidi</b>	<b>Mohammad</b>	mamadtohidi@gmail.com	
<b>Tubertini</b>	<b>Paolo</b>	paolo.tubertini@unibo.it	<b>MC1</b>
<b>Vahid</b>	<b>Saba</b>	saba.vahid@cancercare.on.ca	<b>MC2</b>
<b>Van Brummelen</b>	<b>Sem</b>	s.p.j.vanbrummelen@utwente.nl	<b>MC3</b>
<b>Van de Vrugt</b>	<b>Maartje</b>	n.m.vandevrugt@utwente.nl	<b>TuB3</b>
<b>Van den Berg</b>	<b>Pieter</b>	p.l.vandenberg@tudelft.nl	<b>ThC1</b>
<b>Van Riet</b>	<b>Carla</b>	carla.vanriet@kuleuven.be	<b>MB1</b>
<b>Vanberkel</b>	<b>Peter</b>	peter.vanberkel@dal.ca	<b>ThB1</b>
<b>Vasilakis</b>	<b>Christos</b>	c.vasilakis@bath.ac.uk	<b>Panel, MB3</b>
<b>Visser</b>	<b>Jan</b>	vissers@bmg.eur.nl	<b>ThD3</b>
<b>Wiesche</b>	<b>Lara</b>	lara.wiesche@rub.de	<b>TuB3</b>
<b>Wirnitzer</b>	<b>Jacqueline</b>	wirnitzer@fzi.de	<b>FB1</b>
<b>Xie</b>	<b>Xiaolan</b>	xie@sjtu.edu.cn	
<b>Yalcindag</b>	<b>Semih</b>	semih.yalcindag@cirrelt.net	



## Program at a glance

Sunday July 19th		Monday July 20th			Tuesday July 21st			Wednesday July 22nd	Thursday July 23rd			Friday July 24th												
08:30						Coffee/Tea				Coffee/Tea			Coffee/Tea	08:30										
09:00		Registration and Coffee/Tea	Tua - Tutorial 1 Eric Demeulemeester (KU)	Coffee/Tea				EXCURSION (Biodome - Montreal Tower - Botanical Garden)		ThA - Tutorial 2 Ettore Lanzarone (IMAT)	FA - Plenary 2 Andrea Lodi (Polytechnique)				09:00									
09:30													09:30											
10:00													10:00											
10:30														10:30										
11:00		Conference Opening												11:00										
11:30		MA - Plenary 1 Martin Puterman (UBC)	TuB1 - ORP3	TuB2-HCP3	TuB3-PSch1				ThB1-EMS1	ThB2-Perf1	ThB3-PSch2	FB1-hoCP	FB2-Heco/Proc	11:30										
12:00														12:00										
12:30		Lunch	Lunch	Lunch	Lunch	Lunch	Lunch	Business Meeting / Lunch	Lunch	Lunch	Business Meeting / Lunch	Business Meeting / Lunch	Business Meeting / Lunch	12:30										
13:00																								13:00
13:30																								
14:00														14:00										
14:30		MB1-ORP1	MB2 - HCP1	MB3 - Blood1		Tuc Panel Discussion	Tuc Panel Discussion	Tuc Panel Discussion		ThC1-EMS2	ThC2-Perf2	ThC3-DMP2		14:30										
15:00																15:00								
15:30			Coffee/Tea			Posters / Coffee	Posters / Coffee	Posters / Coffee		Coffee/Tea				15:30										
16:00																16:00								
16:30		MCI-ORP2	MC2 - HCP2	MC3 - Blood2				Transfer to Dock		ThD1-Pflow	ThD2-MoHc	ThD3-RegHS		16:30										
17:00		Get together	Cocktail	Cocktail	TuD1-ORP4	TuD2-HCP4	TuD3-DMP1	Boat Tour						17:00										
17:30																	17:30							
18:00																	18:00							
20:00														20:00										
						Optional Diner (not included)				Gala Diner				20:00										