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2021 CORS Annual Meeting Program Booklet

Monday/Lundi June 07, 2021

■ CHOW A MA 10:00-11:30

Operations research in healthcare

Co-chairs:
Andre Cire, University of Toronto Scarborough
Adam Diamant, York University

• **Stochastic modeling to personalize disease screening decisions**
CHOW Plenary: Oguzhan Alagoz, Professor, College of Engineering, University of Wisconsin-Madison

Abstract: In this talk, I will describe the use of partially observable Markov decision processes (POMDPs) to personalize disease screening decisions with a focus on cancer screening. POMDP models can be used to address several controversial open research questions in disease screening, such as when to start and stop screening and how often to screen. POMDP models provide a well-suited framework to optimize screening decisions because they allow the representation of the unobservable true health condition of a patient and screening tests that provide partial information about the true health condition. They further allow incorporating individual patient preferences into the medical decisions. I will use a previously developed POMDP model for breast cancer screening to demonstrate the development and application of a POMDP model for cancer screening.

Bio: Oguzhan Alagoz is Proctor & Gamble Bascom Professor of Industrial and Systems Engineering at the University of Wisconsin-Madison and a professor at the Department of Population Health Sciences. He serves as the director of NIH-funded Institute for Clinical and Translational Research (ICTR)-Simulation Center as well as the faculty director for the Quality and Safety Improvement Lab. He received his BS from Bilkent University in 1997, MS from Middle East Technical University in 2000, and PhD from the University of Pittsburgh in 2004. His research interests include stochastic optimization, medical decision making, completely and partially observable Markov decision processes, simulation, risk-prediction modeling and health technology assessment with applications in cancer control and infectious diseases. He served as a member of ISPOR-SMDM Modeling Good Research Practices Task Force which developed recommendations for good modeling practices in state-transition modeling for the evaluation of health care decisions in 2012. He is currently serving as the editor-in-chief of IISE Transactions on Healthcare Systems Engineering and associate editor for Operations Research. He has received various awards including a CAREER award from National Science Foundation (NSF), outstanding young industrial engineer in education award from IIE, Dantzig Dissertation Honorable Mention Award from INFORMS, 2nd place award from INFORMS Junior Faculty Interest Group best paper competition, best paper award from INFORMS Service Science Section, best podium presentation award from ISPOR, and best poster award from UW Carbone Comprehensive Cancer Center. He graduated 12 PhD students and is currently serving as the PhD advisor of three students. Dr. Alagoz has been a member of CISNET Breast Cancer Working Group and is co-leading the University of Wisconsin Breast Cancer Simulation model since 2007.

• **Personalized treatment for opioid use Disorder**
Technical Speaker: Kyra Gan, Carnegie Mellon University

Abstract: Wearable devices have the potential to revolutionize treatments for opioid use disorder (OUD) by measuring patient responses to different treatment regimens in real-time, enabling the development of personalized treatments. A variety of wearable devices with different features, sensitivities, and costs are available. Whether such devices are practical and cost-effective to incorporate in treatments for OUD, and if so how they should be used, are critical questions. To investigate these questions, we build a finite-horizon, non-stationary constrained partially observable Markov decision process (CPOMDP). To facilitate the solution of our model, we provide a novel budget reformulation that finds all optimal solutions lying on the original formulation's solution convex hull. We

then show that our reformulation can be solved using a binary search in conjunction with an exact POMDP algorithm. Applying those elements and using parameters estimated from past literature, we perform a numerical study to investigate the values of different wearables in OUD treatments, where we consider different levels of budget, wearable precision, and patient treatment adherence (TA). We find that wearables can be valuable when patients react differently to treatments across the entire population. Furthermore, this value is the largest at low or moderate budgets for patients with low or moderate TA. Outside of these settings, the marginal benefit of wearables is negligible relative to their cost.

Bio: Kyra Gan is a fourth-year Ph.D. student in operations research at the Tepper School of Business, Carnegie Mellon University

■ MDS1 MA 10:00- 11:30

Reasoning under uncertainty

Chair/Président: Adel Guitouni, University of Victoria

• Frigate anomaly detection using autoencoders

Bahaa Khaddaj*
Defence Research and Development Canada

Abstract: Many navies are exploring ways to increase ship availability. One way to achieve this is considering Conditions-Based Maintenance (CBM) versus traditional corrective and preventive maintenance strategies. CBM involves developing models to detect anomalies on ships before failures occur, reducing the time ships spend in maintenance. In this study we investigate the application of Autoencoder Neural Networks to predict failures on Royal Canadian Navy frigates. Models are trained using analogue sensor data and corrective maintenance data from on-board the frigates. During this presentation, we present an overview of the problem, the challenges faced and the current state of this work.

• Bioterrorism and deterrence by sharing microbiological knowledge

Gregory van Bavel*, Ugurhan Berkok , Binyam Solomon
Department of National Defence [1, 3]; Queen's University [2]

Abstract: Global bioterrorism and possible countermeasures motivated our game-theoretical model, which pits a terrorist group or individual (common agent) against two countries (co-principals). We assume that microbiological knowledge can deter bioterrorism, but countries holding this knowledge face a tradeoff: sharing enhances deterrence, but reduces biotechnological superiority. Thus, the countries prefer a quid-pro-quo sharing arrangement, but only if an attack looms. The terrorist prefers that the countries do not share; therefore, the countries can share, quid-pro-quo, the minimum to achieve deterrence, which is a public good, and avoid over-deterrence, which is a public bad that some anti-terrorism efforts have generated.

• Dialogue paradigm for multimodal interactive robot in military communication

Sheuli Paul*, Liam Robertson*
DRDC; DND

Abstract: Human communication is multimodal- a key factor to adequately interpret human-robot interaction. The goal is to create a multimodal interactive robot system(MIRS) that allows the military to communicate with robots using speech, gestures, images, visual story telling and virtual assistance. Speech is the most natural form of communication for humans. We engage in dialogue with people through speech. The objective is to develop a spoken dialogue system(SDS) for military and robotic interaction. Here we will demonstrate an interactive dialogue flow to collaborate and interpret actions and intentions in military communication based on AI conversational scenarios using rasa and deep learning.

• Bayesian Enterprise Analysis Model (BEAM) research: Novel algorithms to solve large-scale zero sum games

Franco Villongco* , Mark Gallagher
Air Force Institute of Technology

Abstract: The Bayesian Enterprise Analysis Model (BEAM) is a novel Defense Enterprise level analysis tool that allows for rapid responses to strategic questions, and incorporates intelligent and adaptive adversarial behavior between two sides. One of the key algorithms within BEAM is the allocation algorithm, which calculates asset-mission assignments for each side within a scenario. Each side faces a vast number of discrete allocation options. The outcome of a scenario depends on each side' allocations. We briefly present the game theoretic model to formulate the allocation problem then present our novel algorithm to calculate near-equilibrium solutions while navigating a large decision space.

■ SG5 MA 10:00- 11:30

Allocation and distribution for social good

Chair/Président: Vince Slaugh, Cornell University

• **A model for synchronization of debris management and distribution of relief supplies after natural disasters**

Luana Almeida*, Floris Goerlandt, Ronald Pelot, Kenneth Sörensen
Dalhousie University [1, 2, 3]; University of Antwerp [4]

Abstract: During the immediate response phase of a natural disaster, decision-makers put into practice a previously defined emergency plan to help affected communities. In this phase, it is considered beneficial to synchronize debris management activities (i.e. road clearing) with the distribution of relief supplies to support as many affected people as possible. This presentation proposes a model that synchronizes these two tasks through the Greedy Randomized Adaptive Search Procedure (GRASP), a meta-heuristics approach which provides an approximate solution for large scale instances. The model is then applied to an illustrative case study in Canada.

• **Allocation of supply constrained blood platelets in emerging economies**

Sudipendra Nath Roy*, Fredrik Odegaard
Western University

Abstract: Platelets are valuable blood components used for treating viral dengue fever, blood-related illness, and as post-chemotherapy treatment. Unfortunately, platelets are highly perishable with a shelf-life of 3-5 days, which coupled with stochastic supply and demand patterns makes platelet inventory management a challenging task, especially in supply-constrained emerging economies. Motivated by experience at an Indian regional hospital, we analyze the platelet allocation decision and propose an allocation heuristic based on revenue management principles, with the objective to maximize the social benefit for priority-differentiated demand streams. It is shown that the RM-based policy outperforms other policies and better serves medically urgent patients.

• **Design and operations of on-demand multimodal transit systems**

Antoine Legrain*, Connor Riley, Pascal Van Hentenryck
Polytechnique Montréal [1]; Georgia Tech [2, 3]

Abstract: On-Demand Multimodal Transit Systems combine dynamically dispatched shuttles in low-density areas with high-occupancy vehicles to serve high-density corridors. They simultaneously address the infamous first/last mile problem by picking-up/dropping-off riders close to their origins and destinations, congestion by aggregating rides in crowded arteries, and parking issues by removing cars from downtown. They fill a sweet spot between ride-sourcing services and traditional transit systems. This paper reviews a series of optimization problems behind the design and operation of these systems: network design, trip splitting, zone allocation, fleet sizing, rostering, and real-time dial-a-ride optimization. Experimental results on Ann Arbor demonstrates the potential benefits.

• **Positional flexibility and consistent assignment in long-term care rostering**

Vincent Slaugh*, Alan Scheller-Wolf
Cornell University; Carnegie Mellon University

Abstract: We study the rostering decisions for assigning caregivers to units of residents every shift. We show that prioritizing part-time employees to work in their "home unit" can significantly improve the consistency of care. Analysis of data from three facilities' schedules reveals an expected 20-30% reduction in the number of unique caregivers assigned to each unit in a month. We also present a stochastic model of the repeated rostering problem to analytically compare the performance of heuristics based on assignment priority for part-time or full-time workers.

■ FRM1 MA 10:00- 11:30

Quantitative finance: Optimization, COVID-19 and social impact

Chair/Président: Luis Seco, University of Toronto

• **COVID-19: Modelling another global systemic phenomenon**

Thomas Hurd*
McMaster University

Abstract: This talk will describe my efforts to comprehend the second great global crisis in our lifetime, based on what I learned from modelling the Great Financial Crisis. Insights into systemic risk made by financial mathematicians lead to network pandemic models that provide unified understanding not easy to discern from conventional SIR models. The Inhomogeneous Random Social Network (IRSN) framework is an offshoot of the Inhomogeneous Random Financial Network (IRFN) framework I developed recently. It combines agent-based assumptions with a hierarchical network architecture for human society, and captures the daily dynamics of the spread of infection in a highly heterogenous population.

• **Integrating health and economic parameters to optimize COVID-19 mitigation strategies**

Alik Sokolov, Yichao Chen*, Jonathan Mostovoy, Andrew Roberts, Luis Seco, V. Kumar Murty
University of Toronto [1, 2, 3, 5]; Queen's University [4]; Fields Institute for Research in Mathematical Sciences [6]

Abstract: Managing the COVID-19 effectively requires a series of mitigating steps that change over time as function of external conditions and previous mitigating steps. Modeling this effectively requires a multi-disciplinary integrative approach that combines epidemiological, economic and social considerations within a unified modeling environment. Our research focuses on incorporating elements from classical utility theory in combination with control theory and machine learning to better model the dynamics of the non-linear trade-offs inherent in managing the pandemic. We postulate a theoretical formulation on how these trade-offs can be modeled, and demonstrate empirical results to elucidate the limiting factors in finding efficient solutions.

• ESG innovations and the COVID-19 pandemic
Alik Sokolov*, Kyle Caverly, Jonathan Mostovoy, Luis Seco
University of Toronto

Abstract: The COVID-19 pandemic has proven to be a catalyst for the growing ESG industry, with a growing understanding within the investment industry in the importance of integrating ESG criteria into portfolio construction decisions. We propose an approach that combines modern machine learning techniques in Natural Language Processing coupled with portfolio optimization to incorporate views of company ESG performance, curated automatically using large scale news-data, into portfolio management decisions, through incorporating the outputs of a machine learning news data classifier into a Black-Litterman views vector.

■ OPT1 MA 10:00- 11:30

Large scale optimization for routing and distribution problems - I

Chair/Président: Borzou Rostami, Wilfrid Laurier University

• Optimal transportation and pricing policies for perishable products supply chains
Sara Babaee*, Mojtaba Araghi, Borzou Rostami
Wilfred Laurier University

Abstract: In this paper, we investigate a supply chain in which a distributor procures perishable products, transports them along the supply chain through distribution centers, and sells them at retail stores. The distributor utilizes tracking technologies to gather updated information on the quality of the products. The objective is to jointly optimize quality-based transportation decisions and pricing policies. We model the problem as a mixed-integer quadratic programming, exploit the special structure of our formulation and develop a benders type decomposition method. We tested our model and solution methodology on the lettuce product distribution network of a known retail chain in Canada.

• Column generation for a class of quadratic combinatorial optimization
Mahdis Bayani*, Borzou Rostami, Louis-Martin Rousseau, Yossiri Adulyasak
Polytechnique Montréal [1, 3]; Wilfrid Laurier University [2]; HEC Montréal [4]

Abstract: Binary Quadratic Problem (BQP) arises in a wide variety of applications in computer vision, management and scheduling among others. BQP is a combinatorial optimization problem with binary variables, quadratic objective function and linear/quadratic constraints. Solving general BQPs are known to be NP-hard. In this research, we discuss a class of BQP with a special structure of the quadratic cost under a unifying framework. This specific structure grants using decomposition method based on Column Generation to solve the model efficiently. The experiments and results of the study are represented for Multi Object Tracking in computer vision and Quadratic Semi-Assignment problem.

• Interactions in routing optimization
Borzou Rostami*
Wilfrid Laurier University

Abstract: This paper studies the routing optimization in the presence of interaction between routes. The interaction is defined as situations where the solution cost/benefit corresponding to a decision is affected (i.e., non-additive effects) by other decisions and is either the result of dependency between decisions or correlation in large-scale stochastic data. We propose a unifying mixed-integer quadratic set partitioning type formulation for the problem and develop an exact solution method. Our methodology relies on a linearization, a Benders decomposition, and a column generation approach. The applications of our approach to some important problems in routing and scheduling show very promising results.

• On-time delivery in routing optimization with stochastic and correlated travel times
S. Davod Hosseini*, Borzou Rostami, Mojtaba Araghi

Wilfrid Laurier University

Abstract: We study on-time delivery in routing optimization with stochastic and correlated travel times under two different modeling frameworks. While the first model uses the total variance of reaching each customer to design a service time window, the second model, on the other hand, provides a robust framework to minimize the risk of the customers' time window violations. These result in mixed-integer conic programming formulations that are solved using decomposition approaches.

■ OPT20 MA 10:00- 11:30

Optimization in healthcare - I

Chair/Président: Gilles Reinhardt, Université d'Ottawa

• Framework for drug formulary decision using multiple criteria decision analysis

Vusal Babashov, Sarah Ben Amor, Gilles Reinhardt*
University of Ottawa

Abstract: Reviewing drugs to determine coverage or reimbursement level is a complex process that involves significant time and expertise. This involves assessments on multiple criteria that often conflict with one another. We propose a Multiple Criteria Decision approach that infers a utility model based on reviews of previously submitted drugs. We deconstruct a set of drugs that have been reviewed and derive global and marginal utility functions consistent with the recommendations. We apply the method to oncology drugs reviewed in Canada between 2011 and 2017. We also illustrate how to conduct scenario analyses and predict the coverage decisions for new drugs.

• A multiple-criteria clustering approach for k-best choice decision problem

Makbule Kandakoglu*, Grit Walther, Sarah Ben Amor
RWTH Aachen University [1, 2]; University of Ottawa [1, 3]

Abstract: We propose a multiple-criteria clustering approach to the k-best choice decision problem with decision-maker' preferences and resource constraints. We combined PROMETHEE outranking method and the K-medoids clustering technique. The multicriteria preference degrees generated for each pair of alternatives by PROMETHEE are used as a measure of distance between the alternatives. Based on these distances, an extension of the K-medoids clustering algorithm is developed through an Integer Programming (IP) formulation to partition the alternatives into ordered clusters. The IP model identifies the best cluster, namely the set of k-best alternatives, by introducing resource constraints and other constraints to only this cluster.

• An adjustable robust optimization approach to personnel scheduling under uncertain demand: A case study at pathology department

Roshanak Mahdavi*, Jonathan Patrick, Sarah Ben Amor
University of Ottawa

Abstract: Scheduling decisions have always been a challenge when the information about the demand is not available ahead of time. In this research, we address a multi-objective personnel scheduling problem where the personnel' workload is uncertain and propose a two-stage robust modeling approach with demand uncertainty. As a case study, the proposed model and the proposed solution approach are applied to an existing scheduling model in the Pathology Department at The Ottawa Hospital. It is shown that the model is successful at reducing the unmet demand while maintaining the performance with respect to other metrics when compared against the deterministic alternative.

• Multiobjective linear programming models for sector duration optimization problem in radiosurgery

Oylum Şeker*, Mucahit Cevik, Merve Bodur, Young Lee, Mark Ruschin
University of Toronto [1, 3]; Ryerson University [2]; Sunnybrook Health Sciences Centre [4, 5]

Abstract: We present a multiobjective linear programming model with five objectives, incorporating conflicting goals of the treatment plan, such as dose limitations for targets and avoidance structures. We propose a two-phase solution strategy that utilizes the epsilon-constraint method, with two alternative courses of implementation. The first phase explores solutions from all parts of the feasible region, while the second aims to achieve an even denser representation of clinically desirable solutions. We generate a collection of solutions, offering flexibility to decision makers to select one that best suits patient-specific needs, and show the efficacy of our approach on previously treated real cases.

■ SMS9 MA 10:00- 11:30

Queueing meets machine learning

Chair/Président: Arik Senderovich, University of Toronto

• Waiting-time prediction with invisible customers

Yoav Kerner, Ricky Roet-Green, Arik Senderovich, Yaron Shaposhnik, Yuting Yuan*
Ben-Gurion University of the Negev [1]; University of Rochester [2, 4, 5]; University of Toronto [3];

Abstract: We study the problem of predicting customers' waiting time in queues when some customers are invisible. We derive closed-form expressions for this problem in a partially visible M/M/1 queue. Based on insights of this simple case, we design relevant features and demonstrate their effectiveness for prediction in more general queues.

• Congestion graphs for improved time predictions in queueing systems

Arik Senderovich*
University of Toronto

Abstract: Time prediction is an essential component of decision making in various application areas, including transportation systems, healthcare, and manufacturing. In this work, we focus on time prediction in congested systems, where entities share scarce resources. We show that in order to achieve accurate and explainable time prediction, features describing system congestion are required. To this end, We propose the model of congestion graphs and show how congestion graphs are mined from raw event data. We evaluate our approach on two real-world datasets from healthcare systems where scarce resources prevail: an emergency department and an outpatient cancer clinic.

• Queueing theory and machine learning for predicting waiting times

Elisheva Chocron, Izack Cohen, Paul Feigin*
Technion - Israel Institute of Technology [1, 3]; Bar-Ilan University [2]

Abstract: Waiting time prediction is a challenging problem in service systems. Recently, research has been conducted in domains such as public health, retail banking and telecommunications. Articles have typically focused on specific systems, recommending solutions based on Queueing Theory (QT) principles or Machine Learning (ML) algorithms, or combinations of both. In this work, a comparison is made between different Queueing Theory and Machine Learning approaches as applied to a variety of systems. Situations are characterized where basic QT methods, after minimal adaptation, are robust enough to be the method of choice. Under other scenarios, ML predictions can outperform basic QT predictions.

■ AIML4 MA 10:00- 11:30
Reinforcement learning

Chair/Président: **Chi-Guhn Lee**, University of Toronto

• Understanding implicit motivation of an expert in inverse reinforcement learning

Babatunde Giwa*, Chi-Guhn Lee
University of Toronto

Abstract: Inverse reinforcement learning (IRL) is primarily concerned with explaining behavior of an expert by learning a reward function. We consider the important task of understanding an implicit motivation of an expert in IRL to facilitate a more insightful explanation of behavioral data. Based on a linear approximation of the reward function in features, the mathematical framework of Markov decision process (MDP) coupled with a likelihood function enables realization of our estimates in a gradient-based manner. We utilize behavioral data from the classical benchmark(s) with experiments and numerical studies to show that our estimation approach is viable.

• Attentive Gaussian processes for probabilistic time-series generation

Kuilin Chen*, Chi-Guhn Lee
University of Toronto

Abstract: We propose a network architecture combined with the Gaussian process regression to generate real-valued sequence, which we call the Attentive-GP. The attention mechanism not only dispenses recurrence and convolutions, but also leads to significantly improved training speed. Moreover, the GP layer naturally learns the factorized generative distribution with Bayesian representation. Also presented is a blockwise training algorithm to train the proposed model effectively, whose convergence has been mathematically proved. The algorithm can be used in training of a wide range of hybrid models such as neural networks with kernel machine layers with limited resources in computation and memory.

• Symmetry augmentation for time series reinforcement learning

Amine Mohamed Aboussalah*, Chi-Guhn Lee
University of Toronto

Abstract: Inspired by recent successes of deep learning in computer vision, we improved statistical pattern identification by encoding the co-occurrence and the latent states of univariate financial time series data into a high-dimensional heterogeneous state-space. We exploited the benefits of the translational invariance property of unsupervised convolutional neural network to learn financial features (symmetries) that will help the reinforcement learning agent better understand the dynamics of the underlying physical sys-

tem to better control it. We applied the formalism of group theory and representation theory to ensure an irreducible and richer representation, so we can fully utilize all the possible hidden features.

• Improving the sample efficiency of model-free reinforcement learning using Bayesian mixtures of experts

Michael Gimelfarb*, Scott Sanner, Chi-Guhn Lee
University of Toronto

Abstract: Despite recent advances in reinforcement learning, sample efficiency remains a genuine concern in many applications. This often arises in settings with sparse reward signals or due to lack of exploration. To tackle this problem, we present a Bayesian framework for improving the reward signal for value-based agents by incorporating advice (experts) from multiple sources. We show how approximate Bayesian inference can be used to learn a good mixture of experts efficiently in an on-line setting. To demonstrate the versatility of this approach, we apply it to develop an exploration policy that can adapt its behavior based on the agent's experience.

■ Tutorial MA 10:00-11:00

Conducting research in AI, ML, and OR for social good

Chair/Président: Merve Bodur , University of Toronto

• Conducting research in AI, ML, and OR for social good

Phebe Vayanos*
Assistant Professor of Industrial & Systems Engineering and Computer Science, University of Southern California

Abstract: In the last decades, significant advances have been made in AI, ML, and OR. Recently, systems relying on these technologies are being transitioned to the field with the potential of having tremendous influences on people and society. With increase in the scale and diversity of deployment of algorithm-driven decisions in the open world come several challenges including the need for robustness, interpretability, and fairness which are confounded by issues of data scarcity and bias, tractability, ethical considerations, and problems of shared responsibility between humans and algorithms. In this talk, we discuss work in collaboration with community partners and policy-makers to identify and solve problems related to deployment of AI systems in the open world. We focus on the problems of homelessness and public health in low resource and vulnerable communities and present research advances in AI, ML, and OR to address one key cross-cutting question: how to assign scarce intervention resources in these domains while accounting for the challenges of open world deployment? We will show concrete improvements over the state of the art in these domains based on real world data. We are convinced that, by pushing this line of research, AI, ML, and OR can play a crucial role to help fight injustice and solve complex problems facing our society.

■ SPCU MA 10:00- 11:30

Student paper competition, undergraduate

Chair/Président: Nadia Lahrichi , Polytechnique Montréal

• Paper Competition Undergraduate

Abstract: Each year CORS conducts a student paper competition to recognize the contribution of a paper either directly to the field of operational research through the development of methodology or to another field through the application of operational research. The competition serves to showcase the high quality of OR education in Canada as well as the excellence of the new generation of operational researchers. Prizes are awarded in two categories: Undergraduate and Open.

■ OSM1 MA 10:00- 11:30

Stochastic modeling and learning in operations management

Chair/Président: Sheng Liu, University of Toronto

• Robust control of Bayesian newsvendor problems

Ya-Tang Chuang*, Michael Kim
McMaster University; University of British Columbia

Abstract: This paper is concerned with optimal inventory control in the presence of model misspecification and statistical learning. We are interested in how decision makers can remain robust to model uncertainty while also learning at the same time. To this end, we introduce a new class of optimization problems: robust Bayesian optimization problems. Such problems contain elements from both Bayesian modeling and robust optimization. The main result shows that the decision maker' optimal decision can be expressed as a myopic decision plus an exploration boost, and minus a robust adjustment, which explicitly explains the trade-offs between optimization, robustness and learning.

• Learning heuristics for mixed integer programming

Elias Khalil*
University of Toronto

Abstract: We present a framework for learning heuristics for integer programming problems in the following setting: given a MIP model (e.g. assignment) and a set of training instances of this problem, the task is to automatically derive a heuristic that efficiently finds feasible solutions for many of these instances. The main driver of this method, a penalty function for fractional variables, is tuned via gradient descent over the training instances so as to encourage finding constraint-feasible integer solutions in few iterations. Experimentally, the proposed framework produces competitive heuristics for a variety of MIP problems with relevance in operations research.

• Flexibly serving a finite number of heterogeneous jobs in a tandem system

Yunfong Lim, Bingnan Lu*, Rowan Wang, Wenjia Zhang
Singapore Management University [1, 3]; University of Minnesota [2]; Chinese University of Hong Kong, Shenzhen [4]

Abstract: Many manufacturing and service systems require a finite number of heterogeneous jobs to be processed by two stations in tandem with a finite buffer in between. We consider two flexible servers that are cross-trained to work at both stations. The duration for a server to finish a job at a station is exponentially distributed with a rate that depends on the server, the station, and the job. We derive the expected makespan of any general non-idling policy. We also analyze the performance of three simple non-idling policies, and extend the model to incorporate moving costs and service defects.

• A robust optimization model for green supplier selection and order allocation in a closed-loop supply chain considering cap-and-trade mechanism

Hossein Mirzaee*, Hamed Samarghandi, Keith Willoughby
University of Saskatchewan

Abstract: We present a green supplier selection problem in a closed-loop supply chain considering cap-and-trade mechanism and propose a multi-objective robust optimization model to deal with the problem. The developed model is solved for randomly generated data. We demonstrate that the generated solutions are in fact optimal through a trade-off in model robustness and solution robustness, as well as investigating the effect of deviation penalty on the results. Furthermore, we present a sensitivity analysis on carbon allowance amount and allowance prices. Finally, the superiority of the cap-and-trade mechanism over the penalty-based system is demonstrated.

■ QUE2 MA 10:00- 11:30

Analysis and design of modern queueing systems

Chair/Président: **Mohammad Delasay**, Stony Brook University

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• Size-based scheduling with estimation errors

Maryam Akbari Moghaddam*, Douglas Down
McMaster University

Abstract: When job sizes are known, Shortest Remaining Processing Time (SRPT) is known to be an optimal (in a very strong sense) scheduling policy for a single server queue under general assumptions on underlying random variables. However, the performance of SRPT is known not to be robust to errors in processing time estimates. For a popular error model, we characterize the optimal policy using a Gittins Index approach and discuss its properties. The implementability of the policy is studied, with suggestions for improvements in this regard. Time permitting, issues for multiple server queues will be highlighted.

• Evaluating capacity planning methods for loss systems

Mohammad Delasay, Armann Ingolfsson, Amir Rastpour*
Stony Brook University; University of Alberta; University of Ontario Institute of Technology

Abstract: We evaluate the accuracy of the stationary independent period-by-period (SIPP) and modified offered load (MOL) methods for capacity planning of loss systems with continuous random cyclic demands. Focusing on the specifications of service systems, we show that SIPP and MOL might miss the quality of service targets drastically.

• A queueing-theoretic framework for evaluating transmission risks in service facilities during a pandemic

Kang Kang*, Sherwin Doroudi, Mohammad Delasay, Alexander Wickeham
University of Minnesota [1, 2, 4]; Stony Brook University [3]

Abstract: We propose a new modeling framework for evaluating the risk of disease transmission during a

pandemic in small-scale settings driven by arrival and service stochasticity, i.e., congestion-prone confined-space service facilities, such as grocery stores. We propose a novel metric inspired by R0, the "basic reproduction number" concept from epidemiology, which measures the transmissibility of infectious diseases. We derive our metric for various queueing service systems by leveraging a novel notion: sojourn time overlaps. We showcase how our metric can be used to explore the efficacy of a variety of interventions aimed at curbing the spread of disease inside service facilities.

• **Delay information sharing in two-sided queues**
Mehmet Aydemir, Mohammad Delasay*, Siddharth Singh, Mustafa Akan
Carnegie Mellon University [1, 4]; Stony Brook University [2]; University College London [3]

Abstract: We model an on-demand platform as a two-sided queueing system and study its delay information disclosure policy when the platform serves two classes of strategic users (consumers and providers) who seek matches to each other using the platform. Users on each side decide whether to join the system or balk based on their expected delay to be matched, conditional on the information provided by the platform to them. We consider different delay information-sharing regimes and compare the matching rates (a proxy for the platform' profit) under these regimes.

■ PRM1 MA 10:00- 11:30
Applications in dynamic pricing

Chair/Président: Guang Li, Queen's University

• **Dynamic pricing under trade-in programs**
Murray Lei*, Sean Zhou, Zhuoluo Zhang
Queen's University [1]; Chinese University of Hong Kong Business School [2, 3]

Abstract: We study a dynamic pricing problem where a firm sells both new and used products. The firm acquires used products through trade-in programs, where customers sell their used products either for cash or for upgrade credits. We analyze the property of the optimal policy and propose near-optimal pricing policies.

• **Oblivious equilibrium on online small seller platforms**
Guang Li*, Mikhail Nediak, Shweta Singh
Queen's University [1, 2]; Warwick University [3]

Abstract: We study the pricing and waiting behaviour of individual sellers in an electronic marketplace and discuss its implications for design of price recommendation systems that target seller trade-off between revenue and time to sell. We find that there exists a stationary distribution for the oblivious equilibrium under which each seller's strategy is oblivious to the other competitors' pricing strategy.

• **Selling and renting mechatronics (digitally controlled physical goods)**
Anton Ovchinnikov, Guang Li, Xianfeng Meng*
Queen's University

Abstract: Goods are always differentiated to meet the demand of various customers. In digital business, firms are adept at offering a subscription or upgrading price to their existing low-level product users for their high-level product. In the physical world, this seldom happens because of the production/upgrading cost. However, more and more exceptions are emerging where there is no hardware difference between a high-level and a low-level physical product. We look into this scenario in the paper by analyzing if it is beneficial for the firm to provide a renting/upgrading option to the existing low-level product users.

■ IND5 MA 10:00- 11:30
Analytics journeys

Chair/Président: Jeremy Adamson, Westjet

• **The blue-collar ai workforce imperative**
Aaron Burciaga*
ECS

Abstract: During this session, Aaron Burciaga CAP, will review the challenges industry and governments are having in developing a qualified and scalable workforce. Aaron will outline the strategies for how to build a "Blue-Collar AI Workforce" with the cooperation of educational institutions, companies and government agencies. Having developed Analytics Centers of Excellence for Fortune 100 Companies, growing and leading teams of over 400 data scientists, and being key advisor to government officials on the establishment of AI programs, Aaron will share how to deliver more "Practical AI" – as in how to design, build, test, deploy, and manage AI systems that matter.

• **Minding the machines: Building and leading analytics teams**
Jeremy Adamson*, Yanik Lacroix Torrent
WestJet

Abstract: Data science and analytics has moved from being an investment in the future to a core component of corporate strategy. In the rush to stand up this new practice, many organizations have had struggles in re-

alizing value. This presentation would provide insights into how to set up an effective practice by focusing on People, Process, and Strategy, and use the specific case of WestJet' recent reboot of their Revenue Management & Pricing Analytics function. This is based on an upcoming book by the same name.

• **THINKING BIG - starting small - A machine learning journey**

Marcie Jones*, Jason Sidhu
TC Energy

Abstract: An enterprise journey in adoption of Machine Learning to unlock high value business opportunities. Learning how to lead experimentation through partnership, patience, and persistence.

• **Benefit from brilliance in AI**

Thom Ives*
UL Prospector

Abstract: As those that love data science, AI, ML, STEM, and more, we learn amazing things. Brilliance is exploding all around us at an ever-increasing rate. There are ways to personally benefit from this brilliance in all areas of our lives. Thom wants to invite you to join him as fellow students of Integrating Brilliance and show you how we can all have MORE TOGETHER!

■ SCM4 MA 10:00- 11:30

Sales and project management decisions in supply chains

Chair/Président: Longyuan Du, University of San Francisco

• **Scheduling projects with uncertain lead times and volatile status**

Ting Wu*, Emily Zhu
Nanjing University; Texas State University

Abstract: This study investigates the optimal strategy of scheduling projects with uncertain lead time and unobservable status, which can change before and when processing them. Specifically, we would like to understand the impacts of preempting unfinished projects and the associated capacity decisions, using queueing and optimization methods.

• **Optimal pricing and production decisions for (re)manufacturing in a dual-channel closed-loop supply chain**

Zhuojun Liu*, Jing Chen, Claver Diallo, Uday Venkatadri
Dalhousie University

Abstract: This work deals with the development of a two-period model for a closed-loop supply chain with dual channels. A monopolistic manufacturer sells new products through a physical channel via a retailer and on its online channel. Remanufactured products are only sold by the manufacturer on its online channel. This study investigates the optimal pricing and production strategies for both the manufacturer and the retailer and identifies the conditions under which the manufacturer should engage in remanufacturing. Numerical experiments provide managerial insights and implications by examining the sensitivity of the optimal solutions to key modelling parameters.

• **A probabilistic model for predicting task accomplishment time based on Bayesian network**

Negin Asadayoobi*, Sharareh Taghipour, Mohamad Jaber
Ryerson University

Abstract: The time needed for accomplishing a task is a primary measure of human performance. Ignoring the uncertain nature of accomplishment time, especially in stressful and time-sensitive tasks (e.g., search-and-rescue), can lead to wrong planning decisions causing, probably, irreparable damage. This study uses a Bayesian Network that incorporates individuals' prior experience, accumulated stress and fatigue, and learning level as leading factors in predicting accomplishment time. The novelty of the proposed model is in the new dimension it introduces, i.e., the number of repetitions of each task type performed, where performance attained in previous tasks affects some leading factors of subsequent ones.

• **Sales effort management under all-or-nothing constraint**

Longyuan Du*, Ming Hu, Jiahua Wu
University of San Francisco; University of Toronto; Imperial College London

Abstract: We consider a sales effort management problem under the all-or-nothing constraint. The seller will receive no bonus/revenue if sales volume fails to reach a predetermined sales target at the end of the sales horizon. Throughout the sales horizon, the sales process can be moderated by the seller through her costly effort. We show that the optimal sales rate is non-monotone with respect to the remaining time or the outstanding sales volume. We then study easy-to-compute heuristics that can be implemented efficiently. We propose a modified resolving heuristic and show that it is asymptotically optimal, and achieves a logarithmic performance loss.

■ Plenary MA 11:30- 12:45

Welcome, and the Harold Larnder Memorial Lecture by Anna Nagurney

Chair/Président: Fatma Gzara, CORS Chair (University of Waterloo)

• Novel supply chain network models inspired by the COVID-19 pandemic - From optimization to game theory

Anna Nagurney
John F. Smith Memorial Professor of Operations and Information Management, University of Massachusetts Amherst

Abstract: The COVID-19 pandemic has dramatically illustrated the importance of labor (and its health and availability) to supply chains from food to healthcare. The pandemic has also revealed the fierce global competition for personal protective equipment (PPEs) and other medical supplies. In this presentation, I will overview some of our timely research on the development and solution of a spectrum of network-based supply chain optimization and game theory models that are inspired by such issues. I will also discuss how our work has influenced policy and decision-makers in the pandemic.

■ CHOW B MB 13:30- 15:00

Econometric modeling in healthcare

Co-Chairs/Présidents: Andre Cire, University of Toronto Scarborough
Co-Chairs/Présidents: Adam Diamant, York University

• Partnering with healthcare organizations on empirical research

CHOW Planery: Anita Tucker
Professor, Questrom School of Business, Boston University

Abstract: This presentation will provide an overview of several ongoing research projects conducted in collaboration with healthcare organizations. There are two broad categories of projects: (1) quantifying and solving a problem faced by the organization; and (2) testing the impact of an organizational change. More specifically, the topics include patient flow, ED boarding, medication shortages, and performance feedback systems. The talk will also focus on the empirical method challenges that need to be overcome, and the approaches used to handle these problems.
Bio: Dr. Anita L. Tucker is a professor of operations and technology management at Boston University Questrom School of Business. Her research aims to improve the quality and efficiency of health care delivery. Professor Tucker conducts research with many healthcare organizations including Kaiser Permanente, Beth Israel Deaconess, and Boston Medical Center. She is an Everett W. Lord Distinguished Faculty Scholar, a Senior Fellow at Boston University's Institute for Health System Innovation and Policy, and a Trustee for the Boston University Medical Group. She is a department editor for M&SOM's Environment, Health and Society department, and an associate editor at Management Science.

• The Cost of Task Switching: Evidence from the Emergency Department

Technical Speaker: Yiwen Jin
University of British Columbia

Abstract: Emergency department physicians treat patients with different symptoms that require constant switching of tasks. Using a comprehensive data set with over 650,000 patient visits to four emergency departments, we investigate the impact of task switching on physician productivity. Our instrumental variable estimation, which exploits the exogenous composition of waiting patients, indicates that switching between patients of different types increases the average pick-to-pick time by 4.9 to 14.7 percent, which is 1.1 to 3.1 minutes per patient. The switch cost likely reflects both a time-consuming cognitive reconfiguration process and interference between tasks. Task switching also affects how physicians route patients, although we find little impact on healthcare quality. Our counterfactual analysis further reveals that the switch cost may have increased the average waiting time per patient by 14 minutes and the average waiting census by 1.6 patients. Our research has important managerial implications for how switch costs can be addressed to improve workplace efficiency.
Bio: Mr. Yiwen Jin is a third year PhD student at Sauder School of Business, University of British Columbia, advised by Prof. Yichuan Ding, Prof. Mahesh Nagarajan and Prof. Steven Shechter. He is broadly interested in data-driven analytics with applications to healthcare and other public sector problems. His researches have been published on Plastic Surgery and Plastic and Reconstructive Surgery - Global Open and have been presented at INFORMS 2020, INFORMS 2021, AEA 2021. He has been awarded with the Shelby Brumelle Memorial Graduate Scholarship at Sauder School of Business and he is now a co-PI of a project funded by CIDER Small Grants in Innovative Data.

■ MDS2 MB 13:30- 15:00

HR management

Chair/Président: Steve Guillouzic, Defence Research and Development Canada

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• Modelling the mentee-mentor population dynamic in military occupations

Samuel Schaffel*, François Bourque, Macauley MacDowell, Slawomir Wesolkowski
Defence Research and Development Canada [1, 2]; Royal Canadian Air Force [3, 4]

Abstract: Absorption in military workforce modelling is often limited to maintaining the personnel based on a healthy state. The mentoring process is rarely modelled to realistically represent the absorption of new personnel under varied occupational health conditions, including high ratios of mentees to mentors. To explore this dynamic, a two-state model is introduced where mentees upgrade to mentors, and the training capacity is modulated by the number of mentors. A continuous and deterministic model is explored, and then compared to a discrete stochastic simulation. The models consider a hypothetical military occupation in which the mentor-mentee relationship is important for career progression.

• Impact of demographic change on Canadian Armed Forces recruitment

Allyson Dale*, Nancy Otis
Director General Military Personnel Research and Analysis

Abstract: An International Working Group was assembled to examine the impacts of demographic change (e.g., decline in working age population, increasing ethnic diversity) on armed forces' personnel recruiting. An online survey was developed to examine subject matter experts' views in this domain. The vast majority (91.7%) of Canadian experts (N = 24) believed demographic change is already impacting or will be impacting the Canadian Armed Forces (CAF) in the next ten years. Enhancing work-life balance was identified as the most effective measure in facing the demographic change. Recommendations that will likely help the CAF organization to adapt and evolve are discussed.

• Simulation of personnel training and resource allocation at Canadian naval fleet schools

Trisha Huber*, Cheryl Eisler, Stephen Okazawa
Defence R&D Canada

Abstract: A stochastic model for training has been developed for the Royal Canadian Navy permitting the simulation of student intake and demand for training resources (personnel and infrastructure) at Canadian Naval Fleet Schools. Courses are offered on a supply and demand basis, applying local business rules. Training details are input into a generic model, permitting changes to almost all aspects of training (intake, requirements, resources, timing, and thresholds). A training example demonstrating the personnel and infrastructure supply and course demand will be presented, along with associated output metrics, such as graduation rate, average student wait time, and average instructor loading.

• The influence of psychological empowerment on job burnout and subsequent turnover intentions among junior non-commissioned members of the Canadian Armed Forces

Matthew Huebner*, Laura Seidel
National Defence

Abstract: The purpose of the present study was to examine the relations between the dimensions of psychological empowerment (i.e., meaning, competence, impact and autonomy), burnout and subsequent turnover intentions among Junior Non-Commissioned Members of the Canadian Armed Forces. Responses from 2606 participants were analyzed using structural equation modelling. Burnout significantly and positively predicted turnover intentions but meaning and competence did not significantly predict burnout. Autonomy significantly and negatively predicted burnout. Interestingly, impact significantly and positively predicted burnout. These findings demonstrate that while personal work-related flexibility can help alleviate burnout, excessive influence can actually have a negative impact on members' well-being.

■ SG4 MB 13:30- 15:00

OR for vulnerable populations

Chair/Président: Andy Trapp, Worcester Polytechnic Institute

• Design of lotteries and waitlists for affordable housing allocation

Nick Arnosti*, Peng Shi
Columbia Business School; USC Marshall School of Business

Abstract: We study a setting in which items are assigned to waiting agents with heterogeneous values and outside options. An ideal match would target items to agents with the worst outside options, and match agents to items for which they have high value. We show that two common approaches (using independent lotteries for each item, and using a waitlist in which agents lose priority when they reject an offer) lead to identical outcomes in equilibrium. Both approaches encourage agents to accept marginal fits. The quality of the match can be improved by using a common lottery for all items.

• Improving outcomes in child care subsidy voucher programs under regional asymmetries
Priyank Arora*, Wei Wei, Senay Solak
University of Massachusetts Amherst

Abstract: Motivated by the emphasis in UN Sustainable Development Goals on providing equitable access to opportunities for low-income families, we study allocation of funds across supply-side activities by the U.S. Child Care Resource and Referral agencies (CCR&Rs) that administer child care subsidy voucher programs in their designated service areas. Using a proportionally fair objective, we consider that the CCR&R makes its investment decisions to minimize an inequity measure, which captures the fairness in terms of the propensity of acceptance of the available voucher across IE families residing in different regions of the CCR&R's service area.

• Improving child welfare outcomes via market design
Vincent Slaugh*, Mustafa Akan, Onur Kesten, Utku Unver
Cornell University [1]; Carnegie Mellon University [2, 3]; Boston College [4]

Abstract: We describe the problem of choosing a family to recommend as a possible adoptive match for a child from a market design perspective. We also provide lessons learned from pilot implementations of the Family-Match platform in two states.

• Integrating vehicle routing and scheduling to optimize foster care visitations
Caroline Johnston*, Shima Azizi, Katharine Dunphy, Renata Konrad, Andrew C. Trapp
University of Southern California [1]; Worcester Polytechnic Institute [2, 3, 4, 5]

Abstract: Foster care visitation scheduling refers to the assignment of drivers and case workers to route foster care children to and from visitation meetings with their biological parents. Motivated by the need to increase the throughput of an actual resource-constrained foster care agency, we develop a mixed-integer optimization model in order to embed it inside of an automated scheduler for staff planning purposes. By generating routes through multiple locations using concurrent driver, case worker, child, and parent availability, we determine a feasible schedule that maximizes the number of weekly visits. We demonstrate our computational results using real data from the agency.

■ FRM2 MB 13:30- 15:00

Quantitative finance: Options, simulation, long-run risk and Bloomberg's new platform

Chair/Président: Gabriel Power, Université Laval

• One simulation is all you need
Pascal Letourneau, Lars Stentoft*
University of Wisconsin Whitewater; University of Western Ontario

Abstract: This paper develops a fast and numerically efficient method for pricing options, particularly with early exercise features, with state-of-the-art simulation and regression based methods. Using nothing but homogeneity of the option price, a property of most option pricing models, and initial dispersion of state variables we show how a single simulation can be used to price a panel of options. Compared to pricing one option individually the cost of pricing additional options is negligible and involves at most a simple cross-sectional regression and evaluating the resulting function approximation at relevant moneyness ratios.

• Simulated Greeks for American options
Pascal Letourneau*, Lars Stentoft
University of Wisconsin Whitewater; University of Western Ontario

Abstract: This paper considers estimation of price sensitivities, so-called Greeks, for American style options using flexible simulation methods combined with initially dispersed state variables. Asymptotic properties of the estimators are studied, and convergence of the method is established under mild regularity conditions. A 2-step method is proposed with an adaptive choice of optimal initially dispersed state variables, that controls and balances off the bias of the estimates against their variance. Numerical results show that the method works extremely well for very reasonable choices of spread sizes, regressors, and simulated paths and demonstrate that the proposed method compares well to existing alternatives.

• On time-consistent multi-horizon portfolio allocation
Simone Cerreia-Vioglio, Fulvio Ortu, Francesco Rotondi, Federico Severino*
Università Bocconi [1, 2, 3]; Université Laval [4]

Abstract: We analyse the problem of constructing multiple mean-variance portfolios over increasing investment horizons in stochastic interest rate markets. Traditional one-period mean-variance optimal portfolios of Hansen and Richard require the replication of two payoffs (one associated with the pricing kernel). When several maturities are considered, different pay-

offs must be replicated each time, with an impact on transaction costs. Using martingale decompositions and risk-adjusted measures at increasing maturities, we provide an intertemporal version of the traditional orthogonal decomposition of asset returns. Then, we construct a multi-horizon mean-variance frontier that is time-consistent and requires the replication of solely two payoffs for all horizons.

• Ross recovery, volatility forecasts and the pricing kernel

Gabriel Power*, Marie-Hélène Gagnon, Dominique Toupin
Université Laval

Abstract: The recovery theorem shows that option data can reveal the market' true (physical) expectations. We adapt this approach to international index options data (S&P, FTSE, CAC, SMI, and DAX) and separate implied volatility into Ross-recovered expected volatility and a risk preference proxy. We investigate the volatility forecasting performance of these variables, constructed domestically or globally. The results show evidence of significantly improved forecasts, and yield new insights on the international dynamics of risk expectations and preferences. Across indexes, models using Ross-recovered, value-weighted global measures of risk preferences perform best. The findings suggest that the recovery theorem is empirically useful.

■ OPT2 MB 13:30- 15:00

Integer programming and applications

Chair/Président: Samir Elhedhli, University of Waterloo

• Automatic structure detection in mixed integer programs

Taghi Khaniyev*, Matthew Galati, Samir Elhedhli
Massachusetts Institute of Technology; SAS Institute, Inc.; University of Waterloo

Abstract: Bordered block diagonal structure in constraint matrices of integer programs lends itself to Dantzig-Wolfe decomposition. We introduce a new measure of goodness to capture desired features in such structures. We, then, propose a new approach to identify the best structure inherent in the constraint matrix. The main building block of the proposed approach is community detection which alleviates one major drawback of the existing approaches: predefining the number of blocks. When tested, the proposed algorithm was found to identify structures that lead to significant improvements both in computation time and optimality gap compared to those detected by the state-of-the-art.

• Blockchain-enabled supply chains: An application in fresh-cut flowers

Paulo de Carvalho*, Joe Naoum-Sawaya, Samir Elhedhli
University of Waterloo [1, 3]; Western University [2]

Abstract: Supply chains have often benefited from breakthroughs in information technology. Most recently, blockchain technology is promising to revolutionize the way supply chains are designed and operated. We propose a framework to optimize the adoption of blockchain technology along the supply chain which accounts for the cost of deployment as well as profitability. The framework is evaluated in a realistic case study inspired by the global supply chain of fresh-cut flowers. The value of the resulting product differentiation on consumers and the supply chain are discussed and insights are presented.

• Risk based allocation of COVID-19 critical supplies and equipment under limited availability

Gohram Baloch*, Fatma Gzara, Samir Elhedhli
University of Waterloo

Abstract: We consider a resource allocation problem for personal protective equipment (PPEs) by integrating government supply and procurement decisions with healthcare facilities' PPE usage policy. We present a modelling framework to make these decisions simultaneously to minimize both infection risk and monetary cost to government. We derive closed-form expressions under different objective criteria to present easy-to-use policies to decision makers. A mixed integer quadratically constrained program (MIQCP) is also proposed to handle real-life PPE distribution planning problems. An Ontario-based case is built to derive managerial insights.

• Next-generation quay crane scheduling

Omar Abou Kasm*, Ali Diabat
New York University

Abstract: A recently patented quay crane design has the potential to sufficiently increase the quay side capacity in container terminals. These next-generation cranes can access two bays simultaneously and can operate on four containers at a time. In this work, we introduce a mixed integer programming (MIP) formulation and an exact solution approach to solve the next-generation quay crane scheduling problem. The solution technique breaks the main problem into two sequential stages. The first stage uses a fast set-partitioning formulation, while the second stage uses a partitioning heuristic combined with a branch-and-

price algorithm. Case studies and computational analyses are conducted.

■ OPT22 MB 13:30- 15:00
Graph optimization problems

Chair/Président: Pierre Miasnikof, University of Toronto

• Graph clustering with a permutational Boltzmann machine

Pierre Miasnikof*, Mohammad Bagherbeik, Ali Sheikholeslami
University of Toronto

Abstract: This presentation aims to achieve four goals. We begin with an introduction to the graph clustering problem, an unsupervised learning task. Second, we show how to convert a graph into a distance matrix, for the purpose of clustering. Third, we modify a quadratic binary formulation from the literature, using this distance. Finally, we present the computational performance obtained using a Boltzmann machine, a neural network suited to permutation optimization problems. For benchmarking, we also compare our computational performances against those obtained using a commercial solver.

• Characterization of QUBO reformulations for the maximum k-colorable subgraph problem and quantum computing

Rodolfo Quintero*, David Bernal, Luis Zuluaga, Tamás Terlaky
Lehigh University [1, 3, 4]; Carnegie Mellon University [2]

Abstract: Adiabatic quantum computers have shown to outperform classical computers in solving some particular instances of NP-hard problems, like the Graph partitioning problem. To do this, a Quadratic Unconstrained Binary Optimization (QUBO) formulation is needed. Given that many combinatorial problems, in particular, NP-hard problems, can be formulated as QUBO instances, the interest in getting implementable QUBO formulations of such problems has grown in recent years. In this presentation, we will focus on the QUBO formulations of the independent set and the maximum k-colorable subgraph problems, and some possible limitations to implement them in quantum computers.

• A sparse matrix approach for covering large complex networks by cliques

Wali Mohammad Abdullah*, Shahadat Hossain, Muhammad A. Khan
University of Lethbridge [1, 2]; InBridge Inc [3]

Abstract: A classical NP-hard problem is the Edge Clique Cover problem, which covers edges of a graph with the minimum number of cliques. This problem has many real-life applications. We propose using a compact representation of network data based on sparse matrix data structures in this work. Building upon an existing heuristic, we proffer adding vertices during the algorithm's clique-growing step in judiciously chosen degree-based orders. Our ordered approach produced smaller-sized clique covers than unordered processing taking only linear time on a set of standard benchmark instances and very large-scale instances on Compute Canada clusters.

• Capacity provisioning for evacuation on path networks

Robert Benkoczi, Oluwaseun Lijoka*
University of Lethbridge

Abstract: In this paper, we introduce the problem of allocating capacities to edges of a dynamic path network with n vertices, in such a way that the evacuation completion time towards a single sink node (minmax criterion) is minimized. Our algorithm determines the optimal assignment of capacities to all edges of the network from a given total budget under the assumption that the location of the sink is known. In perspective with other evacuation and sink location problems, our model is suitable for planning the evacuation of remote and sparsely populated areas. We also present relevant analysis to foster our results

■ SMS10 MB 13:30- 15:00
Advances in stochastic simulation

Chair/Président: Sara Shashaani, North Carolina State University

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• Nested simulation for tail risk measure of variable annuity using likelihood ratio estimators

Jessica Dang*, Ben Feng, Mary Hardy
University of Waterloo

Abstract: The computational burden of assessing tail measures of risk for Variable Annuity (VA) portfolios, based on path-dependent nested simulation, may hamper effective risk management, which requires frequent monitoring. In this paper we propose an efficient two-stage nested simulation procedure for tail risk estimation by recycling existing simulation output via a likelihood ratio estimator. The procedure can be applied to nested simulation of a wide range of VA products, including path-dependent GMWBs. Our numerical results show that our proposed procedure is close to two orders of magnitude more accurate than the straightforward nested simulation procedure.

• Evaluating and comparing simulation optimization algorithms

Sara Shashaani*, David Eckman, Shane Henderson
North Carolina State University; Northwestern University; Cornell University

Abstract: Researchers and practitioners benefit from a methodical framework for comparison and evaluation of optimization algorithms, the former for creating new, or improving existing solvers and the latter for choosing the proper solver or suitable configurations of a solver for a problem at hand. Despite considerable effort in designing such frameworks for deterministic optimization algorithms, we argue that unique characteristics and features of simulation optimization problems and solvers demand a revisit to the existing benchmarking measures, as little about them address these differences. We propose new methods and tools through SimOpt, a growing library of problems and solvers within simulation optimization.

• Adaptive importance sampling for efficient stochastic root finding and quantile estimation

Shengyi He*, Guangxin Jiang, Henry Lam, Michael Fu
Columbia University; Harbin Institute of Technology; Columbia University; University of Maryland

Abstract: We investigate the use of importance sampling in solving simulation-based stochastic root-finding or optimization problems that involve rare events, such as in extreme quantile estimation. One significant challenge is that selecting a good importance sampler requires knowledge of the solution, which leads to a circular issue. To break this circularity, we propose an adaptive approach to reach the optimal sampler and the optimal solution simultaneously. Our approach could be embedded in sample average approximation and stochastic approximation algorithms. We support the superiority of our estimators via an asymptotic analysis that reveals the achievement of a minimax asymptotic variance.

• Screening simulated solutions using stochastic gradient estimators

David Eckman*, Matthew Plumlee, Barry Nelson
Northwestern University

Abstract: We have developed methods for screening out suboptimal solutions of simulation-optimization problems based on replications obtained at only a small subset of solutions. This form of screening is especially valuable for problems with large solution spaces, for which enumeration is impractical. Leveraging known or assumed properties of the objective function, e.g., convexity, we assess the plausible optimality of solutions, even unsimulated ones. We enhance the framework to incorporate direct stochastic gradient estimators, introducing a new standardized discrepancy that allows for dependence between objective and gradient estimates.

■ AIML2 MB 13:30- 15:00

Machine learning for combinatorial optimization

Chair/Président: **Maxime Gasse**, Polytechnique Montréal

• Monte-Carlo tree search as regularized policy optimization

Jean-Bastien Grill, Florent Altche, Yunhao Tang*, Thomas Hubert, Michal Valko, Ioannis Antonoglou, Remi Munos
Google DeepMind [1, 2, 4, 5, 6, 7, 8] Columbia University [3]

Abstract: The combination of Monte-Carlo tree search (MCTS) with deep reinforcement learning has led to significant advances in artificial intelligence. However, AlphaZero, the current state-of-the-art MCTS algorithm, still relies on handcrafted heuristics that are only partially understood. In this paper, we show that AlphaZero's search heuristics, along with other common ones such as UCT, are an approximation to the solution of a specific regularized policy optimization problem. With this insight, we propose a variant of AlphaZero which uses the exact solution to this policy optimization problem, and show experimentally that it reliably outperforms the original algorithm in multiple domains.

• Solving mixed integer programs using neural networks

Vinod Nair*
DeepMind

Abstract: Machine learning offers to automatically construct better heuristics from data to use in Mixed Integer Programming (MIP) solvers by exploiting shared structure among MIP instances in the data. We apply learning to the two key sub-tasks of a MIP solver: 1) generating a high-quality joint variable assignment, and 2) bounding the gap in objective value between that assignment and an optimal one. We evaluate our approach on diverse real-world datasets, including two Google production datasets and the standard benchmark MIPLIB, by training separate neural networks on each. Our approach matches or outperforms SCIP on all datasets at large time limits.

• A branch-and-bound algorithm with machine

learning for the open-shop scheduling problem
Salah Eddine Bouterfif*, Vincent Barichard, Martin Cousineau, Christelle Guéret
University of Angers [1, 2, 4]; HEC Montréal - CIRRELT [3]

Abstract: The Open Shop Scheduling Problem has been widely studied in the field of operations research for several decades. The work carried out in this area consists mostly of heuristic methods tailored to specific problems. Very little research have taken into consideration recent advances in machine learning (ML) when improving exact methods for these problems. Our approach consists in using the data resulting from solving a set of randomly generated problem instances to train a neural network that predicts new arcs of a "good" disjunctive graph on the branch and bound. The predictions are used to derive a new branching strategy.

• **Atari-fying the Vehicle Routing Problem with stochastic service requests**
Nicholas Kullman, Martin Cousineau*, Justin Goodson, Jorge Mendoza
Université de Tours [1]; HEC Montréal and CIRRELT [2, 4]; Saint Louis University [3]

Abstract: We present a new general approach to modeling research problems as Atari-like videogames to make them amenable to recent groundbreaking solution methods from the deep reinforcement learning community. The approach is flexible and applicable to a wide range of problems. We demonstrate its application on a well known vehicle routing problem. We compare our "Atari-fied" solution to a traditional benchmark from Operations Research and to the value of an optimal policy with perfect information. Our results suggest that Atari-fication may be a useful modeling approach for researchers studying problems involving sequential decision making under uncertainty.

• **Learning TSP requires rethinking generalization**
Chaitanya Joshi*, Quentin Cappart, Louis-Martin Rousseau
Institute for Infocomm Research, A*STAR [1]; Polytechnique Montréal [2, 3]

Abstract: End-to-end trained neural networks for combinatorial problems such as TSP are intractable and inefficient beyond few hundreds of nodes. While state-of-the-art learnt approaches perform closely to classical solvers for trivially small sizes, they are unable to generalize to larger instances of practical scales. Towards learning to solve large-scale TSPs, this talk identifies inductive biases and model architectures that promote generalization to instances larger than those seen in training. Our controlled experiments provide the first principled investigation into such zero-shot generalization, revealing that extrapolating beyond training data requires rethinking the neural-combinatorial-optimization pipeline, from network layers and learning paradigms to evaluation protocols.

■ FOR2 MB 13:30- 15:00

Forest value chains

Chair/Président: Taraneh Sowlati, University of British Columbia

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• **Bi-objective optimization of supply chain for forest-based biomass gasification in pulp mills considering economic and environmental criteria.**
Maziyar Khadivi*, Taraneh Sowlati
University of British Columbia

Abstract: A bi-objective optimization model at tactical level is developed to minimize total cost and net greenhouse gas emissions associated with monthly transportation, handling, storage, preprocessing and gasification of forest-based biomass in pulp mills. The model determines preprocessing and storage of biomass depending on the quality and monthly availability. Preprocessing occurs at the mill, while storage can occur either at the mill or terminal yard. The model is applied to a pulp mill in BC and a set of Pareto-optimal solutions is obtained using the improved version of augmented ϵ-constraint (AUGMECON2) method to show the trade-off between the objective functions.

• **Supply chain optimization of forest-based biomass for gasification considering uncertainties**
Sahar Ahmadvand*, Taraneh Sowlati
University of British Columbia

Abstract: An optimization model is developed for the tactical planning of supply chain of forest-based biomass gasification at a pulp mill considering uncertainties. The model prescribes the optimal medium-term flow of biomass between supply chain nodes. The objective is to minimize the total cost of biomass procured and fed to the gasifier. The model is constrained by supply, operational capacity, demand, and balancing constraints of the supply chain. Variations in the availability and quality of biomass are considered in the modeling process. The model is applied to the case of a pulp mill in British Columbia.

• **Multi-site reforestation value chain planning**
Mahtabalsadat Mousavijad*, Luc Lebel, Nadia Lehoux, Caroline Cloutier
Laval University

Abstract: A sustainable timber value chain requires efficient reforestation. Matching seed availability to the needs of the reforestation areas' ecological characteristics and allocating them to suitable seedling nurseries depend on many parameters. The main objective of this project is to improve the management of seedling production. Specific objectives are to: (i) Identify methods, techniques and mechanisms developed to optimize the reforestation value chain and similar industries (ex. agriculture); (ii) Create a decision support tool for supply-demand matching and seed allocation; (iii) Develop a model for production planning based on a multi-product, multi-site cultivation system.

• **Canadian forestry supply chain management hit by COVID-19**
Davoud Ghahremanlou*, William Newell
Memorial University of Newfoundland

Abstract: The COVID-19 pandemic crippled the forest industry globally. The Canadian government provided funding to help avoid a major slowdown in this vital sector of economy. However, the industry is shrinking and trying to find creative solutions to stay operational. We propose a mixed integer linear programing model for the forest value chain, including innovative developments in three areas: marketing, process efficiency, and new commodities production. We employ the model, performing a case study within a region of Canada, and conduct a sensitivity analysis to evaluate the model' reaction to the instability resulting from the pandemic.

■ PP MB 13:30- 15:00

CORS Practice Prize

Chair/Président: **Mikael Rönnqvist** , Université Laval

• **Fleet sizing and routing problem with synchronization for AGVs with dynamic demands**
Imadeddine Aziez*, Jean-François Côté, Leandro Callegari Coelho, Victoria D'Anjou
Université Laval

Abstract: In this paper we study the fleet sizing and routing problem with synchronization for AGVs with dynamic demands (FSRPS-AGV). We introduce a mathematical formulation and propose a powerful matheuristic for the FSRPS-AGV. We compare the performance of our matheuristic under different scenarios, showing that it can handle dynamism of demand very well and achieve near-optimal solutions. We assess our methods using small and large instances generated based on real data from an industrial partner. Finally, we provide managerial insights with respect to the number of AGVs and carts that should be acquired by our industrial partner.

■ OSM2 MB 13:30- 15:00

Advances in discrete choice models and pricing

Chair/Président: **Ningyuan Chen**, University of Toronto

• **Adaptive design of personalized dose-finding clinical trials**
Saeid Delshad, Amin Khademi*
Clemson University

Abstract: In this study we extend the result in design of dose-finding clinical trials to incorporate patient covariates. We adapt one-step look-ahead and posterior sampling to the stochastic dynamic programming formulation and analyze these heuristics. We apply our methods to a real data set from a clinical trial.

• **The use of binary choice forests to model and estimate discrete choices**
Ningyuan Chen*, Guillermo Gallego, Zhuodong Tang
University of Toronto [1]; Hong Kong University of Science and Technology [2, 3]

Abstract: We suggest that standard machine learning techniques based on random forests can serve to estimate discrete choice models with an interpretable output. This is confirmed by our data-driven theoretical results which show that random forests can predict the choice probability of any discrete choice model consistently, with its splitting criterion capable of recovering preference rank lists. The framework has unique advantages: it can capture behavioral patterns; it handles nonstandard formats of training data that result from aggregation; it can measure product importance; it can also incorporate price information and customer features. The performance is validated in synthetic and real datasets.

• **Dynamic pricing with money back guarantees**
Ningyuan Chen, Yan Liu*
University of Toronto Mississauga; University of Science and Technology of China

Abstract: In this paper, we study a retailer's money back guarantee (MBG) policy with dynamic pricing of a limited inventory. A key decision for the retailer is to

decide whether to offer MBGs. When the product can be returned instantly, we find that the optimal MBG is a simple threshold policy: given the inventory level, it is optimal to offer an MBG if and only if the remaining selling time is longer than a threshold. We also address the problem of dynamic pricing with positive return times.

• Operational inefficiency vs. prediction error in personalized pricing
Michael Hamilton*
University of Pittsburgh

Abstract: In the age of big data many firms have begun experimenting with personalized pricing strategies, i.e. strategies that predict a customer's valuation then offer them a tailored price. Ideally, firm's would perfectly predict each customer's valuation and price their goods accordingly. Unfortunately, predictions are noisy and firms are often constrained in their ability to offer many prices. In this work, we give a general framework for analyzing and optimizing personalized pricing strategies by decomposing their lost profits as stemming from either prediction error or limited price flexibility. Using this framework, we exhibit several simple heuristic policies with provable guarantees.

■ QUE3 MB 13:30- 15:00
Optimization of stochastic systems

Chair/Président: Douglas Down, McMaster University

• A c/mu-rule for service resource allocation
George Zhang*, Li Xia
Simon Fraser University; Sun Yat-sen University

Abstract: We study a dynamic server-on/off scheduling problem in a queueing system with multi-class servers, where servers are heterogeneous and can be classified into K groups. Servers in the same group are homogeneous. Customer arrival is a Poisson process and service time is exponentially distributed. Our goal is to find the optimal scheduling policy to minimize the long-run average cost.

• Capacity rationing in multi-server, non-preemptive priority queues
Tianshu Lu*, Opher Baron, Jianfu Wang
University of Toronto [1, 2]; City University of Hong Kong [3]

Abstract: Capacity rationing and ambulance diversion are two important practices in emergency department (ED) management. We model these practices as a two classes non-preemptive priority M/M/c+M queue where high- and low-priority customers correspond to acute and non-acute patients, respectively. We model capacity rationing by reserving k servers to high priority customers, and ambulance diversion by blocking high priority customers from entering the system when the total number of patients is high. We give the first exact results for a multi-server queue with non-preemptive priorities. Numerical results provide insights on the control of capacity rationing and ambulance diversion in EDs.

• Personalized treatment for opioid use disorder
Kyra Gan*, Alan Scheller-Wolf, Sridhar Tayur
Carnegie Mellon University

Abstract: To develop personalized treatment for Opioid Use Disorder (OUD), one can use wearable devices to potentially detect patient treatment responses in real-time. A variety of wearable devices with different features and costs are available. Given algorithms that detect patient health states using those features, to determine whether such devices are practical, and if so how they should be used, we build a finite-horizon, non-stationary Constrained Partially Observable Markov Decision Process. We reformulate the problem and provide a tractable solution method. We numerically evaluate the benefit of wearables in OUD treatments under various scenarios and provide insights.

• Delay-join the shortest queue routing for a parallel queueing system with removable servers
Pamela Badian-Pessot, Douglas G. Down*, Mark E. Lewis
Cornell University [1, 3]; McMaster University [2]

Abstract: We introduce a new class of policies, delay-JSQ, for parallel queues with removable servers. When jobs arrive while all servers are on, they are routed to the shortest queue. However, when servers are off, they turn back only when the number of jobs in all of the non-empty queues exceeds a threshold. In addition to an analysis of the optimality of such policies, a numerical study shows that at moderate loads (where server farms and manufacturing facilities operate), delay-JSQ shows excellent performance. We also see that it performs well without precise knowledge of the input parameters.

■ PRM4 MB 13:30- 15:00
Design of online learning and pricing with constraints

Chair/Président: Rim Hariss, McGill University

• Offering a menu of prices: The role of price dis-

crimination in a two-sided market
Parastoo Liaghat*, Alireza Sabouri
University of Calgary

Abstract: We consider a platform acting as an intermediary in a two-sided market, which provides the buyers' side with two options to choose from: a pay-per-use and a subscription option. We study the optimal pricing structure of the platform, and compare the results with that of a benchmark model with only one option for buyers. Our numerical results suggest that depending on the per-transaction cost, the platform can take two different approaches in order to effectively discriminate buyers: either charging buyers a higher price compared to the benchmark, or increasing the number of transactions by discounting buyers.

• **Price discrimination with fairness constraints**
Maxime Cohen, Adam Elmachtoub*, Xiao Lei
McGill University [1]; Columbia University [2, 3]

Abstract: While price discrimination has become common, regulators often aim to impose fairness. We consider the problem of pricing with fairness constraints. We first propose four definitions: fairness in (1) price, (2) demand, (3) surplus, and (4) no-purchase valuation. We then analyze the pricing strategy of the seller, and the impact of fairness. Under a linear demand, we show that imposing some fairness in price or no-purchase valuation increases social welfare, whereas fairness in surplus or demand are always detrimental. A similar pattern is also observed for other common demand models.

• **A general framework for knapsack constrained revenue management with demand learning and large action space**
Sentao Miao*, Yining Wang
McGill University; University of Florida

Abstract: In this work, we propose a general framework to solve various revenue management problems with demand learning. Our framework combines the method of primal-dual optimization and upper-confidence-bound (UCB) algorithm which is both computationally efficient and leads to low regret in various settings. In this talk, we show a particular example of its application in dynamic assortment optimization with inventory constraints and demand learning.

• **Pricing in the presence of heterogeneity: Application to ticket reselling**
Michael Allen, Max Biggs, Rim Hariss*, Michael Li, Charles Herrmann, Georgia Perakis
Airbnb [1]; University of Virginia [2]; McGill University [3]; Operations Research Center MIT [4,6]; BCG Gamma [5]

Abstract: We develop a framework for estimating heterogeneous price sensitivity in applications such as ticket reselling. We introduce a orthogonalized machine learning approach for a classification setting with confounding. The loss function we derive can be easily incorporated into off-the-shelf machine learning algorithms, including gradient boosted trees and neural networks. Using a wide range of synthetic data sets, we show this approach beats state-of-the-art machine learning approaches for estimating price sensitivity and prove analytical properties for this estimator.

■ IND4 MB 13:30- 15:00
IVADO Labs

Chair/Président: Marie-Claude Côté, IVADO Labs

• **Stochastic storage allocation problem at a container terminal**
Nicolas Boez*, Louis-Philippe Bigras, Simon Boivin, Jean-François Cordeau, Andrea Lodi
Ivado Labs [1, 2,4, 5]; Ray-Mont Logistics [3]

Abstract: We worked with Ray-Mont Logistics, a company specialized in intermodal freight transportation, to improve the management of containers in their terminals. The aim was to determine the optimal location of new loaded containers to reduce retrieval efforts when shipping out containers. The departure date of a container may change after it is stacked, therefore the uncertainty of this information had to be considered to provide robust decisions. The solution, involving a mixed-integer program associated with a Monte Carlo simulation, allowed to significantly reduce operational efforts by almost eliminating "buried" containers in most situations, especially when departure dates shift.

• **Ensemble-learning based predictive model for large-scale aerospace spare-part**
Pierre Dodin, Paul Lemaitre*, Neda Etebari Alamdari, Lea Gauthier, Philippe Grangier, Yossiri Adulyasak, William Hamilton
Bombardier [1]; IVADO Labs [2, 3, 4, 5, 6, 7]; HEC Montréal [6]; McGill University [7]

Abstract: Forecasting spare-part demand is highly challenging due to the fact that the demand of these items is highly sporadic. The team developed a machine-learning based model to predict, at each considered time period, the number of required parts across multiple centers worldwide (part-locations). The parts exhibited different demand patterns (smooth, intermittent) requiring tailored models which were then fed to an ensembler. Through this revised methodology both accuracy and bias were improved.

• Data analytics to detect panic buying and improve products distribution amid pandemic

Ahmed Chaouachi, Gregg Gilbert*, Omar Benomar, Yossiri Adulyasak, Maxime C. Cohen, Warut Khern-am-nuai
IVADO Labs [1, 2, 3]; HEC Montréal [4], McGill University [5, 6)

Abstract: We partnered with a large North American retailer to alleviate the adverse effects of panic buying. Retailers are no strangers to unexpected spikes in high-demand products, but no one was prepared for the massive disruption caused by the COVID-19 pandemic. We first show that our proposed anomaly detection model, which leverages internal and external data sources (e.g., Google Trend and Twitter) can successfully detect pertinent anomalies before it's too late. We then present a prescriptive analytics simulation tool that can help retailers improve products distribution for essential products during uncertain times.

• Prediction and optimization of port rail-container movements under uncertainty

Jean-François Landry*, Jordan Guerguiev, Louis-Philippe Bigras, Philippe Grand'Maison, Emma Frejinger, Jean-François Cordeau
Ivado Labs [1, 2, 3, 4]; Université de Montréal [5]; HEC Montréal [6];

Abstract: We have been working with the Montreal Port Authority to develop a customized solution to predict and fast-track the movement of containers by rail. Given the unpredictable nature of the problem, both an OR and ML approach were combined to achieve best results. First, an ML component built of multiple individual predictors forecasts ETAs, volumes and destinations of incoming containers. Second, an OR-model built on a path-based representation of the movement of containers provides movement recommendations which minimize the overall container dwell-times and provides a view on global KPIs in this context where some inputs are uncertain.

■ SCM8 MB 13:30- 15:00

Hub network design

Chair/Président: Sibel Alumur Alev, University of Waterloo

• Robust-stochastic models for profit maximizing hub location problems

Gita Taherkhani*, Sibel Alumur Alev, Mojtaba Hosseini
University of Waterloo [1, 2]; University of California [3]

Abstract: This paper introduces robust-stochastic models for profit maximizing hub location problems in which two different types of uncertainty including stochastic demand and uncertain revenue are simultaneously incorporated into the problem. A two-stage stochastic program considering stochastic demand is presented. To incorporate uncertain revenues into the problem, robust optimization techniques are used and two particular cases including interval representation with a max-min criterion and discrete scenarios considering min-max regret are investigated. Mixed integer programming formulations for each of these cases are presented and exact algorithms based on Benders decomposition coupled with sample average approximation scheme are developed.

• Integrated hub location and airline operations planning

Aykan Akincilar*, Sibel Alev Alumur
Manisa Celal Bayar University; University of Waterloo

Abstract: In this study, a new integrated problem for airline operations planning, covering both strategic and operational levels, is introduced. In particular, flight scheduling and fleet assignment decisions are integrated into a hub location problem to investigate the impact of such decisions on the design of 1-stop hub networks. A mixed-integer programming model is developed and tested on real data that is collected from a major firm in Turkey to analyze the effect of integrating airline operations planning decisions on hub network design.

• Optimizing shipment frequency in hub network design with multi-period demand

Khaled Shah*, Sibel Alumur Alev, James Bookbinder
University of Waterloo

Abstract: Vehicle dispatching in a hub network for goods transportation can be optimized by combining hub location choices with those of freight consolidation. We incorporate shipment consolidation decisions in hub location problems so as to optimize the locations of hubs, frequency of vehicles to operate between them, and inventory holding decisions. Unlike existing hub models, we consider demands spread over a multi-period planning horizon. We develop mixed integer optimization models for different problem variants investigating the impact of shipment scheduling decisions on hub network design. Our models are evaluated on data sets from the literature.

• An integrated location-inventory model for a slow-moving product with customer waiting time

limitations
Fan E, Kai Huang, Jie Chu*
McGill University; McMaster University; Huazhong Agricultural University

Abstract: This paper studies an integrated location-inventory problem with inventory of an expensive, slow-moving product. The uncertainty, in terms of customer demands and their waiting time limitations, is considered, which can be characterized by a discrete and finite set of scenarios. We develop a two-stage stochastic integer program that seeks to determine optimal location, inventory and transportation decisions. To solve our proposed model, we improve the dual heuristic procedure of Louveaux and Peeters (1992) and integrate it with the Sample Average Approximation (SAA) method.

■ CHOW C MC 15:30- 17:00
Machine learning in healthcare

Co-Chairs/Présidents: Andre Cire, University of Toronto Scarborough
Co-Chairs/Présidents: Adam Diamant, York University

• The allegory of the OR: Ethics, anaesthetics, and cybernetics
Frank Rudzicz
University of Toronto

Abstract: In this talk, I will cover some risks of deep machine learning, mitigation of those risks, the potential of deep machine learning in the operating room, and other implications for practice before discussing the ethics of AI in surgery based on a recent book chapter on the topic. There, we discuss the four key principles of bio-medical ethics from surgical context. We elaborate on the definition of "fairness" and its implications in AI system design, with taxonomy of algorithmic biases in AI. We discuss the shifts in ethical paradigms as the degree of autonomy in AI systems continue to evolve. We also emphasize the need for continuous revisions of ethics in AI due to evolution and dynamic nature of AI systems and technologies.
Bio: Frank Rudzicz is a scientist at the Li Ka Shing Knowledge Institute at Unity Health Toronto, Director of Artificial Intelligence at Surgical Safety Technologies Inc., an associate professor of Computer Science at the University of Toronto, co-founder of WinterLight Labs Inc., faculty member at the Vector Institute for Artificial Intelligence, and CIFAR Chair in Artificial Intelligence. His work is in machine learning in healthcare, especially in natural language processing, speech recognition, and surgical safety. His research has appeared in popular media such as Scientific American, Wired, CBC, and the Globe and Mail, and in scientific press such as Nature.

• Hospital-wide Inpatient Flow Optimization
Jean Pauphilet
London Business School

Abstract: To improve quality and delivery of care, operations need to be coordinated and optimized across all services in real-time. We propose a multi-stage adaptive robust optimization approach combined with machine learning techniques to achieve this goal. Informed by data and predictions, our framework unifies the bed assignment process across the entire hospital and accounts for present and future inpatient flows, discharges as well as bed requests - from the emergency department, scheduled surgeries and admissions, and outside transfers. Based on historical data from a large academic medical center, we demonstrate that our optimization model can be solved in seconds for a 600-bed institution, reduces off-service placement by 23% on average, and boarding delays in the emergency department and post-anesthesia units by 52% and 24% respectively. We also illustrate the benefit from using adaptive linear decision rules instead of static assignment decisions. Altogether, holistic hospital optimization offers a unique opportunity to revitalize healthcare delivery with optimization and data at the core. Joint work with Dimitris Bertsimas (MIT).
Bio: Jean is an Assistant Professor in Management Science and Operations at the London Business School. His research interests lie at the intersection of large-scale discrete optimization, robust optimization, and machine learning, with a particular application focus on healthcare operations. His work has been featured in the likes of Mathematical Programming, Statistical Science and M&SOM, and recognized by many awards, including the George E. Nicholson and the INFORMS Computing Society best student paper awards. Jean received a Ph.D. in Operations Research from MIT and a Diplôme d'ingénieur from Ecole Polytechnique (Paris).

■ MDS3 MC 15:30- 17:00
Optimization and forecasting

Chair/Président: François Bourque, DRDC CORA

• Solving the fraction-of-missing-resource levelling problem for schedule planning
Steve Guillouzic*, François Cazzolato
DRDC

Abstract: We developed a schedule planning tool for military activities using a Fraction-of-Missing-Resource Levelling Problem (FMRLP) formulation. The

tool allows the rapid development and update of effective training and operational schedules. In this presentation, we define the FMRLP and describe the composite objective function and a novel schedule encoding that were developed to solve it. The schedule encoding - which could be used with any Resource Levelling Problem (RLP) defined over a bounded scheduling period - encapsulates precedence relationships between activities, which simplifies the use of off-the-shelf optimizers. We present sample results obtained with this framework using Palisade Evolver.

• Collision rates among Canadian Armed Forces vehicles

Geoff Pond*, Chris Belanger, Melissa Boatman
Royal Military College of Canada; University of Ottawa; Royal Canadian Air Force

Abstract: The Canadian Armed Forces (CAF) operates one of the largest vehicle fleets in the country. While it includes the typical war-fighting vehicles characteristic of armed combat, the largest component of the fleet consists of logistical unarmoured vehicles. This work compares ten years of collision data obtained by the CAF (arranged by division) and compares that to corresponding provincial jurisdictions. Forecasting is undertaken by a variety of methods including STL decomposition (or Loess decomposition), Fast Fourier Transforms, ARIMA and simple moving averages. Models are relatively consistent in characterizing the rate of decline in collision rates.

• Observing populations: Survivors are different

Robert Bryce*
Defence Research and Development Canada

Abstract: In contrast to widespread belief, current members of a population ("survivors") are not representative members. Conceptual and analytic results are developed using a stationary stochastic survival model of a population. We find survivors as a group are longer lived, e.g., for a memoryless survival model the observed population will have double the overall population's average life span, and therefore are a biased sample. Survivors are different, indicating that their properties (e.g., characteristics and opinions) differ from the properties of the overall population of interest, calling into question naive interpretation of business reports on database snapshots, surveys, and the like.

■ SG6 MC 15:30- 17:00

Robustness, interpretability, and fairness in decision-making for social good

Chair/Président: Phebe Vayanos, University of Southern California

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• Learning optimal prescriptive trees from observational data

Nathanael Jo*, Sina Aghaei, Phebe Vayanos, Andrés Gómez
University of Southern California

Abstract: We consider the problem of learning a personalized policy in the form of a binary tree from observational data. This problem arises in numerous socially important domains where interpretable interventions are sought based on data gathered from deployment rather than from controlled, randomized trials. Notable applications include public health, such as substance abuse treatment, and personalized medicine, such as determining a patient' optimal drug dosage given their medical history. We propose a mixed-integer optimization (MIO) method shown to be asymptotically exact and demonstrate that our asymptotic guarantees translate to performance improvements in finite samples on both synthetic and real data.

• Biodiversity preservation via adjustable robust optimization

Yingxiao Ye*, Christopher Doehring, Angelos Georghiou, Hugh Robinson, Phebe Vayanos
University of Southern California [1, 2, 5]; University of Cyprus [3]; Panthera [4]

Abstract: To protect biodiversity against human impact, existing methods purchase lands to maximize the value of the protected area with the given budget. However, budget is usually received progressively over time, and also, the existing models cannot capture the uncertainty in development. We propose a multistage, robust optimization problem with a data-driven uncertainty set to minimize the biodiversity loss due to human impact. We prove that the problem can be reformulated into a robust problem with exogenous objective uncertainty. The numerical results based on real data show that the proposed method outperforms the MARXAN, a conservation planning software, in 90% cases.

• Robust multi-stakeholder preference elicitation and aggregation for treatment prioritization during the COVID-19 pandemic

Caroline Johnston*, Simon Blessenohl, Phebe Vayanos
University of Southern California

Abstract: During the COVID-19 pandemic, triage committees must make ethically difficult policy decisions that are complicated by diverse stakeholder interests. We propose an automated approach to support

such group decisions, recommending a single policy to the group that best aggregates potentially conflicting individual preferences. Our system elicits preferences by asking a moderate number of strategically selected queries, each taking the form of a pairwise comparison posed to a specific stakeholder. We propose a novel multi-stage robust optimization formulation of this problem and evaluate our approach on the problem of recommending policies for allocating ICU beds to patients with COVID-19.

• Learning fair optimal classification trees

Sina Aghaei*, Jack Benson, Andres Gomez, Phebe Vayanos
University of Southern California

Abstract: The increased use of machine learning (ML) in high stakes domains has created an urgent need for ML algorithms that are fair and interpretable and that leverage the available data to its full extent to yield the most accurate predictions. In this paper, we propose a versatile framework for learning optimal and fair classification trees based on mixed integer optimization technology. Our framework is flexible to capture arbitrary fairness notions from the literature such as statistical parity, conditional statistical parity, etc. We evaluate our method on numerous datasets from the literature and investigate the trade-off between accuracy and fairness.

■ FRM3 MC 15:30- 17:00

Finance and risk management

Chair/Président: David Saunders, University of Waterloo

• Climate change risk and agriculture-related stocks

Ruihong Jiang*, Chengguo Weng
University of Waterloo

Abstract: Our work analyzes climate change risk in the stock market. We use trends of the Actuaries Climate Index (ACI), as proxies for the risk. The ACI is found to have significant predictability on agricultural production and corporate profits, which motivates the test about the predictability on stock returns. We construct a stock trading strategy that adjusts to climate change risk. Our strategy earns positive returns with zero expense, implying the return predictability of the ACI and the market inefficiency toward climate change risk. From subsample tests, we find changes in the market efficiency, which highlights the importance of follow-up studies.

• The Generalized Shiryaev Problem and financial applications

Alexander Kreinin*
University of Toronto

Abstract: We consider the following inverse problem for the first hitting time distribution, called the Generalized Shiryaev Problem (GSP): given a Wiener process with a random initial state, probability distribution, F(t), and a linear boundary, b(t)=kt, find a distribution of the initial state of the process such that the distribution of the first hitting time is F. This problem has important applications in credit risk modelling where the first hitting time represents a default event and the boundary separates the healthy states of the obligor from the default state. We discuss a calibration algorithm for the GSP.

• High-water mark fee structure in variable annuities

Yumin Wang*, David Landriault, Bin Li, Dongchen Li
University of Waterloo [1, 2, 3]; University of St. Thomas [4]

Abstract: The fee structure of variable annuities is important for both insurers and policyholders. The existing literature on fee structures of variable annuities mainly focuses on proposing a new fee structure and investigating its risk management implications merely from insurers' standpoint. This paper proposes a novel high-water mark fee structure and examines its implications from both insurers' and policyholders' standpoints. From insurers' perspective, we discuss the risk management implications under this fee structure. From policyholders' perspective, we examine the welfare of three types of policyholders and discover that their welfare is in general improved under this fee structure.

• Cost-efficient claims with Choquet pricing

Michael Zhu*
University of Waterloo

Abstract: We examine a problem of the Neyman-Pearson type, in which an investor seeks the cheapest contingent claim that achieves a minimum performance subject to a maximum allowed risk exposure, where all expectations are taken in the sense of Choquet. Solutions to our problem are called cost-efficient claims, and are anti- comonotonic with respect to the underlying asset, and therefore a hedge against its risk. By viewing our problem in the context of convex optimization, we apply a Karush-Kuhn-Tucker theorem to give necessary and sufficient conditions for cost efficiency. Under some additional assumptions, we explicitly characterize cost-efficient claims in closed-form.

■ OPT10 MC 15:30- 17:00

Large scale optimization - I

Chair/Président: Ricardo Fukasawa, University of Waterloo

• The complexity of branch-and-price algorithms for the capacitated vehicle routing problem with stochastic demands

Joshua Gunter, Ricardo Fukasawa*
University of Waterloo

Abstract: The capacitated vehicle routing problem with stochastic demands (CVRPSD) is a variant of the deterministic capacitated vehicle routing problem where customer demands are random variables. A core component of branch-and-price algorithms for the CVRPSD is the 2-stage route pricing problem, which computes the route with minimum expected reduced cost. We prove that when demands are given as a finite set of scenarios, solving the 2-stage route pricing problem is strongly NP-Hard. We also prove an additional hardness result for the 2-stage route pricing problem in the case of independent normal demands.

• Vessel service planning in seaports

Lingxiao Wu*, Yossiri Adulyasak, Jean-François Cordeau, Shuaian Wang
HEC Montréal [1, 2, 3]; Old Dominion University [4]

Abstract: This study investigates a vessel service planning problem in seaports. We introduce a compact mixed-integer linear programming formulation for the problem. To solve large-scale instances, we develop an exact solution approach that combines Benders decomposition and column generation in a novel and effective way. The approach is enhanced through practical acceleration strategies. Extensive computational results using data instances from one of the world's largest seaports show that these acceleration strategies significantly improve the performance of our solution approach and that it can obtain optimal or near-optimal solutions for instances of realistic scale.

• A novel stochastic programming approach for scheduling of batch processes with decision dependent time of uncertainty realization

Kavitha Menon*, Ricardo Fukasawa, Luis A Ricardez-Sandoval
University of Waterloo

Abstract: Uncertainty modelling is key to obtain a realistically feasible solution for large-scale optimization problems. In this study, we consider two-stage stochastic programming to model discrete-time batch process operations with a type II endogenous uncertainty, where time of uncertainty realizations are dependent on the model decisions. We propose a novel approach to ensure non-anticipativity implicitly. The key novelty of this approach is that it does not require auxiliary binary variables or explicit non-anticipativity constraints. The proposed approach is validated using a large-scale scientific services industrial plant. The computational results from the case study depicts significant benefits in using the proposed approach.

• Approximating downward monotone sets via knapsacks

Ricardo Fukasawa*, Brendan Ross
University of Waterloo

Abstract: We study the problem of approximating a downward monotone set via a knapsack set. Such a problem arises in the context of chance-constrained vehicle routing, but also in other contexts like support vector machines (SVM), and game-theory. This preliminary work has the purpose of examining how this problem is approached in these different contexts and trying to draw conclusions based on ideas from these different fields.

■ OPT29 MC 15:30- 17:00

Large scale optimization - II

Chair/Président: Moira MacNeil, University of Toronto

• A cut-and-branch algorithm for the Quadratic Knapsack Problem

Franklin Djeumou Fomeni*, Konstantinos Kaparis, Adam Letchford
ESG-UQAM; University of Macedonia; Lancaster University

Abstract: The Quadratic Knapsack Problem (QKP) is a well-known NP-hard combinatorial optimization problem, with many practical applications. We present 'cut-and-branch' algorithm for the QKP, in which a cutting-plane phase is followed by a branch-and-bound phase. The cutting-plane phase is more sophisticated than the existing ones in the literature, incorporating several classes of cutting planes, two primal heuristics, and several rules for eliminating variables and constraints. Computational results show that the algorithm is competitive.

• Integer and constraint programming approaches to discretizable distance geometry problems

Moira MacNeil*, Merve Bodur
University of Toronto

Abstract: The Discretizable Distance Geometry Problem (DDGP) is a feasibility problem, based on determining total orders in graphs. Recently, measures of the quality of these orders have been proposed, transforming the DDGP from a feasibility problem to an optimality problem. We present novel integer and constraint programming formulations for an optimality-based DDGP problem. We also develop hybrid integer-constraint programming Combinatorial Benders Decomposition algorithms to solve this problem. Computational experiments show these novel approaches outperform existing integer programming formulations in the literature on several test sets.

• **Unified branch-and-Benders-cut for two-stage stochastic mixed-integer programs**

Arthur Mahéo, Simon Belieres*, Jean-Francois Cordeau, Yossiri Adulyasak
Monash University [1]; HEC Montréal [2, 3, 4]

Abstract: Two-stage stochastic programs (2SMIPS) are stochastic problems where data uncertainty is discretized into scenarios, making them amenable to Benders decomposition. However, classic Benders decomposition is not applicable to general 2SMIPS due to the restriction that second stage variables must be continuous. We propose a novel Benders decomposition-based framework that accommodates mixed-integer variables in both stages and uncertainty in all recourse parameters. The proposed approach is a unified branch-and-Benders algorithm, where a heuristic maintains a global upper bound and a post-processing phase determines the optimal solution. The proposed framework outperforms state-of-the-art methods.

• **Copositive duality for discrete markets and games**

Cheng Guo*, Merve Bodur, Joshua Taylor
University of Toronto

Abstract: Optimization problems with discrete decisions are nonconvex, which limits the usefulness of tools such as shadow prices and KKT conditions. Burer (2009) shows that mixed-binary quadratic programs can be written as convex completely positive programs (CPPs). CPP reformulations of discrete optimization problems therefore have strong duality. We apply this perspective in two ways. First, we write unit commitment in power systems as a CPP, and use the dual copositive program to design pricing mechanisms. Second, we reformulate integer programming games as CPPs, and use KKT conditions to obtain Nash equilibria. We also design a cutting plane algorithm for copositive programs.

■ SMS11 MC 15:30- 17:00

Stochastic and empirical models in healthcare operations

Chair/Président: Arik Senderovich, University of Toronto

• **Infinite-server queueing models for demand prediction in healthcare: Some examples and some ideas for further work**

David Worthington*, Martin Utley, Dan Suen
Lancaster University [1]; University College London [2]

Abstract: Despite the apparently unrealistic assumption of infinite resources, infinite-server queueing models have played a central role in the development of queueing theory and its applications. In healthcare modelling applications have often centred upon the prediction of “offered load" across a wide range of health systems. This presentation will describe some major healthcare applications to date, identifying some key results and highlighting the predictive nature of the applications. Finally the presentation will outline some potential future healthcare applications, including relationships to existing approaches, the need for new approaches and the use of infinite-server models alongside other modelling methodologies.

• **Assessing the Impact of redesign of the emergency department: Lessons from ED at Southlake RHC**

Dmitry Krass, Opher Baron, Tianshu Lu, Zhoupeng Zhang*, Marko Duic
University of Toronto [1, 2, 3, 4]; Southlake Regional Health Center [5]

Abstract: We develop an empirical analysis framework for policy evaluation using time series data with feedback effects among variables. We first estimate a simultaneous equations model to capture the feedback effects. We then perform an iterative counterfactual analysis to examine policy impacts in both short- and long-term. Furthermore, we develop a Bootstrap method to construct 95% confidence intervals for policy impacts and compare them with asymptotic approximated intervals. Our approach can offer insights into the evolution and significance of a policy. We demonstrate by analyzing the impacts of a waiting time improvement project at the Southlake hospital near Toronto.

• **Adapting an AI method for use in OR: A POMDP for COVID-19 contingency planning**

Emile Pelletier*
Defence Research and Development Canada

Abstract: Partially Observable Markov Decision Processes (POMDPs) are used for AI in applications such as robotics. POMDPs have not seen popular use in OR. This presentation covers two POMDP models: a) addresses only the health of one individual (seeking advice from a health representative by phone, 811 in NS) and proposes an optimal action based on their recent observations of symptoms or potential exposure; and, b) a COVID-19 SIR model providing a contingency plan in that it simultaneously shows the outcome from both optimal and sub-optimal actions. The presented method has general potential for OR.

• **Low-acuity patients delay high-acuity patients in the ED**

Danqi Luo*, Mohsen Bayati, Erica Plambeck, Michael Aratow
Stanford University [1, 2, 3]; San Mateo Medical Center [4]

Abstract: This paper provides evidence that the arrival of an additional low-acuity patient substantially increases the wait time to start of treatment for high-acuity patients, contradicting the long-standing prior conclusion in the medical literature that the effect is negligible." Whereas the medical literature underestimates the effect by neglecting how delay propagates in a queuing system, this paper develops and validates a new estimation method based on queuing theory, machine learning and causal inference. Wait time information displayed to low-acuity patients provides a quasi-randomized instrumental variable.

■ AIML1 MC 15:30- 17:00

Topics at the of machine learning and optimization

Chair/Président: Elias Khalil, University of Toronto

• **Flow-based attribution in graphical models: A recursive shapley approach**

Raghav Singal*, George Michailidis, Hoiyi Ng
Amazon [1, 3]; University of Florida [2]

Abstract: We study the attribution problem in a graphical model, wherein the objective is to quantify how the effect of changes at the source nodes propagates through the graph. We develop a model-agnostic flow-based attribution method, called recursive Shapley value (RSV). RSV generalizes a number of existing node-based methods and uniquely satisfies a set of flow-based axioms. In addition to admitting a natural characterization for linear models and facilitating mediation analysis for non-linear models, RSV satisfies a mix of desirable properties discussed in the recent literature, including implementation invariance, sensitivity, monotonicity, and affine scale invariance.

• **On-time last mile delivery: Order assignment with travel time predictors**

Sheng Liu*, Long He, Zuo-Jun Shen
University of Toronto; National University of Singapore; University of California, Berkeley

Abstract: Working with a major food delivery service provider in China, we develop a data-driven optimization framework to minimize the expected delivery delay. Motivated by the real-world data set, we propose a machine learning approach to predicting the actual travel time considering drivers' routing behaviors. Combined with the travel time prediction, our optimization framework is flexible and yields significantly better results than the existing models that assume drivers follow the shortest routes.

• **Market segmentation trees**

Ali Aouad, Adam Elmachtoub*, Kris Ferreira, Ryan McNellis
London Business School [1]; Columbia University [2, 4]; Harvard Business School [3]

Abstract: We propose a general methodology, Market Segmentation Trees (MSTs), for tackling a broad class of personalized decision-making problems including applications in advertising and revenue management. The MSTs learn an interpretable market segmentation which is driven by modeling differences in user behavior. We provide a modular, computationally-efficient, and open-source code base for training MSTs in Python. We evaluate our MSTs' predictive performance compared to benchmarks on numerous data sets.

• **Better fitting hyperplanes**

John Chinneck*, Paul Brooks
Carleton University; Virginia Commonwealth University

Abstract: Most hyperplane fitting techniques try to optimize some type of distance measure, e.g. minimize the sum of the squared distances to the data points. This contrasts with the intuitive understanding that the best fitting hyperplane is "closer" to more points than other hyperplanes. We present the Relative Better Measure and associated algorithm which works towards this cardinality goal and show experimentally that it provides better fits.

■ FOR3 MC 15:30- 17:00

Forest logistics

Chair/Président: Tasseda Boukherroub, École de

technologie supérieure

• **Integrated decision-making of production and transport in the Swedish wood supply**
Oskar Gustavsson*, Sara Holappa Jonsson, Victor Asmoarp
Skogforsk - Forestry Research institute of Sweden

Abstract: The harvesting and destination decisions in the Swedish wood supply are made with slightly different goals. The harvesting decisions aim to maximize the value of the harvested wood. The destination decisions aim to minimize the transport costs. The difference in aims induce non-optimality. To mitigate this, we propose an integrated model for production and destination management. Tests in two case studies indicate costs decreasing by 2-4 %. To further increase the profitability of the supply chain, models describing wood properties are added to the control parameters. This allows for supplying customers with specific wood properties, according to their future demands.

• **Optimization of log logistics considering synchronization**
Salar Ghotb*, Taraneh Sowlati
University of British Columbia

Abstract: Log truck scheduling considering synchronization and compatibility requirements is a complex problem. To address the problem with a one-month planning horizon, this study introduces an optimization model using decomposition-based approach where daily flows and number of truckloads are obtained through the first phase. In the second phase, routing and scheduling decisions for each truck considering synchronization of trucks and loaders are determined to reduce waiting time of trucks and to minimize total transportation costs. The proposed optimization model is applied to a case study in British Columbia where a company aims to improve its transportation planning.

• **Regional logistics center: Application to eastern Canada**
François Sarrazin*, Luc LeBel, Lehoux Nadia
CIRRELT [1]; Université Laval [2, 3]

Abstract: The establishment of triage and consolidation yards, distinct from forest sites and mills, offers multiple opportunities for value maximization and cost minimization. To better understand the interaction between a logistics centre and a complex forest network, a profit maximization model is presented and applied for a case study in the Mauricie region of Quebec, Canada. The results show that a logistics centre could increase the profit by %0.90 (Canadian dollars) for each cubic metre of wood available for harvesting. A dynamic effect was also observed between the operation of a processing yard and the use of load returns.

• **Truck platooning in forest transportations**
Saba Gazran*, Tasseda Boukherroub, Mikael Rönnqvist, Marc Paquet
École de technologie supérieure (ÉTS) [1, 2, 4]; Laval University [3]

Abstract: Truck platooning is a new technology in the area of autonomous transportation with the main advantage of fuel consumption and manpower savings and other benefits depending on the level of automation. We start by a review of the literature on truck platooning transportation planning based on Operations Research methods. Next we propose a detailed optimization model to include truck platooning with ordinary forest trucks in a network of harvest areas, terminals and mills. The models include both direct and backhaul alternatives. Results from a set of case studies where different levels of truck platooning and backhauls are described and analyzed.

■ SPCO MC 15:30- 17:00
Student paper competition, open

Chair/Président: Tamon Stephen, Simon Fraser University

• **Student paper competition, open**
Aliaa Alnaggar*, Gohram Baloch*, Maryam Daryalal*, Saman Lagzi*, Nasrin Yousefi*
University of Waterloo [1, 2]; University of Toronto [3, 4, 5]

Each year CORS conducts a student paper competition to recognize the contribution of a paper either directly to the field of operational research through the development of methodology or to another field through the application of operational research. The competition serves to showcase the high quality of OR education in Canada as well as the excellence of the new generation of operational researchers. Prizes are awarded in two categories: Undergraduate and Open.

Finalists in the Open Category

Student: **Aliaa Alnaggar** Institution: University of Waterloo Supervisor: Fatma Gzara Title: Heatmap design for crowdsourced delivery Full author list: Aliaa Alnaggar, Fatma Gzara and James Bookbinder

Student: **Gohram Baloch** Institution: University of Waterloo Supervisor: Fatma Gzara Title: Risk based allocation of COVID-19 critical supplies and equip-

ment under limited availability/supply Full author list: Gohram Baloch, Fatma Gzara and Samir Elhedhli

Student: **Maryam Daryalal** Institution: University of Toronto Supervisor: Merve Bodur Title: Lagrangian dual decision rules for multistage stochastic mixed integer programming Full author list: Maryam Daryalal, Merve Bodur and James Luedtke

Student: **Saman Lagzi** Institution: University of Toronto Supervisor: Andre Cire Title: Model-free assortment pricing with transaction data Full author list: Ningyuan Chen, Andre Cire, Ming Hu and Saman Lagzi

Student: **Nasrin Yousefi** Institution: University of Toronto Supervisor: Timothy Chan Title: An Inverse Optimization approach to measuring clinical pathway concordance Full author list: Nasrin Yousefi, Timothy Chan, Yusuf Shalaby, Maria Eberg, Katharina Forster, Claire Holloway and Luciano Ieraci

■ OSM3 MC 15:30- 15:00

Contract design and efficiency models in operations management

Chair/Président: Mona Imanpoor, Simon Fraser University

• **Effects of usage-based auto insurance: A dynamic mechanism-design approach**

Mona Imanpoor Yourdshahy*, Mahesh Nagarajan, Hao Zhang
Simon Fraser University [1]; University of British Columbia [2, 3]

Abstract: Tracking drivers' behaviour, Usage Based Insurance (UBI) allows insurance companies to connect insurers' premiums more closely to their actual driving performance. This paper provides a theoretical model to capture the effects of UBI on the auto insurance market. We formulate the underlying problem as a dynamic principal-agent model with hidden information and hidden action. Developing a dynamic programming algorithm, we characterize the full history-dependent optimal contract. The model results lead to interesting managerial insights including the extent to which a UBI policy can outperform a traditional policy, and how the potential gains depend on the demographics of the target market.

• **The Interplay between product upgradability and servicizing**

Tina Arabian*, D. Marc Kilgour, Hamid Noori
Wilfrid Laurier University

Abstract: Servicizing offers new economic opportunities, but it also entails technological obsolescence risk, as the firm retains ownership of the product. Offering upgradable products may help firms to address this risk. We investigate the interaction between two product design strategies, upgradable and non-upgradable, and two business models, selling and servicizing. First, we characterize the conditions under which upgradable-product design strategy is more profitable than non-upgradable one under each business model. We next analyze the impact of adopting upgradable-product design strategy on a firm' business model choice. Finally, we examine a firm's joint choice of business model and product design strategy.

• **Weather rebate contracts for different risk attitudes of supply chain members**

Piyal Sarkar*, Mohamed Wahab Mohamed Ismail, Liping Fang
Ryerson University

Abstract: How weather rebate contracts can help to improve the performance of a supply chain under weather uncertainties is investigated. The performance of weather rebate contracts is analyzed for three combinations: risk-neutral supplier and risk-averse retailer, risk-averse supplier and risk-neutral retailer, and risk-averse supplier and risk-averse retailer. To incorporate the risk attitudes, Conditional Value at Risk is used as the risk measure. The results show that the weather rebate contract outperforms the regular wholesale-price contract. To the best of our knowledge, this is the first study that investigates the weather rebate contract incorporating the risk attitude of the supply chain members.

• **Ranking invariant efficiency measures of healthcare units**

Jafar Sadeghi*, Mehmet Begen, Fredrik Odegaard
Western University

Abstract: In non-parametric production efficiency models the non-Archimedean infinitesimal plays a key role as a multiplication factor to the sum of input and output slacks in the objective function, equivalently, it is used as a lower bound for the input and output weights in productivity multiplier models. To ensure the relative ranking of the evaluated units remain consistent we provide two bounds for the non-Archimedean infinitesimal. The first, labeled positive efficiency guarantee, is to ensure the ensuing production efficiency measures are always well-defined, and the second, labeled ranking invariance guarantee, is a refinement such that the relative efficiency rankings remain consistent.

■ QUE1 MC 15:30- 17:00

Queues: Theory and applications

Chair/Président: David Stanford, Western University

• A stylized model for the impact of a screening protocol in healthcare delivery

Olga Bountali*, Sila Cetinkaya, Farnaz Nourbakhsh
University of Toronto [1]; Southern Methodist University [2, 3]

Abstract: We consider a patient profile that is subject to potentially multiple'screen, reject & revisit' loops due to a screening protocol which results in severe hospital congestion and poor patient outcomes. We explore and analyze two alternative proposals: one that modifies the existing protocol considering available capacity, and one that schedules the future revisits in order to regulate patient flow.

• Queues with strategic arrivals and strategic servers

Ragavendran Gopalakrishnan*, Amy Ward, Yueyang Zhong
Queen's University [1]; University of Chicago [2, 3]

Abstract: We revisit Naor's seminal study of an observable queue where arrivals are strategic (with linear utilities), but with strategic server(s) that choose their service rate. We find that a joint equilibrium between the arrivals and server(s) may not exist, nor be unique when it does exist. Moreover, a socially optimal threshold for the arrivals (as defined by Naor) could exceed an equilibrium threshold, a phenomenon that does not occur in Naor's model (where the server is not strategic). We discuss the consequences of these results in designing optimal policies for service systems involving strategic behaviour from both arrivals and servers.

• Modeling yellow and red alert durations for ambulance systems

Amir Rastpour, Armann Ingolfsson*, Bora Kolfal
University of Ontario Institute of Technology [1]; University of Alberta [2, 3]

Abstract: Design of EMS systems aims to have sufficient capacity to respond to emergencies with high probability. Capacity shortages do occur, however, and quick recovery is important. We formulate Erlang loss models to compare adding servers vs. expediting service, as recovery actions. We validate the models against EMS data from Calgary and Edmonton and find that a Markovian state-dependent model fits well. One of our findings is one should not wait until a Red Alert (all ambulances busy) before adding ambulances, because the expected number of lost calls increases rapidly as the number of available ambulances decreases.

• A simulation model for ABO compatible liver transplantation

David Stanford*, Jiliang Li, Hao Yu
Western University

Abstract: In previous work, it was shown that comparable waiting times and access can be achieved for liver transplantation if the rates of B (respectively, AB) donor organs are supplemented by a small fraction of O (respectively, A) donor organs for type B recipients. The present study implements such a strategy in a simulation which bootstraps the donor organ availability times and patient placements, using recent datasets derived from the donor organ availability and patient placement times in Ontario. The results of this ongoing study already confirm that small to moderate rates of O-to-B and A-to-AB cross transplantation suffice.

■ PRM8 MC 15:30- 17:00

Pricing and learning applications

Chair/Président: Recep Bekci, McGill University

• Multi-priority queue for on-demand service platforms with delays

Osman Alp, Marco Bijvank*, Serasu Duran
University of Calgary

Abstract: We model a sharing-economy platform where customers request service by providing price quotes (or bids) as a multi-priority queue where servers (or contractors) can take vacations. In particular, a server will vacate if no customer bid exceeds the server' reservation price. These reservation prices are random variables that get updated at customer arrival and departure. Expressions are derived to calculate expected wait times for a given state such that customers can make informed decisions when they place a bid.

• When does eco-efficiency rebound or backfire? An analytical model

Régis Chenavaz, Stanko Dimitrov*, Frank Figge
KEDGE Business School [1, 3]; University of Waterloo [2]

Abstract: We develop an analytical dynamic model for eco-efficiency, in which a firm may invest in eco-efficiency of a product as well as set the product's price. Using general functions, we determine when the rebound effect, backfire, and reverse background may occur. We identify three effects that collectively determine if rebound occurs. We interpret our result

from both a managerial and a theoretical perspective.

• **Inventory learning and control for one warehouse multi store system**
Recep Yusuf Bekci*, Mehmet Gumus, Sentao Miao
McGill University

Abstract: We consider a fundamental two-echelon inventory model called One Warehouse Multi Store System (OWMS). This system has a central warehouse that receives an initial replenishment and distributes its inventory to multiple stores in each period during a finite horizon. The objective is to minimize the total expected cost. Even with complete information about the demand distribution, the structure of the optimal policy is notoriously difficult. In our study, we will consider the system without imposing any assumption about demand distribution. We present an online learning algorithm that achieves a sub-linear regret bound that matches the known demand setting.

■ IND1 MC 15:30- 17:00

Pricing and retail analytics

Chair/Président: Arash Habib, Kinaxis

• **Machine learning and advanced analytics to forecast in a volatile COVID retail market**
Arash Habib*, Sharon Yang
Kinaxis

Abstract: Market disruptions such as a pandemic or a major catastrophe often lead to drastic changes in customer behaviour. This poses the problem of how can we leverage historical data to drive machine learning (ML) predictions if the data is not representative of the current market. Advanced analytics can be leveraged to improve the ML forecast to adjust during times of disruptions. In this use case, we demonstrate how we leveraged advanced analytics to improve and adjust the ML forecast to drive better accuracy. This improved performance of the ML models during COVID and enabled better management of supply and demand.

• **All you Need is consistent promotions**
Tianle Chen, Kanchana Padmanabhan*
Kinaxis

Abstract: In retail demand planning, promotion planning is the task of deciding what products to promote, when to promote, and what promotion parameters (e.g., mechanic, discount, amount that the vendor/supplier will fund etc.) to apply. Optimize is an AI driven product, by Kinaxis, that automates this process. The product allows the retailers to simulate several “what if" promotional planning scenarios and choose the scenario that best lines up with their business use case. In this talk, we will describe some interesting challenges faced when building an AI model for this use case and our solutions to overcome the challenges.

• **Price optimization for banking**
Amir Farshbaf Geranmayeh*
National Bank of Canada

Abstract: I would like to talk about the applications of machine learning and operations research for price optimization in the banking industry. Pricing and promotions are essential for banks to better transform their value proposition and to take customer satisfaction to a higher level. When determining the optimal price, banks face a trade-off between the retention of clients and the profit margin. For this purpose, we need to capture the willingness-to-pay of the clients by machine learning techniques and maximize the profit using operations research.

• **Data & intelligence maturity model**
Anirvan Basu*
Leroy Merlin

Abstract: The Data& Intelligence Maturity Model is a strategy and operations framework for enterprises, that associates holistically their business performance to their usage of data and AI in their activities. It helps enterprises to: assess their current maturity level& set their vision based on the destination maturity level as well as to develop a transformation roadmap to achieve their vision, and measure the success throughout the process. Key elements explained in this talk: Proof-of-Value, Data Positivity, PoC-to-Production Agility, Phygitality, and Personalisation @ Scale.

■ SCM10 MC 15:30- 17:00

Supply chain applications

Chair/Président: Shayan Tavakoli Kafiabad, Concordia University

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• **Single-supplier multi-retailer cold chain management for fresh produce**
Guo Chen, Mohamed Wahab Mohamed Ismail*, Liping Fang
Ryerson University

Abstract: This research investigates effectively designing and managing a single-supplier and multiple-retailer cold chain for fresh produce, whose quality degradation is affected by storage temperature and time. The quality of the fresh produce is a function of

many aspects, and the global stability index (GSI) is used to measure the overall quality. Quality degradation is slowed by keeping fresh produce at a relatively low temperature. Appropriate replenishment times, for the supplier and retailers, can minimize the supply chain' total cost. When a certain structure of the unit wholesale price is charged to the retailers, the coordination of the chain is ensured.

• A systematic literature review of sustainable biomass supply chain management

Mona Jazinaninejad*, Mohammadreza Nematollahi, Azam Shamsi Zamenjani, Alireza Tajbakhsh
University of New Brunswick [1, 3, 4]; University of Quebec in Montreal [2]

Abstract: Sustainability-driven decsions have attracted scholars' attention in recent years. Planning effective regulatory mechanisms incorporating tax and incentive strategies have significant impacts on the sustainable management of supply chains. One of the promising solutions in the context of sustainability development is smart use of biomass to produce bioproducts; thus saving the environment, society, and money. Several studies have reviewed biomass supply chains literature. However, we realize the need for a comprehensive review on optimization of sustainable biomass supply chains considering governments' role. The present review aims to fill this research gap using a systematic review of 450 quantitative studies between 1997-2020.

• Quadruple-channel agricultural supply chains: Organic vs. conventional agriculture produces

Mona Jazinaninejad*, Mohammadreza Nematollahi, Bahareh Mosadegh Sedghy, Azam Shamsi Zamenjani, Alireza Tajbakhsh
University of New Brunswick [1, 4, 5]; University of Quebec in Montreal [2]; University of Lethbridge [3]

Abstract: To characterize the important role of the organic agribusiness sector in microeconomic decisions, this study aims to propose an optimization approach centred on a centralized agricultural supply chain that reflect competition between conventional and organic farmers. Motivated by a real-world apple-picking case, we explore a four-channel agricultural network including a conventional farmer, an organic farmer, and a retailer. Both farmers sell their agricultural products through the retailer and short channels, where organic-driven subsidies promote organic farming across the network. To estimate demand functions' coefficients, the USDA databases are utilized to perform predictive analytics in the US apple market between 2007-2020.

• An integrated strategic and tactical planning model for maintenance centers with considering risk mitigation strategies

Shayan Tavakoli Kafiabad*, Masoumeh Kazemi Zanjani, Mustapha Nouerlfath
Concordia University [1, 2]; Laval University [3]

Abstract: The maintenance companies are confronted with challenges like demand uncertainty, high lead time, and risk of supply disruptions. To be responsive and control the shortages, the maintenance companies exert various risk mitigation strategies like lateral transshipment and operator sharing policies. In this paper, an integrated strategic and tactical planning model is proposed to determine the optimal allocation of users to repair centers, inventory levels, and the optimal repair and transportation decisions with the goal of minimizing the total cost of the system. Numerical findings illustrate the importance of integrating risk mitigation strategies in controlling the cost of the system.

• Competition or coopetition? Equilibrium analysis in the presence of process improvement

Wei Li, Xuan Zhao*
Southwestern University of Finance and Economics; Wilfrid Laurier university

Abstract: Coopetition is a business phenomenon that dominates many supply chains. We aim to understand why and how coopetition occurs in supply chains with the presence of process improvement in an upstream component production process. An original equipment manufacturer can purchase the component from either a non-competing supplier or a competing supplier that also sells substitutable products in the consumer market. We demonstrate that without process improvement, coopetition does not exist. Two cases are considered in which process improvement is present: supplier-initiated improvement, where the suppliers conduct self-investment, and OEM-initiated improvement, where the OEM invests in the supplier' process.

Tuesday/Mardi June 08

■ HC1 TA 10:00- 11:30

Transportation in healthcare

Chair/Président: Valérie Bélanger, HEC Montréal

• **A dynamic discretization discovery algorithm over a time-expanded network for the biomedical sample transportation problem**

Daniel M. Ocampo-Giraldo, Ana María Anaya-Arenas*, Claudio Contardo
ESG-UQAM

Abstract: Inspired by an application on logistics planning for regional healthcare networks in Quebec, this talk presents a two-step algorithm to solve the biomedical sample transportation problem. Here, a multitude samples need to be transported from specimen collection centres to a laboratory in the region, but the short lifespan of the commodities requests multiple pickups at the locations and restricts the route length, creating a complex decision interdependency in the routing planning. To address these timing issues, we model this problem as a service network design over a time-expanded network and propose an algorithm to solve a set of real-life instances.

• **The value of "near-to-be-available" ambulances in dispatching policies for emergency medical services**

Gabriel Lavoie, Valérie Bélanger*, Nadia Lahrichi
Urgences-santé; HEC Montréal; Polytechnique Montréal

Abstract: Dispatching policies for emergency medical services determine which ambulance to send to answer an emergency call. While the traditional policy consists of sending the "closest-idle ambulance", recent research explores other alternatives. In this project, we propose four new dispatching policies. The first three includes “near-to-be-available" resources in the dispatching process while the fourth suggests to send a newly available ambulance to already assigned low priority request if this would improve response time by a certain threshold. We developed a discrete-event simulation model based on a real case to compare these policies and estimate their impact in practice.

■ HC9 TA 10:00- 11:30

Healthcare analytics - I

Chair/Président: Kimia Ghobadi, Johns Hopkins University

• **Machine learning prediction of post-operative emergency department hospital readmission**

Velibor Misic*, Kumar Rajaram
UCLA Anderson School of Management

Abstract: Readmissions are costly, markers of poor quality care and under the Affordable Care Act, lead to financial penalties for hospitals. While readmission prediction has been studied in medical/non-surgical patient populations, it has received less attention in surgical populations. In this talk, we present our collaboration with a large academic medical center to develop prediction models for surgical readmissions, using modern machine learning methods. Our models obtain more accurate predictions than existing scoring rules for readmission risk, and can be applied as early as 36 hours after the completion of surgery.

• **An analysis of advance scheduling problem in health care systems with uncertainty**

Nafise Niazi Shahraki*, Hossein Abouee Mehrizi, Houra Mahmoudzadeh
University of Waterloo

Abstract: Patients’ waiting times have increased significantly over the past decades. Lengthy waiting times caused by limited capacity or inefficient patient scheduling can have serious consequences for patients by potentially allowing reversible medical conditions to become chronic or irreversible conditions. In this talk, we present an adaptive scheduling approach for the advance patient scheduling problem with demand uncertainty. The problem is formulated using a robust optimization approach and an adversarial-based solution algorithm is developed to solve it. The proposed method is implemented for an MRI scheduling problem and possible practical policy implications for health care professionals in such settings are provided.

• **Evidence of worse outcomes related to out-of-hospital cardiac arrest during the COVID-19 pandemic due to patient reluctance to seek care**

Christopher L. F. Sun*, Sophia Dyer, James Salvia, Laura Segal, Retsef Levi
MIT [1, 5]; Massachusetts General Hospital [1]; Boston University School of Medicine [2]; Boston Emergency Medical Services [2, 3, 4]

Abstract: Delays in seeking emergency care stemming from patient reluctance may explain the rise in cases of out-of-hospital cardiac arrest (OHCA) and associated poor health outcomes during the coronavirus disease 2019 (COVID-19) pandemic. In this talk, we will discuss how we used emergency medical services

(EMS) call data from the Boston area to describe the association between patient reluctance to call EMS for cardiac-related care and both excess OHCA incidence and OHCA-related outcomes during the COVID-19 pandemic.

• Outcome prediction after radiotherapy in liver cancer

Ibrahim Chamseddine*, Yejin Kim, Harald Paganetti, Clemens Grassberger
Massachusetts General Hospital and Harvard Medical School [1, 2, 3, 4]; Korean Advanced Institute of Science and Technology [2]

Abstract: Radiotherapy is an effective treatment for unresecetable hepatocellular carcinoma, a common malignancy with high mortality. However, radiation-induced hepatic toxicity and immune cell depletion portend inferior outcomes. We show via voxel-based analysis of medical images and dose distributions that radiation to different locations correlates differentially with these toxicities. We build multiple novel classifiers and survival models that integrate these insights with pre-treatment and dosimetric features, and validate them on unseen external data. Our models show high predictive performance and robustness, can impact clinical management and help tailor radiotherapy, particularly in the context of additional treatment with immunotherapy.

■ HC7 TA 10:00- 11:30

Healthcare delivery - I

Session Co-Chair: Jonathan Patrick, University of Ottawa

Session Co-Chair: Antoine Sauré, University of Ottawa

• Markov decision process to design public policies in a public health network

Alejandro Cataldo, José Tomás*, Antoine Sauré
Pontificia Universidad Católica de Chile [1, 2]; University of Ottawa [3]

Abstract: Proper management in hospitals has a direct impact on patient outcomes, especially in areas such as ICU and emergency departments. However, the management has proven to be highly complex. One of the main determinants of the complexity of this task is the uncertainty inherent in decision-making on health-policy (patient admission to patient diagnostic) and resource planning at any level. To address this challenge, describe the stochastic aspects behind the processes mentioned above, and ultimately support decision making, it is necessary to develop and implement novel stochastic operations research approaches to identify guidelines that better support decision making in hospital networks.

• Dynamic home care routing and scheduling problem with uncertain arrivals and number of visits

Danial Khorasanian*, Antoine Sauré, Jonathan Patrick
University of Ottawa

Abstract: We describe a Markov decision process (MDP) model for the home care nurse scheduling and routing problem. We incorporate the uncertainty around the new arrivals and the number of visits for each patient. Decisions include whether or not to accept a new patient and if accepted how to route the nurse in order to minimize the costs. Given the size of the state space we employ the linear programming approach to approximate dynamic programming in order to find a feasible solution to the problem that we then test via simulation.

• A decision support system for home dialysis scheduling and routing problem

Ahmet Kandakoglu*, Antoine Sauré, Wojtek Michalowski
University of Ottawa

Abstract: We propose a user-friendly decision support system for home dialysis services. The system employs a mixed integer programming model to create daily visit schedules and routes for nurses that minimize the cost of providing such services. In this model, we also consider nurses' workload balance, overtime work, need for mealtime breaks, restrictions and preferences associated with the time of the visits, and different types of services. The model was validated using data provided by the Division of Nephrology at The Ottawa Hospital. Results show the cost of home dialysis service can be potentially reduced by more than 25 percent.

• Exploratory analysis of the maximum wait time guarantee policy for a rheumatology central intake clinic

Toni Tagimacruz*, Monica Cepoiu-Martin, Deborah A Marshall
University of Calgary

Abstract: Using discrete event simulation modelling, we analyze the impact of the maximum wait time guarantee policy for routing referrals for the initial rheumatologist consults on wait time performance measures. We then explore waiting cost and capacity cost conditions that make the maximum wait time guarantee policy a cost-effective alternative for a rheumatology clinic with a centralized referral intake system.

■ FRM6 TA 10:00- 11:30

Recent advances in financial engineering

Chair/Président: Clarence Simard, Université du Québec à Montréal

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• Optimal nested simulation via likelihood ratio for financial risk management

Ben Feng*, Eunhye Song
University of Waterloo; Pennsylvania State University

Abstract: We propose an optimal nested simulation experiment design that achieves a given accuracy with minimal computational efforts. Nested simulation is widely used in financial applications such as enterprise risk management (ERM). Despite its flexibility in and wide range of applications, nested simulation is notoriously known for its heavy computational burden. We propose to use the likelihood ratio method to pool simulation outputs from different sampling distributions. Based on effective sample size in importance sampling, we formulate an optimization problem that minimizes the computational budget while achieving a desired accuracy. Our numerical studies show encouraging results.

• Forecast performance and bubble analysis in noncausal MAR(1,1) processes

Joann Jasiak*, Christian Gourieroux, Andrew Hencic
York University; University of Toronto; Toronto Dominion Bank

Abstract: This paper examines the performance of nonlinear short-term forecasts of noncausal processes from closed-form functional predictive density estimators. The processes considered have mixed MAR(1,1) dynamics and non-Gaussian distributions with either nite or in nite variance. The forecast assessments are based on the forecast error behavior and the goodness of fit of the estimated predictive density. We show that two-step ahead predictive densities of future trajectories can be used as a method of graphical analysis for detection of bubble outsets in data that display economic bubbles and spikes. The method is applied to the Bitcoin/US Dollar exchange rates and commodity futures.

• Risk management under weighted limited expected loss: Optimal policies and equilibrium implications

An Chen, Thai Nguyen*
Ulm University; Université Laval

Abstract: We introduce and solve an optimal asset allocation problem under a weighted limited expected loss (WLEL) constraint, which contains the risk management problem under the limited expected loss constraint of Basak and Shapiro [2001] as a special case. Furthermore, we link our risk management problem under the WLEL constraint with an optimal asset allocation with a random reference-based preference (RRBP) and find the optimal wealth with RRBP owns the same form as the optimal solution under the WLEL constraint. In addition, we carry out a general equilibrium analysis in the presence of a WLEL risk manager.

• Optimal execution in a stochastic limit order book model

Clarence Simard*
Université du Québec à Montréal

Abstract: In a limit order book model, the size of a transaction has an adverse impact on price per share. It is well-known by researchers and practitioners as well that, to avoid this adverse impact, large transactions should be broken into smaller ones. The question of how subdividing a large transaction is known as the optimal execution problem. In Predoiu, Shaikhet, and Shreve (2011), the optimal execution strategy is derived for a limit order book model with non-stochastic dynamic. In this talk, I will discuss the optimal execution strategy for a stochastic limit order book model, generalizing the aforementioned result.

■ OPT5 TA 10:00- 11:30

Optimization and machine learning applications - I

Chair/Président: Cheng Guo, University of Toronto

• Reinforcement learning for integer programming: Learning to cut

Yunhao Tang*, Shipra Agrawal, Yuri Faenza
Columbia University

Abstract: Integer programming (IP) is a general optimization framework with many applications. Modern IP solvers rely on handcrafted heuristics tuned with human expertise. In this work, we show that the performance of those solvers could be greatly enhanced using reinforcement learning (RL). We investigate a specific methodology known as the Cutting Plane Method. We present a deep RL formulation for adaptive selections of cutting planes. Across a wide range of tasks, we show that our trained agent significantly outperforms baseline heuristics. The trained agent also benefits the application of cutting plane methods in Branch-and-Cut algorithm, the backbone of commercial IP solvers.

• Multistage stochastic programming with deep

learning-based time-series forecasts
Juyoung Wang, Mucahit Cevik*, Merve Bodur
University of Toronto [1, 3]; Ryerson University [2]

Abstract: Multistage stochastic programming provides a modeling framework for sequential decision-making problems involving uncertainty. One overlooked aspect of this methodology is how the uncertainty is incorporated into the modeling. Traditionally, statistical forecasting techniques such as AR(p) are used to extract scenarios to be added to the models to represent the uncertain future. However, oftentimes, the performance of these forecasting models are not thoroughly assessed. In this study, we adopt a modern deep learning-based time-series forecasting method, DeepAR, and compare the quality of the obtained policies with the case where a traditional time-series model, namely AR(1), is used to model the uncertainty.

• Predicting optimal radiation therapy plans for cancer treatment
Aaron Babier*, Andrea McNiven, Timothy Chan
University of Toronto [1, 3]; Princess Margaret Cancer Centre [2]

Abstract: Radiation therapy is one of the main modalities that clinics use to treat cancer. A key component of radiation therapy is the patient-specific treatment plan that can be generated via a predict-optimize pipeline. These two-stage pipelines use a prediction stage to estimate parameters of an optimization model, which is then optimized in the second stage. We propose a new pipeline that only has a prediction stage, and can thus bypass the need for conventional optimization approaches by predicting the decision variables rather than model parameters. This new pipelines generate high-quality plans in a fraction of the time of conventional approaches.

• An adaptive iterated local search using reinforcement learning for solving combinatorial optimization problems
Maryam Karimi Mamaghan*, Bastien Pasdeloup, Patrick Meyer, Mehrdad Mohammadi
IMT Atlantique

Abstract: Considering the non-stationarity of the search space of combinatorial optimization problems, we incorporate multiple search operators into the iterated local search meta-heuristic to enhance its exploration and exploitation abilities. Using reinforcement learning, the most appropriate operators are adaptively selected at each step of the search process based on the status of the search and the operators' performance history. We evaluate our algorithm on two NP-hard problems: traveling salesman and scheduling. The results show that our algorithm provides better solutions in terms of optimality gaps and convergence behavior, without imposing significant computational overhead, compared to meta-heuristics with individual operators.

■ OPT11 TA 10:00- 11:30

Inverse optimization - I

Chair/Président: Houra Mahmoudzadeh, University of Waterloo

• An inverse optimization approach to measuring clinical pathway concordance
Nasrin Yousefi*, Timothy Chan, Maria Eberg, Katharina Forster, Claire Holloway, Luciano Ieraci, Yusuf Shalaby
University of Toronto [1, 2, 7]; IQVIA [3]; Ontario Health (Cancer Care Ontario) [4, 5, 6]

Abstract: Clinical pathways outline standardized processes in the delivery of care for a specific cohort of patients. Patient journeys usually diverge from the recommended pathways, also called reference pathways, for different reasons. We quantify the concordance of patient-traversed pathways to the reference pathways using a data-driven inverse optimization method. Our methodological approach considers a patient's journey as a walk in a directed graph, where the costs on the arcs are derived by solving an inverse shortest path problem. We apply our methodology to a real dataset of colon cancer patients and show that it has a statistically significant association with survival.

• Data-driven inverse optimization for constraint inference
Houra Mahmoudzadeh*, Kimia Ghobadi
University of Waterloo; Johns Hopkins University

Abstract: In this talk, we propose a multi-point inverse optimization framework to infer the constraint parameters of a forward optimization problem. We focus on linear models in which the objective function is known but the constraint matrix is partially or fully unknown. We develop an inverse model and introduce a tractable reformulation that can be solved efficiently. We also provide several generalized measures to inform the desirable properties of the feasible region based on user preference and historical data. Our numerical examples verify the validity of our approach, emphasize the differences between the proposed measures, and provide intuition for data-driven implementations.

• Inverse optimization in semi-infinite linear pro-

grams
Archis Ghate*
University of Washington

Abstract: Given the costs and a feasible solution for a finite-dimensional linear program (LP), inverse optimization involves finding new costs that are close to the original ones and render the given solution optimal. Ahuja and Orlin employed the absolute weighted sum metric to quantify distances between costs, and then applied duality to establish that inverse optimization reduces to another finite-dimensional LP. This talk extends this to semi-infinite linear programs. A convergent Simplex algorithm to tackle the inverse SILP will be proposed.

• Learning linear programs from optimal decisions
Yingcong Tan, Andrew Delong, Daria Terekhov*
Concordia University

Abstract: We view inverse optimization as a learning problem where targets are generated by an optimization process. Leveraging this perspective, we develop a gradient-based non-linear programming approach to solve a bi-level representation of a general linear inverse optimization problem. The resulting method is, to the best of our knowledge, currently the most flexible approach to learning linear programs from optimal decisions: it is able to determine the cost vector and the constraints, independently or jointly, for both non-parametric and parametric linear programs, starting from one or multiple observations. Our work also solidifies the connection between inverse optimization and machine learning.

■ SMS1 TA 10:00- 11:30

Stochastic models in service operations - I

Chair/Président: Danqi Luo, Stanford University

• Treating to the priority in heart transplantation
Sait Tunc, Burhaneddin Sandikci, Philipp Afèche*
Virginia Tech; University of Chicago; University of Toronto

Abstract: The US heart transplantation system assigns priorities to candidates based on the therapies they receive, based on the assumption that the severity of their therapies reflects candidates' urgency for transplantation. However, it is widely suggested that such therapy-based prioritization creates incentives for gaming the system. Manipulation of the waitlist priority is even acknowledged by the medical community, with an active debate on the issue. We propose a novel framework to analytically study the gaming decisions of heart transplant centers, understand under what condition strategic gaming emerges, and how it can be prevented within the confines of the current system.

• Profit or growth? Dynamic order allocation a hybrid workforce
Eryn (Juan) He*, Joel Goh
National University of Singapore [1, 2]; Harvard Business School [2]

Abstract: Several firms augment their traditional labor supply of employees by engaging freelancers supplied by on-demand platforms. How should demand be allocated between employees and freelancers? Under what conditions is the system (the firm plus its platform) sustainable in the long run? We develop a discrete-time, stochastic dynamic program that captures the system's profit from serving demand and the platform's growth dynamics. We find that the answers to our research questions critically depend on two parameters: the mean and variance of cross-network effects. We conduct a numerical study with both synthetic data and data from a last-mile delivery firm in Vietnam.

• Cherry-picking and spillover on service level: Evidence from a radiology work ow platform
Timothy Chan, Nicholas Howard, Saman Lagzi*, Gonzalo Romero
University of Toronto [1, 3, 4]; Assurance IQ [2]

Abstract: Using a large dataset from a radiology workflow platform we empirically investigate whether radiologists cherry-pick tasks with high pay-to-workload, and if cherry-picking has a negative impact on service level. In our platform, radiologists have discretion to select tasks from a common pool and the service level is characterized by meeting priority-specific turnaround time targets. We show turnaround time and likelihood of delay is monotonically decreasing in pay-to-workload. Moreover, we also show a spillover effect. Namely, that cherry-picking of low priority tasks can lead to longer turnaround times for higher priority tasks, resulting in delays and their accumulation in the system.

• Abandonment from observable queues under different levels of priority information
Philipp Afeche, Junqi Hu*, Rouba Ibrahim, Vahid Sarhangian
University of Toronto [1, 2, 4]; University College London [3]

Abstract: Motivated by the Left Without Being Seen (LWBS) behavior of patients in Emergency Depart-

ments, we propose and study models of customer abandonment from observable multiserver priority queues. The abandonment behavior of the customers depends on their knowledge of their own priority levels as well as those of other customers present in the system. We investigate the performance of the system under different levels of information (no information, partial information, full information) by analyzing a fluid approximation of the corresponding queueing models.

■ AIML3 TA 10:00- 11:30

Model-based approaches for training in supervised learning

Chair/Président: Andre Cire, University of Toronto

• Training binarized neural networks using MIP and CP

Rodrigo Toro Icarte, León Illanes, Margarita Castro*, Andre Cire, Sheila McIlraith, J. Christopher Beck
University of Toronto

Abstract: In this work, we investigate a model-based approach to training Binarized Neural Networks (BNNs) using constraint programming (CP), mixed-integer programming (MIP), and CP/MIP hybrids. BNNs are an important class of neural networks characterized by weights and activations restricted to the set $\{-1, +1\}$. Our experimental results on the MNIST digit recognition dataset suggest that - when training data is limited - the BNNs found by our hybrid approach generalize better than those obtained from a state-of-the-art gradient descent method. More broadly, this work enables the analysis of neural network performance based on the availability of optimal solutions and optimality bounds.

• Learning to optimize with hidden constraints

Rafid Mahmood*, Aaron Babier, Timothy Chan, Adam Diamant
University of Toronto [1, 2, 3]; Schulich School of Business [4]

Abstract: We consider a framework for learning to solve optimization problems where the feasible set varies with instance-specific auxiliary information. Using historical decisions, we first train a classifier that learns to approximate a barrier function, which we use to train a generative model via an interior point method (IPM). We develop IPM theory for using a relaxation of the feasible set, and extend the results to obtain learning guarantees. Finally, we apply our framework to predict personalized dose prescriptions for head-and-neck cancer patients undergoing radiation therapy, where our model outperforms current baselines on learning hidden clinician preferences.

• Optimal robust classification trees

Nathan Justin*, Andres Gomez, Phebe Vayanos, Sina Aghaei
University of Southern California

Abstract: In many high-stakes domains, the data used to drive machine learning algorithms is noisy (due to e.g., the sensitive nature of the data being collected, limited resources available to validate the data, etc). In this paper, motivated by the need for interpretability and robustness in these domains, we present an efficient MIP-based method for learning optimal classification trees that are robust to perturbations in the data features. We evaluate the performance of our approach on numerous publicly available datasets and show significant improvements over the state-of-the-art.

■ Tutorial TA 10:00- 11:00

Contextual optimization

Chair/Président: Vahid Sarhangian , University of Toronto

• Contextual optimization: Bridging machine learning and operations research

Adam Elmachtoub
Associate Professor, Columbia University

Abstract: Many operations problems are associated with some form of a prediction problem. For instance, one cannot solve a supply chain problem without predicting demand. One cannot solve a shortest path problem without predicting travel times. One cannot solve a personalized pricing problem without predicting consumer valuations. In each of these problems, each instance is characterized by a context (or features). For instance, demand depends on prices and trends, travel times depend on weather and holidays, and consumer valuations depend on user demographics and click history. In this talk, we review recent results on how to solve such contextual optimization problems, with a particular emphasis on techniques that blend the prediction and decision tasks together.

■ TL4 TA 10:00- 11:30

Transportation and logistics under uncertainty

Chair/Président: Ahmed Saif, Dalhousie University

• An integer programming model and directed Steiner-forest based heuristic for routing less-than-truckload freight

Tamvada Srinivas Subramanya, Bahareh Mansouri*,

Elkafi Hassini, Theodore Pribytkov
McMaster University [1, 3]; Saint Mary's University [2]; Purolator Inc. [4]

Abstract: Less-than-truckload freight transportation is a vital part of the economy with cascading impact on many other industries. LTL operators often have to deal with large volumes of shipments and uncertainty in demand patterns. In this work, we present an integer linear programming model formulation for routing LTL freight. To solve the resulting large scale ILP, we use directed Steiner-forest to a time-space network and develop a hybrid heuristic. We test our heuristic on a real life case study. Experiments indicate that our heuristic and ILP model can produce good quality solution.

• Competitive bidding in transportation services procurement with stochastic prices
Farouk Hammami, Monia Rekik*, Leandro Callegari Coelho
Université Laval

Abstract: In combinatorial auctions for the procurement of transportation services, each carrier has to determine the set of profitable shipments to bid on and the associated ask prices. This is known as the Bid Construction Problem (BCP). Our paper adresses a BCP with stochastic clearing prices taking into account uncertainty on other competing carriers' offers. The problem is formulated with chance constraints. Both exact and heuristic solution methods are proposed. Experimental results will be presented.

• Transportation flexibility: Fixed routes with overlapped assignment for vehicle routing with stochastic demand
Kirby Ledvina, Hanzhang Qin, David Simchi-Levi, Yehua Wei*
MIT [1, 2, 3]; Duke University [4]

Abstract: We propose a fixed routing strategy for a vehicle fleet facing stochastic demand. Each vehicle has an a priori fixed route before customer demand is realized, and some vehicle routes overlap so that customers are shared between two vehicles. The design of the overlapped fixed routes is inspired by the classical chaining structure from the flexible manufacturing literature. In addition, we propose a recourse policy for the overlapped fixed routes in response to the stochastic demand. We show that our routing strategy exhibits strong asymptotic performances (measured by total distance traveled) and performs well numerically.

• Decision-based scenario clustering for decision-making under uncertainty
Michael Hewitt, Janosch Ortmann*, Walter Rei
Loyola University Chicago [1]; Université du Québec à Montréal [2, 3]

Abstract: Many problems related to transport can be formulated in terms of the optimisation of some quantity subject to constraints which are only partially known in advance. In stochastic programming, scenarios are used to approximate the distributions of the unknown parameters and formulate and solve multi-stage stochastic optimization models. However, optimising with respect to each scenario is computationally costly and it is often difficult to see how a change in assumptions impacts the solution. I will discuss how applying unsupervised clustering methods to the scenarios can lead to new upper and lower bounds and a better insight into the problem itself.

■ OSM7 TA 10:00- 11:30

Topics on ride-sharing and supply chain management

Chair/Président: Arseniy Gorbushin, University of Toronto

• Courier sharing in food delivery
Ming Hu, Arseniy Gorbushin*
University of Toronto

Abstract: The food delivery market has started to migrate to platforms rapidly. One reason food delivery platforms benefit this market is the potential to optimize courier routing by sharing couriers among many restaurants. Our analysis addresses the following questions with a spatial queueing model. First, how courier sharing contributes to the reduction of delivery costs? Second, how platforms affect restaurant positioning and food delivery market coverage. We show that sharing couriers between restaurants attains less wait time for customers. Moreover, when the market is sufficiently sensitive to taste, sharing couriers can lead to an increase in restaurant variety and market coverage.

• A model for last-mile e-commerce deliveries service time estimation using smart mobilized lockers in city transit systems
Si Liu*, Elkafi Hassini
McMaster University

Abstract: We propose a design of a smart mobilized locker for use with city transit systems to address the parking and congestion issues related to e-commerce last-mile deliveries. In addition, we present a model for estimating delivery service time at the bus stop using compound Poisson processes. The resulting service

time and the delivery cost are compared with typical current delivery methods for validation.

• **Exploring sustainable agri-food supply chain using multi-agent modelling and simulation**
Cynthia Waltho*, Fatemeh Fathallahi, Adel Guitouni
University of Victoria

Abstract: Our goal is to investigate intelligent solutions for the Agri-Food supply chain to improve farmers' triple bottom line (TBL). We focus on the British Columbia blueberry supply chain (BSC) which often involves many stakeholders and distribution networks, obscuring traditional methods of oversight, coordination, and collaboration. To study these chains, we propose a reinforcement-learning multi-agent modelling and simulation (M&S) environment. Agents with reinforcement-learning capability represent actors involved in the value chain activities. In this presentation, we present the M&S environment of the BSC and discuss supply chain management solutions to improve farmers' TBL.

• **Share or solo? Private and social choice in ride-sharing**
Hengda Wen*, Ming Hu, Jianfu Wang
Rotman School of Management [1, 2]; City University of Hong Kong [3]

Abstract: Ride-hailing platforms provide two types of services: solo and shared rides. Shared rides not only provide riders lower prices compared to solo ride, but also balance the supply and demand when the number of riders is greater than the number of drivers. In reality, although both Uber and Lyft provide customers with pooling options, researchers estimate only 20%-30% of rides in major metro areas are pooled. Our paper proves that the self-interested riders tend to under-share, which leads to a more congested system compared to the social-optimal strategy; and we provide remedies to make customers behave in a social-optimal manner.

• **Assortment planning in omni-channel retailing with returns**
Amin Aslani*, Osman Alp
University of Calgary

Abstract: Consider an omni-channel retailer consisting of an online sales website and a traditional store where product returns are considered. Unlike the website, due to capacity constraint and operational costs, it may not be possible to show all products in the store. Therefore, the retailer needs to find an optimal selection of products to make available in the store. Our model accounts for the interaction between product selections in the store and their impact on consumers' purchase decisions in the website. Results indicate that the optimal decision is a compromise between sales and the value of information that a selection releases.

■ QUE4 TA 10:00- 11:30

Queueing theory and matrix-analytic methods

Chair/Président: Haoran Wu, University of Waterloo

• **Catastrophes and queueing systems with time-varying periodic transition rates**
Barbara Margolius*, Sherif Ammar
Cleveland State University; Menofia University

Abstract: We study the asymptotic periodic distribution of queues with time-varying periodic transition rates and catastrophes that occur randomly according to an exponential distribution with time-varying periodic rate. When a disaster occurs, the system resets, all customers are lost and an exponentially distributed period of time elapses before the repair is complete. Service is governed by a phase distribution. The asymptotic periodic distribution of the queue process is analogous to the steady state distribution for a system with constant transition rates.

• **Multi-layer MMFF processes and their queueing applications**
Qi-Ming He*, Haoran Wu
University of Waterloo

Abstract: This talk consists of two parts: i) Introduction to multi-layer Markov modulated fluid flow (MMFF) processes and ii) Queueing applications. For multi-layer MMFF processes, we focus on the basic quantities and the joint stationary distribution. We also outline their computational methods. For queueing applications, we show how to introduce a multi-layer MMFF process to queueing models. We also show how queueing quantities can be obtained from the joint stationary distribution of the multi-layer MMFF process. In this talk, we consider an MAP/PH/K queue with customer abandonment. In another talk, we consider a double-sided queue and its extensions.

• **Double-sided queues with marked Markovian arrival processes and abandonment**
Haoran Wu*, Qi-Ming He
University of Waterloo

Abstract: In this paper, we study a double-sided queueing model with marked Markovian arrival pro-

cesses and general abandonment times. We apply the theory of multi-layer Markov modulated fluid flow (MMFF) processes to analyze the queueing model. We analyze the multi-layer MMFF process to find queueing performance measures related to the age processes, matching rates/probabilities, waiting times, and queue lengths for both sides of the queueing system. We obtain a number of aggregate quantities as well as quantities for individual types of inputs, which can be useful for the analysis and design of, for example, passenger-taxi service systems and organ transplantation systems.

■ PRM6 TA 10:00- 11:30

Optimization and revenue management

Chair/Président: Fredrik Odegaard, Ivey Business School

• Revenue management with endogenous buy-up
Mihai Banciu, Fredrik Odegaard*, Alia Stanciu
Bucknell University [1, 3]; Western University [2]

Abstract: We consider a single-resource that is sold via multiple fare classes with uncertain but statistically dependent demand. Customers may upgrade their class in an endogenous fashion, given their fare valuations. We determine the seller's optimal allocation capacity policy and investigate the behavior of the corresponding revenue function.

• Dynamic pricing competition: Lessons and thoughts
Kyle Maclean*
Western University

Abstract: The dynamic pricing competition is an annual international competition. Teams from both academia and industry submit data-driven pricing algorithms to be evaluated and to compete to make the most money under various scenarios. In the 2019 version, we placed first place under two out of the three scenarios. We discuss our approach and lessons learned in the process.

• A quadratic programming model for online pricing with customer reviews
Seyed Shervin Shams-Shoaaee*, Elkafi Hassini
McMaster University

Abstract: We propose a data-driven quadratic programming optimization model for online pricing in the presence of consumer ratings. To account for ratings, we develop a new demand function for a multi-product, finite horizon, online retail environment. To solve the problem we introduce a myopic pricing heuristic as well as exact solution approaches. Using customer reviews ratings data from Amazon.com, we validate a new customer reviews rating forecasting model and provide several analytical, and numerical insights.

■ IND6 TA 10:00- 11:30

Distinguished talks on banking/finance

Chair/Président: Achille Ettorre, Ettorre & Associates Ltd

• Machine learning implementation at a bank: Banorte's success story
Jose Murillo*
Grupo Financiero Banorte

Abstract: During a 6-year span of time Banorte made more than 4 billion USD in net revenue through AI and data science projects. Dr. Murillo will talk about the highly successful AI initiatives which faced technical barriers for its implementation and how they were sorted out. This will be a frank discussion on the main barriers faced by large organizations aiming to have a highly profitable AI program focusing on three dimensions: data, technology, and human resources. The use cases shown in this talk will illustrate why AI matters for those who want to further the understanding of their customers, enhance their experience, and increase the customer lifetime value.

• Trusted data and artificial intelligence systems (AIS) for financial services
Pavel Abdur-Rahman*
IBM Canada

Abstract: Ethical deployment of Data and Technology is at the heart of Open Banking and ESG Transformation for Financial Services. In this IEEE Finance Playbook global initiative, we will continue to curate, survey, summarize, and contextualize trusted data and AI implementation high level requirements and best practices for financial services. Please join our journey to develop a global consensus-based standards and certifications program for high value AI applications and intelligent workflows. This talk will walk you through an industry-specific implementation playbook that encourages technologists in the financial services to prioritize human well-being and ethical considerations in the applications Data and Autonomous and Intelligent Systems (AIS).

■ ENRE1 TA 10:00- 11:30

Energy and natural resources

Chair/Président: Lindsay Anderson, Cornell Uni-

versity

• **A multiobjective policy search approach for stakeholder engagement in microgrid management**
Vivienne Liu*, Lindsay Anderson
Cornell University

Abstract: A sustainable energy transition is predicated on increasing distributed energy resources, renewables, and consumer engagement. Microgrids are receiving increasing interest as a candidate approach for managing these components. In this presentation, we explore a simulation based approach to multiobjective optimization of an energy management strategy for a community microgrid. The approach does not require a priori assumption of objective priorities, and provides a mechanism for community stakeholders to understand tradeoffs and engage in informed decision making.

• **A differential game model for world oil production**
Junhe Chen, Matt Davison*
Western University

Abstract: World oil market producers decide production levels based on varying cost structures and reserves. Oil demand varies in response to stochastic economic and geopolitical drivers. We study the interplay between these factors on price formation and impact on production decisions using a differential game approach. We present a stylized game with four (US conventional, US shale, Saudi Arabia and Russia) players and a linear price model. US conventional reserves are finite while others are modelled as infinite. We challenge the model with real production and consumption data and compare its production predictions with actual observations.

• **Real option valuation of a mining project using simulation and exercise boundary fitting**
Yuri Lawryshyn*
University of Toronto

Abstract: Real option analysis is recognized as a superior method to quantify the value of real-world investment opportunities. In previous work we presented a methodology employing the idea of fitting optimal decision making boundaries to optimize the expected value, based on Monte Carlo simulated stochastic processes that represent important uncertain factors. The focus of this presentation is the application of the methodology in the context of mining valuation. Our model accounts for commodity price uncertainty, uncertainty associated with the quality of the mine and the optionality associated with expanding or abandoning the mine.

• **A risk-constrained Holacracy Model for smart grids considering residential demand response and plug-in electric vehicles**
Peyman Afzali*, Elaheh Rashidinejad, Masoud Rashidinejad, Amir Abdollahi
Shahid Bahonar University of Kerman [1, 4]; University of Toronto [2]; Queen's University [3]

Abstract: In a smart microgrid, some electricity consumers may have chance to produce electric energy and inject it into the local grid. Since residential consumers may produce electricity via virtual power plants (VPPs) considering the variety of energy resources such as solar panels, wind turbines and plug-in electric vehicles (PEVs), they can be known as ProCumers. On the other hand, the more integration of electricity aggregators and the participation of smart homes in the residential demand response programs (RDRPs) can help to electricity decentralization. This paper presents a new concept of a self-organizing system based upon holacracy model for decentralized management.

■ Plenary 11:30- 12:30

Plenary Lecture by Susan Athey

Chair/Président: Timothy Chan, CORS2021 Program Chair (University of Toronto)

• **Learning targeted treatment assignment policies**
Susan Athey
Economics of Technology Professor, Stanford University

Abstract: This talk will review recent research on methods to estimate optimal targeted treatment assignment policies, including both offline (using observational data) and online learning. It will further present several applications.

■ NN1 TB 13:30- 15:00

Neural Network Workshop 1

Chair/Président: Maxime Gasse
Polytechnique Montréal/Mila

• **Neural Networks for OR professors, researchers and practictioners**
Animesh Garg
University of Toronto/Vector Institute

Abstract: This session consists of a 30-minute invited talk on recent research directions by Animesh

Garg (University of Toronto/Vector Institute), and a 60-minute lecture covering the foundations of deep learning.

■ HC25 TB 13:30- 15:00

Managing healthcare operations during the COVID-19 pandemic - I

Chair/Président: Vahid Sarhangian, University of Toronto

• Optimal resource and demand redistribution for healthcare systems during COVID-19 surges

Felix Parker*, Fardin Ganjkhanloo, Farzin Ahmadi, Kimia Ghobadi
Johns Hopkins University

Abstract: Managing COVID-19 capacity demands has been challenging for many hospitals and health systems. Simply increasing hospitals' COVID-19 capacity when there are surges can overburden staff and can adversely impact patient outcomes. Patient transfers can be significantly more effective, if done correctly. We propose a data-driven optimization model to redistribute patients and resources between hospitals to optimally alleviate the burden from demand surges. This model is robust against demand uncertainty and incorporates operational constraints and preferences, so it is practical for real-world adoption. We have also developed an interactive tool to demonstrate its potential impact in over 4,800 US hospitals.

• Prediction of personal protective equipment use in hospitals during COVID-19

Eugene Furman*, Alex Cressman, Saeha Shin, Alexey Kuznetsov, Fahad Razak, Amol Verma, Adam Diamant
University of Toronto [1, 2, 5, 6]; St. Michael's Hospital [3]; York University [4]; Schulich School of Business [7]

Abstract: Demand for Personal Protective Equipment (PPE) has increased significantly since the onset of COVID-19. As hospitals resume regular operations, staff will be required to wear PPE at all times while additional PPE will be mandated during medical procedures. This will put increased pressure on hospitals which have had problems predicting PPE usage and sourcing its supply. We propose a queueing approach to predict PPE demand. We derive closed-form estimates for the expected amount of PPE required and apply our technique to a data set of 22,039 patients admitted to the internal medicine department at St. Michael' hospital in Toronto, Canada.

• Comparisons of N95 and elastomeric respirators for use during pandemics - A literature review

Ceilidh Bray*, Peter Vanberkel
Dalhousie University

Abstract: SARS-CoV-2 has posed implications for personal protective equipment supply. In this research we determine if elastomeric facepiece respirators (EFRs) are efficacious substitutes for N95s by reviewing function and cost factors for equipment comparisons. We found, among other things, that users favour N95 respirators for comfort but prefer EFRs for protection. EFRs are more cost effective when N95s are used as designed (single use) but mixed strategies minimize costs when N95s are reused (as practiced during shortages). Future research is needed on multicriteria analyses and to incorporate SARS-CoV-2 specific data to support future pandemic planning.

• Optimizing inter-hospital patient transfers during a pandemic

Frances Pogacar*, Tim Chan, Vahid Sarhangian, Fahad Razak, Amol Verma
University of Toronto [1, 2, 3]; Unity Health - St. Michael's Hospital [4, 5]

Abstract: During the COVID-19 pandemic in Ontario, a province-wide initiative began to redistribute patients across hospitals. Our work demonstrates that redistributing patients can potentially balance the COVID+ burden and have significant improvements on ward and ICU occupancy. Using queueing models and their fluid approximations to consider the dynamics between ward and ICU, we develop linear and mixed-integer programs to find optimal transfers of incoming patients. We validate our queueing model with historical occupancy data and quantify the benefit of optimized transfer decisions in terms of the distribution of COVID+ burden and number of patient-days over 95% ICU and ward occupancy.

■ HC24 TB 13:30- 15:00

Healthcare delivery - II

Chair/Président: Nadia Lahrichi, Polytechniqe Montréal

• Patient rescheduling in radiotherapy

Dina Ben Tayeb*, Nadia Lahrichi, Louis-Martin Rousseau
Polytechnique Montréal

Abstract: Patient scheduling in radiotherapy is managed under hard constraints. Patients start their treatment on a specific machine and for a determined period. In real life, many disruptions can change the plan-

ning process. Our work focuses on patient rescheduling in radiotherapy centers in the context of machine breakdown. We develop a mixed integer programming model that minimizes the changes compared to the initial planning. We also propose various strategies of rescheduling. We simulate and evaluate different scenarios considering a dynamic environment to better inform management on the best way to handle these disruptions.

• Simulation of patient flow and surgical block optimization considering bed management in a university hospital

Adam Lebrigui*, Alberto Lacort Burgos, Nadia Lahrichi
Polytechnique Montréal [1, 3]; Universitat Politécnica de València (UPV) [2]

Abstract: The project aims to generate an overview of bed utilization in a university hospital based on the hypothesis that patient flow in the emergency department and the operating room are key factors for its management. The objective of the project is to provide tools to ensure efficient scheduling of the operating room and proper bed management. To this end, this project offers two solutions that help decision making: a simulation model, which aims to analyze the flow of incoming patients, as well as an optimization model, which generates Surgical Master Schedules accounting for the availability of beds.

• Optimization of lung cancer patients trajectory by using Jackson networks

Mengfei Li*, Michèle Bally, Nadia Lahrichi, Peter Vanberkel
Polytechnique Montréal [1, 3]; Centre de recherche du Centre hospitalier de l'Université de Montréal [2]; Dalhousie University [4]

Abstract: Open Jackson network is a queueing network that allows to model patients coming from outside the hospital and transfers between investigations until they undertake treatment. We apply this methodology in this study to describe the diagnostic procedures for lung cancer patients and to assign priorities for reducing average waiting time. We divides investigations by type of resource and use Process Mining analyze the structure of this network. Finally, simulation modeling is used to assess the performance and accuracy of the analytical model. Lung cancer patients in Centre hospitalier de l'Université de Montréal (CHUM) from 2017-2018 are used as case study.

• Data-driven strategic planning to maintain quality of care in radiotherapy centers during the pandemic of COVID-19

Marc-Andre Renaud*, Nadia Lahrichi, Louis-Martin Rousseau
Polytechnique Montréal

Abstract: We analyze the impact of the disruptions caused by the COVID-19 pandemic on the operations of a radiotherapy centre. We present the patients' trajectories in the particular case of breast cancer and evaluate the future impact of the COVID-induced shutdown in the screening activities that took place in early 2020. We present simulation and optimization models that allow estimating if and when surges in demand for radiotherapy treatment will occur once the centre reopens. Finally, we present managerial insights that highlight the nonlinear effect between the length of the shutdown and the time necessary for delays to return to normal.

• Generic simulation model for the decontamination of surgical instruments and analysis of automation and scheduling scenarios

Marzieh Ghiyasinasab*, Nadia Lahrichi, Nadia Lehoux
Polytechnique Montréal [1, 2]; Laval University [3]

Abstract: In hospitals, decontamination centers are required to sort, sterilize, package and store surgical instruments prior to their return to the operating rooms. The market trend is to automate this function to increase the level of productivity, reduce the risk of human error and minimize the risk of musculoskeletal injuries related to the handling of heavy loads. The goal of this research is to study the automation of a decontamination center and the use of a particular technology to make the system more efficient and safer.

■ HC10 TB 13:30- 15:00

HCOR SIG student presentation competition

Chair/Président: Valérie Bélanger, HEC Montréal

• HCOR SIG student presentation competition

Vusal Babashov*, Evgueniia Doudareva*, Peyman Kafaei*, Hossein Piri*
University of Ottawa; University of Toronto; Polytechnique Montréal; University of British Columbia

Finalists:

- **Vusal Babashov** (University of Ottawa) — Setting wait time targets in a multi-priority setting: An inverse optimization approach
- **Evgueniia Doudareva** (University of Toronto) — The development of a generic emergency department discrete event simulation model
- **Peyman Kafaei** (Polytechnique Montreal) — Deep Q-learning for beam orientation and tra-

jectory optimisation for radiosurgery

- **Hossein Piri** (University of British Columbia) — Dynamic individualized patient monitoring under alarm fatigue

■ FRM10 TB 13:30- 15:00

Finance and Machine Learning (FinML)

Chair/Président: Saeed Marzban, HEC Montréal

• Equal risk pricing and hedging of financial derivatives with convex risk measures

Saeed Marzban*, Erick Delage, Jonathan Li
HEC Montréal [1, 2]; University of Ottawa [3]

Abstract: We consider the problem of equal risk pricing and hedging in which the fair price of an option is the price that exposes both sides of the contract to the same level of risk. Focusing for the first time on the context where risk is measured according to convex risk measures, we establish that the problem reduces to solving independently the writer and the buyer's hedging problem with zero initial capital. By further imposing that the risk measures decompose to satisfy a Markovian property, we provide dynamic programming equations to solve the hedging problems for both European and American options.

• Equal risk pricing of derivatives with deep hedging

Alexandre Carbonneau*, Frédéric Godin
Concordia University

Abstract: In this talk, I will present a deep reinforcement learning approach to implement the equal risk pricing (ERP) framework for financial derivatives pricing. ERP entails solving for a derivative price which equates the optimally hedged residual risk exposure associated respectively with the long and short positions in the contingent claim. The solution to the hedging optimization problem considered is obtained through the use of the neural networks representing global hedging policies with the deep hedging algorithm of Buehler et al. (2019). Numerical experiments are presented under a large variety of market dynamics to demonstrate the practicability of our approach.

• Event driven high frequency market making

Francis Huot-Chantal*, Fabian Bastin, Gabriel Yergeau
Université de Montréal [1, 2]; HEC Montréal [3]

Abstract: We describe a quoting policy for market making based on inventory models optimization, leading to a threshold policy, in the context of high-frequency trading. In our model, the market maker aims to maximize his profit while providing liquidity to the stock market and keeping the risk at a reasonable level. We assess the policy performance in terms of profitability and robustness using backtesting and agent-based simulation. Various simulation frameworks are considered, using policies based on time intervals or discrete events, and a zero-intelligence policy as a baseline. We also consider parametric and non-parametric stochastic processes to generate the events.

■ OPT6 TB 13:30- 15:00

Optimization in healthcare - II

Chair/Président: Carolina Riascos, University of Toronto

• Dealing with uncertainty in kidney exchange

Duncan McElfresh*, Ke Ren, Hoda Bidkhori, John Dickerson
University of Maryland, College Park [1, 4]; University of Pittsburgh [2, 3]

Abstract: Kidney exchange is a real-world barter market, where patients with end-stage renal disease swap their paired willing living donors. Exchanges account for about 10% of living donations in the US, and is growing rapidly worldwide. Kidney exchange is an (NP-complete) packing problem on a directed graph, consisting of both cyclic swaps and "chains" initiated by a donor. Uncertainty (e.g., over which transplants are feasible) causes substantial inefficiency in real exchanges. We cover related work using robust optimization, stochastic optimization, and conditional value at risk. We briefly discuss ongoing work using information discovery and recourse in a real exchange setting.

• A learning Tabu search algorithm to improve the patient flow by determining a physician schedule

Nazgol Niroumandrad*, Nadia Lahrichi
Polytechnique Montréal

Abstract: Meta-heuristic algorithms are widely known and chosen to solve many combinatorial problems. Over the last years a large number of algorithms were presented in which they combine various methods, sometimes from other optimization algorithms and outside of meta-heuristic fields. In this research project, we are studying the effects of employing learning methods to improve the performance of a Tabu Search algorithm. We use a physician scheduling problem to illustrate the performance of the method.

• A Lagrangian-based branch and bound for the

kidney exchange problem
Carolina Riascos*, Merve Bodur, Dionne Aleman
University of Toronto

Abstract: We present a novel decomposition algorithm for the Kidney Exchange Problem (KEP). Given a digraph, the KEP aims to select a vertex-disjoint cycle and path packing of the graph, satisfying cardinality constraints and maximizing total arc weight. We propose a Lagrangian decomposition of the problem, for which we represent the sub-problems as decision diagrams. This transformation allows us to solve the subproblems efficiently through a longest path algorithm. We embed the Lagrangian relaxation in a Branch and Bound algorithm. We show that our approach outperforms the state of the art.

• **Multistage stochastic distributed operating room scheduling**
Anna Deza*, Cheng Guo, Merve Bodur
University of Toronto

Abstract: The stochastic distributed operating room (OR) scheduling problem aims to assign surgeries to ORs across collaborating hospitals, in the face of surgery duration uncertainty. We extend this problem to a multistage setting, where at each stage previously cancelled patients are rescheduled. The objective is to minimize total operational and cancelation costs. We obtain policies and bounds for our multistage stochastic programming model via traditional approximation methods and Lagrangian dual decision rules.

■ OPT12 TB 13:30- 15:00
Robust and stochastic optimization - I

Co-Chairs/Présidents: Amir Ardestani-Jaafari, University of British Columbia
Co-Chairs/Présidents: Peter Zhang, Carnegie Mellon University

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• **A robust integration of EVs charging behavior in smart grid's capacity expansion planning**
Sajad Aliakbari Sani*, Olivier Bahn, Erick Delage
HEC Montréal GERAD

Abstract: Battery charging of a fleet of EV users is an important load in smart grids. Charging behavior influences not only the expansion plan of the smart grid, but also the total marginal price of electricity production. In this paper, we exploit a Mean-Field-Game (MFG) to model how electricity prices affect the charging behavior of a large number of EV users connected to a smart grid. This in turn, allows us to use this information to characterize demand response uncertainty in a conservative approximation of a robust multi-period capacity expansion problem, and iterate until an equilibrium is reached.

• **Risk-averse regret minimization in multi-stage stochastic programs**
Mehran Poursoltani*, Erick Delage, Angelos Georghiou
HEC Montréal [1, 2]; University of Cyprus [3]

Abstract: Within the context of optimization under uncertainty, a well-known alternative to minimizing expected value or the worst-case scenario consists in minimizing regret. In a multi-stage stochastic programming setting with a discrete probability distribution, we explore the idea of risk-averse regret minimization, where the hindsight decisions benefit from getting access to the realizations of a certain number of stages ahead. We provide theoretical and numerical insights about this paradigm under popular risk measures and shed light on the effect of the length of the period used by the decision-maker when evaluating regret.

• **The value of randomized strategies in distributionally robust risk averse maximum flow network interdiction problems**
Utsav Sadana*, Erick Delage
HEC Montréal

Abstract: We introduce a distributionally robust maximum flow network interdiction problem where the interdictor randomizes over the feasible interdiction plans in order to minimize the worst-case Conditional Value at Risk (CVaR) of the flow with respect to both the unknown distribution of the capacity of the arcs and his randomized strategy over interdicted arcs. The flow player, on the contrary, maximizes the total flow in the network. For solving this problem to any given optimality level, we devise a spatial branch and bound algorithm. Our numerical experiments show that randomized strategies can have significantly better performance than optimal deterministic ones.

• **Optimality criteria of constant and affine policies in adjustable robust linear optimization**
Ningji Wei*, Peter Zhang
Carnegie Mellon University

Abstract: We provide general conditions under which constant (a.k.a. static) policies and affine policies (a.k.a., linear decision rules) are optimal for adjustable robust linear optimization. Our results provide a unifying framework to reinterpret and extend several existing results in the robust optimization literature, and provide new geometric insights to understand this class of problems.

■ SMS2 TB 13:30- 15:00

Empirical studies of queueing systems

Chair/Président: Raha Imanirad, Schulich School of Business

• **Geographic resource pooling: Data-driven tradeoff between waiting and traveling**

Yangzi Jiang*, Jan Van Mieghem, Hossein Abouee Mehrizi
Northwestern University [1, 2]; University of Waterloo [3]

Abstract: MRI hospitals are evaluated by their ability to treat patients within wait time targets. Using patient-level data from 72 MRI hospitals gathered over five years, we find that over 60% of patients exceed their targets. We conduct an empirical investigation on how to reduce the percentage of patients exceeding the target. We propose a geographic resource pooling model that analyzes the tradeoff between driving distance and wait time reduction. Genetic Algorithms are used to generate optimal resource pools for various tradeoff coefficients. We demonstrate that our resource pooling model can reduce the percentage of exceeding patients to 34%.

• **The impact of acute care length of stay on rehabilitation outcomes**

Jing Dong, Berk Gorgulu*, Vahid Sarhangian
Columbia Business School [1]; University of Toronto [2, 3]

Abstract: Acute patients often require rehabilitation after the acute episode of their care is completed. Using data from a network of hospitals in Ontario, we investigate whether the acute care length of stay (LOS) and waiting time of patients before being admitted to rehab has an impact on their rehab outcomes and length of stays. We further investigate the operational implications of the relationship using a queueing network model of patient flow from acute to rehab care.

• **Do physicians influence one another's performance? Evidence from the Emergency Department**

Raha Imanirad*, Soroush Saghafian, Stephen Traub
Harvard Business School; Harvard University; Mayo Clinic Arizona

Abstract: We use evidence from Emergency Medicine to study whether and how physicians who work during the same shifts affect one another's performance. We find strong empirical evidence that physicians affect one another's speed and quality in our setting. We identify resource spillover from peers' utilization of shared resources as the main driver of the effects and show that during high-volume shifts (when shared resources are most constrained),the magnitude of the effects increases. Our findings have implications in various services in which workers utilize shared scarce resources, and shed light on the connection between constrained capacity and influence of workers on one another's performance.

• **Learning to recommend using non-uniform data**

Mohsen Bayati, Wanning Chen*
Stanford University

Abstract: Recommendation systems are widely used by online platforms. One noteworthy phenomenon, for example in the movie-streaming services, is that some people rate more movies, and some movies get rated more. These two sources of non-uniformity degrade the power of many existing recommendation algorithms, as they assumed that the observed movie ratings are sampled uniformly at random among user-movie pairs. Thus, we design a theory-driven algorithm that restores the non-uniformity element and show that this addition of information will boost the recommendation performance.

■ FOR1 TB 13:30- 15:00

Analytics in forestry

Chair/Président: Mikael Rönnqvist, Université Laval

• **Machine learning models for variability control: The case of the wood recovery industry**

Ilyas Rahhali, Loubna Benabbou*, Sébastien Fillion, Foroogh Abasian
Polytechnique Montréal [1]; Université de Quebec à Rimouski (UQAR) [2]; FPinnovations [3, 4]

Abstract: In the wood recovery industry, logs go through several steps before being cut into specific design patterns. One of these steps is rotating the log into an optimal angle that maximizes the profit of products extracted from it. For this project specifically, the most impactful source of variance is the rotation angle error of the machine responsible in turning these logs. The objectives of the project are analyzing variability sources, collecting and preprocessing relevant data and designing predictive models of the most impactful sources of variability from the data prepared beforehand using a machine learning approach.

• **Prediction of softwood lumber prices using descriptive models**

Salim Belkhous*, Maha Ben Ali, Luc Adjengue
Polytechnique Montréal

Abstract: Softwood lumber planners use price forecasts to define new selling prices and to drive production plans, especially with long delays from harvesting to distribution. These forecasts are also important for the construction and financial sectors. While players in the financial market use forecasts for speculation purposes, softwood lumber managers need to understand factors that influence prices, in order to anticipate the demand and protect themselves against unexpected price variations, particularly important during unstable economic phases. Our study proposes statistical models that predict accurately softwood lumber prices for different time horizons and identify the most significant factors influencing market prices.

• Artificial Neural Networks (ANN) for best performance modeling of sawmills in Ontario

Shashi Shahi, Mohamed Dia*
Laurentian University

Abstract: The sawmills in Ontario are operating inefficiently due to high market demand and supply uncertainties. Past studies have assessed their efficiencies using Bootstrap Data Envelopment Analysis (DEA) methodology. The Artificial Neural Networks (ANN) models use abstract learning from a limited set of information and provide the predictive power. The complementary modeling approaches of the DEA and ANN models provide an adaptive decision support tool for improving the performance of sawmills. The trained ANN models demonstrate promising results in predicting the relative efficiency and optimal combination of the inputs and outputs of sawmills in Ontario for their continuous performance improvement.

• Optimization of primary extraction routes using DSS BestWay

Mikael Ronnqvist*, Patrik Flisberg, Erik Willén, Mikael Frisk
Université Laval [1]; Forestry Research Institute of Sweden [2, 3]; Creative Optimization - Sweden [4];

Abstract: There is increasing attention improving productivity in forest logging operations while reducing negative impact on soil and water streams. The position of primary extraction routes is crucial in these efforts as it has a huge impact on efficient and sustainable forwarder passages. The DSS Bestway comprises of an optimization model and method, detailed digital terrain model, depth-to-water maps and forest volume from lidar data. The information is supplemented with position of the landing(s), nature and culture conservation sites, and any known unavoidable crossings in the terrain, e.g. streams. The system has been evaluated on two large case studies.

■ OSM6 TB 13:30- 15:00

Novel applications in operations management

Chair/Président: Gonzalo Romero, University of Toronto

• Interpretable optimal stopping

Velibor Misic*, Florin Ciocan
UCLA Anderson School of Management; INSEAD (France)

Abstract: Optimal stopping is the problem of deciding when to stop a stochastic system to obtain the greatest reward. In this paper, we propose a new approach to optimal stopping, wherein the policy is represented as a binary tree, in the spirit of naturally interpretable tree models commonly used in machine learning. Through experiments with problem instances from option pricing, we show that our method obtains policies that (1) outperform state-of-the-art non-interpretable methods (namely, the simulation-regression method of Longstaff and Schwartz and the pathwise optimization method of Desai, Farias and Moallemi) and (2) possess a remarkably simple and intuitive structure.

• Interpretable machine learning for analyzing national immigration policy

Mohammad Fazel-Zarandi*, Dimitris Bertsimas
MIT

Abstract: In this study, we investigate how interpretable machine learning can be used to analyze significant public policy problems. We present an interpretable machine learning method to study how the Immigration and Customs Enforcement (ICE) carries out major national immigration policies of the United States. The method uses a combination of state-of-the-art machine learning algorithms and a natural policy experiment to discover ICE's implicit decision-making strategies. We demonstrate that our algorithm can predict ICE's decisions with high accuracy. Our algorithms enable us to provide rigorous empirical evidence on how ICE enforces the emigration laws of the US.

• Innovative business models in ocean plastic recycling

Opher Baron, Gonzalo Romero, Zhuoluo Zhang*, Sean Zhou
Rotman School of Management [1, 2]; Chinese University of Hong Kong [3, 4]

Abstract: With growing concern about ocean plastic pollution, reducing it has become imperative. Based on

collaboration with a plastic recycling start-up, we develop and analyze models that resemble its practices. Based on the optimal solutions derived, we discuss and compare various business models to quantify both their environmental and societal impact.

• **Multi-period outsourcing decision in the presence of supplier copycatting**

Shobeir Amirnequiee*, Hubert Pun, Joe Naoum-Sawaya
Ivey Business School

Abstract: Counterfeits pose an unprecedented threat to the businesses worldwide. A common form of counterfeiting are the "ghost shift", which happens when firms outsource their production to the suppliers overseas, and the suppliers activate a "third shift" to produce a counterfeit product using the firm's intellectual property. In this paper, we develop a multi-period, probabilistic game to model the relationship between an outsourcing manufacturer and two types of suppliers: a low-quality supplier and a high-quality copycat supplier. We study the manufacturer's optimal strategy when future outsourcing opportunities exist and copycat supplier's optimal strategy when encroaching to the market has future repercussions.

■ QUE6 TB 13:30- 15:00

Approximations, inference, and optimization for queueing systems

Chair/Président: Yiqiang Zhao, Carleton University

• **Exact tail asymptotics for fluid models driven by an M/M/c queue**

Wendi Li*, Yuanyuan Liu, Yiqiang Zhao
Central South University [1, 2]; Carleton University [3]

Abstract: In this talk, we investigate exact tail asymptotics for the stationary distribution of a fluid model driven by the M/M/c queue, which is a two-dimensional queueing system with a discrete phase and a continuous level. We extend the kernel method to study tail asymptotics of its stationary distribution, and a total of three types of exact tail asymptotics are identified.

• **On Bayesian estimation for join the shortest queue model**

Ehssan Ghashim*, Zhao Yiqiang
Carleton University

Abstract: A system of two parallel M/M/1 queues managed by the Join the Shortest Queue policy is considered in this talk. Assuming the steady-state case, Queues length distribution for such model is very complicated and applying Bayesian estimation techniques is not an easily accomplished task. We propose a new technique to estimate the traffic intensity for JSQ-2 model. The new technique is based on fitting queues length data with a suggested general bivariate geometric distribution and new version of general bivariate beta distribution as a prior distribution for the unknown parameters. MCMC method with slice sampling is applied and supported numerical results are provided.

• **Mean-field model for multiple TCP and UDP connections through a network implementing a dynamic routing**

Ahmed Sid-Ali*
Carleton University

Abstract: We present a fluid Markovian model for multiple TCP and UDP connections interacting through a network of queues implementing a dynamical routing protocol. The presence of both TCP and UDP flows in addition to the dynamical routing gives rise to a complex interacting system. We analyze a mean-field limit when the number of connections goes to infinity and we establish a propagation of chaos result according to which the connection evolutions should become independent and converge in law. Particularly, the behaviour of the TCP connections can be represented by the solution of a nonlinear stochastic differential equation of lower dimensionality.

• **Exhaustive stochastic decomposition approach – Application for tail asymptotics of a retrial queue**

Bin Liu, Yiqiang Zhao*
Anhui Jianzhu University; Carleton University

Abstract: We propose an exhaustive stochastic decomposition approach, which can be used for decomposing a transformation of a probability distribution into detailed components, each having a probabilistic interpretation. In terms of a retrial queueing model, we demonstrate how to this approach to obtain tail asymptotic properties for the stationary number of customers in the system.

■ PRM5 TB 13:30- 15:00

Platforms in revenue management

Chair/Président: Murray Lei, Queen's University

• **Dynamic workforce acquisition for crowdsourced last-mile delivery platforms**

Murray Lei*, Stefanus Jasin, Jingyi Wang, Houtao

Deng, Jagannath Putrevu
Queen's University [1]; University of Michigan [2]; Duke University [3]; Instacart [4, 5]

Abstract: We consider a Dynamic Workforce Acquisition problem for crowdsourced last-mile delivery platforms that need to match supply with demand. We develop near-optimal algorithms for a general problem with uncertainties in both workers' responses and demand arrivals.

• Quantifying mileage runs: Strategic consumer behavior in premium-status loyalty program
Yang Chen*, Anton Ovchinnikov
Queen's University

Abstract: We report on the results of a large-scale field quasi-experiment done at a major loyalty program to understand strategic consumer behavior with respect to the premium status tier reward. We find that strategic behavior is quite pronounced and adds to nearly 4% increase in the target group' spending. However, we also observe on substantial heterogeneity in consumer behavior, which confirms the existing theory and enriches the existing empirical evidence of strategic consumer behavior.

• Sequential individual rationality in dynamic ridesharing
Ragavendran Gopalakrishnan*, Theja Tulabandhula, Koyel Mukherjee
Queen's University; University of Illinois at Chicago; Games24x7

Abstract: In dynamic ridesharing systems, both operational policies (e.g., ride-matching) and economic policies (e.g., pricing) impact the Quality of Service (QoS) perceived by users. Recent field experiments have found that firms benefit from proactively compensating users whose QoS expectations are violated. This motivates a broader analytical study of how behavioral perceptions of QoS impact operational and economic policy design in ridesharing systems. We introduce a QoS-centric framework that bridges operational effects (detours) and economic effects (prices or cost shares) to characterize a ride's optimal shareable region in both commercial and carpooling settings, and draw some useful insights from our analysis.

• Multi-stage and multi-customer assortment optimization with inventory constraints
Elaheh Fata*, Will Ma, David Simchi-Levi
Massachusetts Institute of Technology [1, 3]; Columbia University [2]

Abstract: We consider an assortment optimization problem where a customer chooses an item from a sequence of non-overlapping sets shown to her, while limited inventories constrain the items offered to a sequence of customers over time. The special case where all assortments have size one captures the online stochastic matching with timeouts problem. For this problem, we derive a polynomial-time approximation algorithm which earns at least 1-ln(2-1/e) of the optimum. This improves upon the previous-best approximation ratio of 0.46, furthermore, we show that it is tight. For the general assortment problem, we establish the first constant-factor approximation ratio of 0.09.

■ IND3 TB 13:30- 15:00

Analytics in business operations

Chair/Président: Amira Dems, Hydro Quebec Research Institute

• A successful approach for canadian forestry supply chains to perform in new business environment created by COVID-19
Davoud Ghahremanlou*, William Newell
Memorial University of Newfoundland

Abstract: The negative impact of the COVID-19 pandemic on Canadian Forestry Supply Chains (CFSCs) led their leaders to contemplate solutions to improve their efficiency. To that end, we review the literature and develop a customized algorithm to find, narrow down, and prioritize the opportunities for improvements. This provides insights to CFSCs as to which priorities they should allocate their resources to obtain higher efficiency. For example, these priorities can fall within inbound and outbound logistics, production, and interorganizational collaborations. We conduct a real-life case study in one of the Canadian regions.

• Applications of AI/OR techniques to solve some complex problems in Hydro-Québec
Amira Dems*, Arnaud Zinflou
Hydro-Quebec Research Institute

Abstract: The presentation explores four real-world machine learning and advanced analytics applications in the energy & utilities sector. In the first part, application of AI to forecast energy consumption (Artificial Intelligence to improve short term load forecasting) and the use of deep learning in visual inspection (Deep learning techniques applied to thermal inspection of the underground distribution cables) are addressed. The last part discusses optimization applications, one dealing with asset management (Combining Historical Data and Domain Expert Knowledge Using Optimization to Model Electrical Equipment Reliability) and

the second with a network design problem (Location-Allocation optimization of HQ distribution network).

• **Data& intelligence maturity model – Interactive session**
Anirvan Basu*
Leroy Merlin

Abstract: Introduce framework& key elements of data and intelligence maturity model, and apply collaboratively to business scenarios: Phygital Retailing, Supply Chain& Fulfillment.

• **PyCaret - My story from quitting to creating PyCaret**
Moez Ali*
PyCaret

Abstract: If you are looking for inspiration, then this talk is for you. I will share my journey of building PyCaret, how it all started for me, what problems I faced, and most importantly, how did I do all this without a background in computer science and software engineering. You will learn about my learning process and how I took PyCaret from zero to half a million downloads in less than a year. PyCaret is an open-source, low-code machine learning library in Python that allows you to go from preparing your data to deploying your model within minutes in your choice of environment. This talk is a practical demo using PyCaret in your existing workflows and supercharges your data science team's productivity.

■ ENRE3 TB 13:30- 15:00

Energy and the environment

Chair/Président: John Simpson-Porco, University of Toronto

• **Measuring the remoteness of maritime locations in the arctic using risk-based ship transit times in sea ice**
Mark Stoddard*, Ronald Pelot, Laurent Etienne
Dalhousie University [1, 2]; ISEN (France) [3]

Abstract: The remoteness of a maritime accessible location, hereafter referred to as maritime remoteness, is often cited as one of the most important considerations when planning ship operations in the polar regions. In this talk we will discuss maritime remoteness in the Canadian arctic, emphasizing the importance of understanding the year-round accessibility of arctic maritime locations by Polar Class Ships and the role it plays in measuring remoteness. Year-round accessibility is assessed using risk-based ship transit times in ice, which will serve as a measurable proxy indicator of maritime remoteness in the arctic for this study.

• **Feedback-based optimization for power grid modernization**
John Simpson-Porco*
University of Waterloo

Abstract: Deployment of distributed energy resources across all layers of the power grid is changing the way power systems are operated and controlled, with more emphasis being placed on control architectures and on real-time optimization. This talk summarizes a recently developed control method in which projected gradient-type optimization algorithms are modified to accept system measurements and placed in feedback with the power system to dynamically optimize grid operation. Ideas from variational inequalities and robust semidefinite programming are leveraged to obtain closed-loop stability certificates. The framework is illustrated with applications to coordinated voltage control in distribution and transmission systems.

• **Power tracing with Circuit Theory**
Christine Chen*
University of British Columbia

Abstract: Power tracing is the task of disaggregating the power injection of a generator (or a load) into a sum of constituent components that can unambiguously be attributed to loads (generators) and losses. Applications of power tracing range the broad spectrum of: transmission services pricing, loss allocation in distribution networks, fixed-cost allocation, modelling bilateral transactions, and financial storage rights. We develop an analytical approach to power tracing leveraging elementary circuit laws. The method is rigorous from a system-theoretic vantage point, and it yields unambiguous results that are consistent with circuit laws that describe the steady-state behaviour of power networks.

• **Neural Network-based machine learning method for AC optimal power flow**
Amir Lotfi*, Mehrdad Pirnia
University of Waterloo

Abstract: Due to the nonconvex and nonlinear nature of the optimization problems in power systems and the large size of the power networks, traditional iterative optimization algorithms that are used to find generators' dispatch instructions require significant amount of time to converge and therefore approximation methods, leading to non-economical solutions are used. However, recent developments in machine learning has led to new approaches towards solving

such problems faster and more flexible and accurate. In this paper, a neural network-based machine learning algorithm is implemented on small to large case studies to show the accuracy and efficiency of the ML-based algorithms.

■ NN2 TC 15:30- 17:00

Neural Network Workshop 2

Chair/Président: Maxime Gasse
Polytechnique Montréal/Mila

• Hands-on implementation

■ HC2 TC 15:30- 17:00

Recent advances in patient healthcare delivery for emergency care and cancer care

Chair/Président: Marco Bijvank, University of Calgary

• ICU discharge policy under down stream congestion: An MDP model based on NEMS
Yawo Kobara*, Felipe Fontes Rodrigues, David Stanford
University of Western Ontario

Abstract: A Step-Down Unit (SDU) provides an intermediate level of care for patients from an Intensive Care Unit (ICU) as their acuity lessens. SDU congestion, as well as upstream patient arrivals, force ICU administrators to incur in sub-optimal and often costly Alternate Level of care (ALC). Basing on a proxy for patient acuity level called "Nine Equivalents of Nursing Manpower Score" (NEMS), we develop a finite horizon Markov Decision Process (MDP) that selects policies to reduce the cost of ALC. Preliminary results show that optimal policies are highly sensitive to actions' costs/rewards and are often counter-intuitive.

• Improving emergency department operations through analytics
Gerald Potkah*, Mahnoosh Aslani, Daria Terekhov
Concordia University

Abstract: In this presentation, we describe the application of descriptive, predictive and prescriptive analytics for improving the operations of the emergency department at the Lakeshore General Hospital, located in Pointe-Claire, Quebec. First, we show that using descriptive analytics and sharing the results with the emergency department physicians can lead to identification of immediate solutions to existing issues. Second, we explore various time-series models for the prediction of the demand for medical care in terms of daily arrivals to the emergency department. Finally, we present the results of a detailed simulation model of the emergency department in order to identify operational improvements.

• Patient selection by emergency physicians during their shift
Mahdi Shakeri*, Marco Bijvank
University of Calgary

Abstract: We study the patient selection decision-making of physicians in emergency departments (EDs) over the course of their shift when there are multiple types of patients in the waiting area. Current patient selection policies prioritize patients based on their severity score or waiting time, regardless of the time remaining in a physician' shift. In particular, when physicians get closer to the end of their shift, they need to be more mindful of which patient to select. We formulate the problem which patient to select as a finite horizon Markov decision process (MDP) and illustrate its application to a case study.

• Predicting breast cancer patients' response to chemotherapy
Caleb Braun*, Alireza Sabouri, Omar Khan, Marya Hussain
University of Calgary [1, 2, 4]; Tom Baker Cancer Centre [3]

Abstract: Medical oncologists have the option to treat breast cancer patients with chemotherapy before surgery to increase their likelihood of breast conservation and to observe the cancer' response to treatment. If patients do not respond to treatment, they incur harsh side effects with no benefit. To support oncologists with this decision, we build a predictive model using readily available patient data and evaluate its performance on external data. We compare our model' performance with similar models in the literature.

■ HC12 TC 15:30- 17:00

Game theory applications in healthcare

Chair/Président: Lauren Cipriano, Ivey Business School

• The impact of promoting companion diagnostic tests for personalized medicine
Hossein Reihani*, Greg Zaric
Western University

Abstract: We investigate the impact of reimbursement and companion diagnostics on the efficient use of personalized treatments. We evaluate the consequences of reimbursing every eligible member of the

patients' population when companion diagnostics are available. We find that the health payer might be worse off when the treatment manufacturer is providing a treatment with high clinical utility. We also find the preferred types of policies from either the health payer or the manufacturer's perspective based on the treatment's characteristics. For those personalized treatments without current available companion diagnostic tests, we also find the required criterion for a post-approved test to be commercialized.

• **Influencing primary care antibiotic prescription behavior using financial incentives**

Salar Ghamat, Mojtaba Araghi*, Lauren Cipriano, Michael Silverman
Wilfrid Laurier University [1, 2]; Western University [3]; Lawson Health Research Institute [4]

Abstract: Unnecessary antibiotics prescription is a major public health concern and despite guidelines, antibiotics continue to be prescribed at high rates for non-bacterial acute upper respiratory infections. We consider a system that consists of a payer, a healthcare provider, and a sequence of patient experiencing symptoms which could be due to either a viral or bacterial infection. We explore the existence and features of payer-provider contracts designed to reduce antibiotic prescriptions for viral infections and maximize social welfare.

• **Implication of non-operating room anesthesia policy on OR efficiency**

Yihang Liang*, Reena Yoogalingam
Brock University

Abstract: This study investigates the challenges associated with implementing non-operating room anesthesia (NORA) strategies and their impact on operating room (OR) efficiency. A simulation optimization approach is used to determine the best schedules in terms of patient waiting time, idle time and overtime for a set of elective procedures in a multi-OR setting. We then compare the best NORA scheduling with traditional OR scheduling policies. Real data from a hospital surgery suite will be used to numerically evaluate the performance of each policy.

■ HC8 TC 15:30- 17:00

Appointment scheduling and capacity planning

Session Co-Chair: Jonathan Patrick, University of Ottawa
Session Co-Chair: Antoine Sauré, University of Ottawa

• **Dynamic advance patient scheduling with short-term follow-up appointments**

Vusal Babashov*, Antoine Saure, Onur Ozturk, Jonathan Patrick
University of Ottawa

Abstract: In many healthcare systems patients require multiple visits to a healthcare provider. In general, the first visit is known as the consult visit and all the subsequent visits are known as the follow-up visits. The later typically occur according to predefined booking guidelines. We develop a Markov Decision Process model to efficiently allocate available capacity to consults and follow-up visits in a dynamic fashion.

• **Combined advance and appointment scheduling for multi-priority, multi-class patients with stochastic service times**

Ahmet Kandakoglu*, Antoine Sauré, Mehmet A. Begen, Jonathan Patrick
University of Ottawa [1, 2, 4]; Western University [3]

Abstract: We propose a framework that combines the advance and appointment scheduling problems to consider multi-priority, multi-class patients with stochastic service times. We first model the advance scheduling problems as a Markov Decision Process (MDP), and then transform it to a Linear Programming (LP) model that is later solved via Column Generation (CG). Second, we trained a Deep Neural Network (DNN) model to predict the appointment scheduling cost and integrate this to the advance scheduling part by introducing additional constraints to the subproblem. A comprehensive numerical analysis on a number of scenarios is provided to demonstrate the model.

• **Scheduling of elective patients in hospitals during pandemics: The case of COVID-19**

Peyman Varshoei*, Jonathan Patrick, Onur Ozturk
University of Ottawa

Abstract: Thousands of hospital elective admissions across Canada were postponed due to the COVID-19 pandemic. There is an argument to be made that hospitals were emptied to a greater extent than was necessary. This study aims to provide an adaptive elective admission scheduling policy that allows the admittance of more elective patients during a pandemic while maintaining the ability of a hospital to empty a certain number of beds as necessary over a short warning period (e.g. 5 days). The results for a 30-day planning horizon confirm the efficiency of the proposed scheduling policy when compared with the existing policy.

■ FRM4 TC 15:30- 17:00

Frontiers in financial optimization

Chair/Président: Roy Kwon, University of Toronto

• Tail risk hedging models in financial optimization

Yuehuan He*, Roy Kwon
University of Toronto

Abstract: We present a risk-return optimization framework to minimize the cost of buying put options with different strike prices and quantities in a tail risk hedging strategy. Put options could protect portfolio under tail risk events while its return suffers hugely in the long run due to the high cost. Tractable formulations are developed, and option market price data are used to perform the optimization and analysis of the structure of optimal tail risk hedging strategies. Optimized strategy reserves its advantage against extreme tail risk with a proper cost that resulted in a more desirable return in long term.

• Integrating prediction and portfolio optimization

Andrew Butler*, Roy Kwon
University of Toronto

Abstract: Many problems in quantitative finance involve both predictive forecasting and decision-based optimization. Traditionally, predictive models are optimized with unique prediction-based objectives and constraints, and are therefore unaware of how those predictions will be used in the context of their final decision-based optimization. We present a stochastic optimization framework for integrating predictive model parameter estimation in a portfolio optimization setting. We make use of recent advances in neural-network architecture for efficient optimization of batch convex programs. We present several historical simulations using real asset price data and demonstrate the benefits of the integrated approach in comparison to the decoupled alternative.

• Data-driven distributionally robust risk parity portfolio optimization

Giorgio Costa*, Roy Kwon
University of Toronto

Abstract: We propose a distributionally robust formulation of the traditional risk parity portfolio optimization problem. We consider an ambiguity set that allows us to find the most adversarial probability distribution based on an investor' confidence level. The resulting optimization problem is a constrained convex-concave minimax problem. We propose a novel algorithmic approach to solve this minimax problem, which blends projected gradient ascent with sequential convex programming. This algorithm is highly tractable and scalable. Our numerical experiments suggest a distributionally robust portfolio can yield a higher risk-adjusted rate of return when compared against the nominal portfolio.

• Multivariate extreme event analysis via orthogonal-unimodality distributionally robust optimization

Zhenyuan Liu*, Henry Lam, Xinyu Zhang
Columbia University

Abstract: A challenge in extreme event analysis is the scarcity of data by the very definition of extremes. The conventional extreme value theory, which extrapolates tails parametrically, could face challenges in the simultaneous control of bias and variance and technical complications in multidimensional settings. We propose a framework using distributionally robust optimization to extrapolate multivariate tails, in particular building a new notion of multivariate unimodality that well-suits this application. We demonstrate how this approach leads to statistically valid extremal bounds, and study tractable reformulations of the proposed shape-constrained distributional optimization problems.

■ OPT3 TC 15:30- 17:00

Stochastic mixed integer programming and applications

Chair/Président: Andre Cire, University of Toronto

• Stochastic RWA and lightpath rerouting in WDM networks

Maryam Daryalal, Merve Bodur*
University of Toronto

Abstract: In a telecommunication network, Routing and Wavelength Assignment (RWA) is the problem of finding a lightpath for every incoming request. We present the first two-stage stochastic integer programming model for the RWA problem with incoming request uncertainty, to maximize the expected number of granted requests. We present a decomposition-based solution approach, which uses various relaxations of the problem and a newly developed cut family. Evaluating obtained solutions in a multistage setting in a rolling-horizon framework, we show that our method provides high-quality solutions, especially compared to the ones obtained from defragmentation algorithms employing a traditional deterministic RWA.

• Integrated staffing and scheduling for service systems via multistage stochastic mixed integer programming

Maryam Daryalal*, Merve Bodur
University of Toronto

Abstract: In the first part of this talk, we provide an overview on the use of Lagrangian dual decision rules (LDDRs) for multistage stochastic mixed integer programs (MSMIP). We study two approaches for employing LDDRs in lower bounding MSMIPs and compare the strength of the obtained relaxations. In the second part of the talk, we consider server scheduling in multi-class service systems under uncertainty. We introduce an MSMIP model to simultaneously decide on the staffing and scheduling decisions. We will evaluate the performance of the discussed MSMIP framework in this setting and compare our MSMIP model with an existing two-stage approximation.

• **A multi-stage stochastic programming approach to fractionated IMRT planning**
Juyoung Wang*, Mucahit Cevik, Merve Bodur
University of Toronto [1, 3]; Ryerson University [2]

Abstract: Intensity Modulated Radiation Therapy (IMRT) is a cancer treatment technique where practitioners send radiation beams to tumors. Coping with position uncertainty in IMRT is an important task since the randomness of a patient' position during treatments can result in some additional tissue under/overdose. As a way to handle such randomness, deterministic and one-stage stochastic models were proposed. In this work, we propose a multi-stage stochastic programming model, which provides a more accurate representation of the underlying problem. We solve our proposed model via stochastic dual dynamic programming algorithm and provide numerical results on the quality of the obtained solutions.

• **Min-Max infeasibility robust optimization: A new approach to optimization under uncertainty**
Alireza Ghahtarani*, Ahmed Saif, Alireza Ghasemi
Dalhousie University

Abstract: We propose a new method called "min-max infeasibility" that minimizes the maximum infeasibility of constraints with uncertain parameters subject to their support sets. This new approach has advantages over robust optimization (RO), globalized robust optimization (GRO), and robustness optimization. Unlike RO, uncertain parameters in the new method are not restricted to uncertainty sets. Additionally, the new method is less conservative than RO. As opposed to RO and GRO, a decision-maker does not need to determine the size of uncertainty sets. Unlike robustness optimization, this new method shows the amount of infeasibility of each constraint with uncertain parameters.

■ OPT14 TC 15:30- 17:00

Resource allocation and scheduling problems

Chair/Président: **Xinyuan Zhang**, University of British Columbia

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• **Dimension reduction for nonparametric online decision-making**
Wenhao Li*, Ningyuan Chen, Jeff Hong
City University of Hong Kong; University of Toronto; Fudan University

Abstract: In contextual continuum-armed bandits, the contexts x and the arms y are both continuous and drawn from high-dimensional spaces. The literature has shown that for Lipschitz-continuous functions, the optimal regret is $\tilde{O}(T^{\frac{d_x+d_y+1}{d_x+d_y+2}})$, where d_x and d_y are the dimensions of contexts and arms, and thus suffers from the curse of dimensionality. Under some mild conditions, we develop an algorithm that achieves regret $\tilde{O}(T^{\frac{d_x^*+1}{d_x^*+2}})$. Our results generate valuable insight on how to deal with high-dimensionality in contextual bandits.

• **Workload balancing for flight dispatcher scheduling**
Rebecca Rayner*, Fatma Gzara
University of Waterloo

Abstract: Flight dispatchers prepare for and monitor flights with duties including route planning, creating weather reports, calculating fuel requirements, and monitoring active flights. Dispatchers are centrally located and can each service many flights from several locations at once, with each flight requiring a differing amount of their effort. Currently, there is no streamlined process to assign flights to dispatchers once flights have been planned. This paper focuses on assigning flights to dispatchers with the aim of balancing the effort exerted per dispatcher. A set covering formulation is provided and is solved using column generation.

• **Transfer time optimization in public transit scheduling**
Zahra Ansarilari*, Merve Bodur, Amer Shalaby
University of Toronto

Abstract: Timetables should be fully synchronized to provide effective transfer-based transit networks. Otherwise, long transfer waiting times occur and discourage people to use public transit. In this study, we formulated transfer time optimization as a mixed-integer programming model. Due to complexity, a

Lagrangian-based decomposition method is designed for efficiently solving large scale transit networks. In order to validate the proposed model and gain key insights for decision-makers, a detailed numerical study is performed on an instance with multiple transfer nodes in the City of Toronto. The results showed considerable improvements in comparison to the current state of practice.

• **Considering attractiveness factors in category space management**

Sara Babaee*, Mojtaba Araghi, Borzou Rostami, Ignacio Castillo
Wilfred Laurier University

Abstract: This research provides a general model for determining the optimal strategy to allocate the in-store space to each category considering the location-based attractiveness and the dynamic relationship between product-based attractiveness and the assignment decisions. We model the problem using a two-stage procedure whereby in the first stage each product category is assigned to an aisle in store and the decision regarding the width of the segment allocated to each category will be made. In the next stage, having the output of the first stage we will design each aisle such that the overall profitability measure of the aisle is maximized.

■ SMS5 TC 15:30- 17:00

Stochastic control and applications to bandit models

Chair/Président: Gabriel Zayas-Caban, University of Wisconsin-Madison

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• **Dynamic pricing provides robust equilibria in stochastic ride-sharing networks**

J. Massey Cashore*, Peter Frazier, Eva Tardos
Cornell University

Abstract: Algorithms designed for stochastic systems often use fluid limits, making them essentially deterministic. We propose a two-level hierarchical model, focusing on ridesharing networks, that retains the tractability fluid limits provide while being substantially more robust. We obtain prices by solving a stochastic program arising from a stochastic large-market limit. The dynamic nature of our mechanism is important: a static variant using top-level state dependent prices, without reacting to the realized distribution of drivers, is not subgame-perfect. A simple example shows the static mechanism can substantially underperform the dynamic one. Thus, dynamic pricing is important for robustness in practice.

• **Contextual reinforcement learning: Learning optimal intervention policies for a heterogeneous population**

Aditya Modi*, Ambuj Tewari
University of Michigan

Abstract: Many real world RL applications like learning adaptive treatment plans involve repeated interactions across a pool of heterogeneous entities. Such interactive platforms have to ensure that they utilize all data across users but still allow some level of personalization. A common aspect in these problems is that for each user, some representative information is available. We study this under the contextual MDP model where a high-dimensional task representation is given and studies the structural assumptions under which learning is tractable. We design efficient learning algorithms for varying contextual mappings and provide a thorough sample complexity analysis in the PAC/regret framework.

• **Robustness to incorrect system models in stochastic control**

Ali Kara*, Serdar Yuksel
Queen's University

Abstract: In stochastic control, typically ideal models (on which designs are based) are assumed, raising the problem of robustness due to the mismatch with the actual system. We will view this problem through a topological approach involving spaces of transition kernels. We consider both fully and partially observed setups for continuous spaces. We show that robustness cannot be established under weak and setwise convergences of transition kernels in general. Imposing further assumptions (such as continuous convergence of transition kernels or a total variation continuous measurement channel), we establish robustness and study applications in data-driven control. (Joint work with Serdar Yuksel (Queen's))

• **An asymptotically optimal heuristic for general non-stationary finite-horizon restless multi-armed multi-action bandits**

Gabriel Zayas Caban*
University of Wisconsin-Madison

Abstract: We propose an asymptotically optimal heuristic, which we termed the Randomized Assignment Control (RAC) for restless multi-armed bandit problems with discrete-time and finite states. We consider a finite horizon with multiple actions and time-dependent upper bound on the total number of bandits that can be activated each time period. The asymptotic setting is obtained by letting the number of bandits and other related parameters grow to infinity. Our main

contribution is that the asymptotic optimality of RAC in this general setting does not require indexability properties or the usual stability conditions of the underlying Markov chain or fluid approximation.

■ FOR6 TC 15:30- 17:00

Forestry SIG paper competition

Chair/Président: Maha Ben Ali, Polytechnique Montréal

• Forestry SIG paper competition

Marzieh Ghiyasinasab*, Siamak Mushakhian*, Ali Rahimi*
Polytechnique Montréal; ETS; Université Laval

Abstract: This award recognizes outstanding scientific contributions on the theory, methodology and/or practice of OR in forestry by an undergraduate, a graduate student or a postdoctoral. The competition is for the best student paper submitted, published or accepted for publication in a peer-reviewed journal in the two years before the year of the competition. The award was named in honor of Professor Martell for his outstanding contributions to the development and application of OR in forestry in Canada and beyond as well as for his many contributions to the COR Society.
Marzieh Ghiyasinasab*, Nadia Lehoux, Sylvain Ménard and Caroline Cloutier, 2020. Production planning and project scheduling for engineer-to-order systems-case study for engineered wood production, International Journal of Production Research, 59:4, 1068-1087.
Siamak Mushakhian*, Mustapha Ouhimmou, Mikael Rönnqvist, Julio Montecinos, 2021. The integration of spraying and harvesting planning to minimize wood losses during an outbreak of Spruce Budworm.
Ali Rahimi*, Mikael Rönnqvist, Luc LeBel and Jean-François Audy, 2021. Evaluation of sourcing contracts in wood supply procurement using simulation. International Transactions in Operational Research, 1-21.

■ TL3 TC 15:30- 17:00

Managing and planning for disruption and hazardous materials in transportation systems

Chair/Président: Nader Azad, Ontario Tech University

• Designing emergency logistics networks for hazardous materials with link disruptions

Jiana Lu, Ginger Y. Ke*, James H. Bookbinder
University of Waterloo [1, 3]; Memorial University of Newfoundland [2]

Abstract: Hazardous material shipments are integral to the development of any industrial society. It is thus important that an emergency logistics system considers hazmat incidents in the presence of random disruptions. With possible disruptions on links, this study addresses a robust emergency logistics system for hazmats to minimize both the time-based rescue risk and the system cost. Numerical experiments throw light on the benefit of the proposed model for designing an emergency response network. Managerial insights, derived from those experiments, reveal the network's sensitivity to various parameters and facilitate a more efficient emergency response.

• Supply chain network planning under financial disruption risks

Seyyed Hossein Alavi*, Manish Verma
McMaster University

Abstract: Financial disruption could be detrimental to supply chain performance. This paper proposes a mixed integer programming to model risks in a supply chain network planning using credit rating of suppliers, where bank credit and trade credit are used as financial leverage by buyer. The objective is to maximize supply chain profit in multi-period planning. Our findings show that the buyer becomes less dependent on cash flow by cooperating with higher credit-rated suppliers. Moreover, bank credit is preferred when suppliers have lower credit ratings.

• A subsidy policy to ensuring hazmat risk equity in the railroad transportation network: A risk mitigation strategy

Nishit Bhavsar*, Manish Verma
McMaster University

Abstract: Given the widespread use of railroad transportation for hazardous material, risk-mitigation during transportation is need of the hour. Hence, we propose subsidy policy to be considered by government for equitable distribution of risk in railroad network. The government' objective is to achieve risk equity in the network, whereas, the carriers' cost effective approach leads to increased risk in low-cost service-legs. To model this, we formulate the problem as a bi-level mixed integer program. We derive the single level mixed integer linear program and solve it for realistic mid-west United States rail infrastructure using the state-of-the-art solver cplex in reasonable time.

• Designing emergency response network for rail hazmat shipments: An optimization program and a case study

Ali Vaezi*, Jyotirmoy Dalal, Manish Verma
Brock University; Indian Institute of Management Lucknow; McMaster University

Abstract: In North America, a significant portion of hazardous materials (hazmat) shipments are moved by railroads. Installing an effective emergency response network is one of the primary levers to mitigate the adverse consequences of rail hazmat incidents. We propose a two-stage stochastic program to locate emergency response facilities and determine equipment packages to be stockpiled at each facility. Several publicly available data sets were analyzed and then fed into the proposed optimization program, which was tested on a realistic railroad network in Ontario (Canada). Our computational experiments provide useful managerial insights about the effectiveness of the resulting network.

• Optimal investment and sourcing strategies in decentralized supply chains with supply disruption

Nader Azad*, Elkafi Hassini, Manish Verma
Ontario Tech University [1]; McMaster University [2, 3]

Abstract: We investigate the optimal supplier and buyer' reactions to supply disruption. More specifically, the buyer may need to decide on whether to have a dual supply strategy where one of the suppliers can act as a redundant source, or develop a long-term relationship with one single supplier who would be extended (direct/ indirect) financial support during disruption. We propose Stackelberg game models for both sole and dual sourcing scenarios and present analytical findings for deterministic and stochastic demand cases. We also develop a decision typology that provides guidance to supply chain practitioners to choose the best recovery strategy.

■ OSM4 TC 15:30- 17:00

Revenue management in services and related topics

Chair/Président: **Mahsa Hosseini**, University of Toronto

• Prioritize an engineer hire but a salesperson layoff: Workforce capacity decisions in early-stage technology ventures

Sonia Bagherirad*, Moren Lévesque
York University

Abstract: Workforce capacity decisions are crucial for the founders of early-stage technology ventures due to their limited financial capital. We examine who among an engineer from the STEM category, a salesperson from the non-STEM category, or no one, a founder should hire next during a growing phase or layoff next during a business declining phase. We combine the venture' accumulated cash and the founder' aversion toward risk to formulate finite-horizon dynamic programming models and derive optimal decision rules. We identify founder-, venture- and workforce-based conditions under which the founder should prioritize a STEM hire (layoff) over a non-STEM employee hire (layoff)

• Dynamic relocations in car-sharing networks

Mahsa Hosseini*, Joseph Milner, Gonzalo Romero
University of Toronto

Abstract: We study the dynamic problem of repositioning vehicles using steady-state behavior for a network with uncertain, unbalanced demand. To provide interpretable reposition policies, we use the structure of the underlying transition matrix to estimate the relocation gradient as a function of the current number of vehicles in each location. we project the full-dimensional problem onto the lower-dimensional space of reposition decisions. Then we segment this space and estimate the local change to the steady-state and interpret the meaning of these gradients via absorbing Markov chain concepts. These gradients then provide a state-dependent heuristic for the dynamic vehicle repositioning problem.

• Store sequencing for online order fulfillment in an omni-channel retailer

Sinem Kinay (Savaser)*, Opher Baron, Andre Cire
Rotman School of Management

Abstract: We consider the online order fulfillment processes of an omni-channel retailer in Canada. Initially, online orders attempted to be satisfied from the distribution center. If there is insufficient inventory, stores are requested to ship the order. Our main aim is to improve the store selection process in these cases. Different from the existing studies, we face a decentralized system where stores can accept or reject an order fulfillment request. We show that for single item orders, a myopic store sequence is optimal. For multi-item orders we present an approximation algorithm and evaluate its effectiveness.

• Social newsboys

Setareh Farajollahzadeh*, Ming Hu
University of Toronto

Abstract: We study two sharing settings (sharing unused capacity and sharing unsatisfied demand) with a large network of socially connected newsvendors. Each newsvendor makes a stocking decision considering that she may receive some shared supply (demand) from the leftovers (excess demand) of her neighbors. Two measures may influence the sharing activity: in-

teraction frequency (tie strength) and sharing magnitude (sharing portion). We show that (i) the total stocking level and welfare of newsboys monotonically depends on the degree distribution in the population. (ii) The two sharing measures have an opposite secondary effect on the total stocking level and welfare.

■ QUE5 TC 15:30- 17:00

Modern approaches to the analysis of queues with applications

Chair/Président: Eugene Furman, University of Toronto

• Inter-departure times in queueing systems with different customer types

Eliran Sherzer*, Opher Baron, Oded Berman, Dmitry Krass
University of Toronto

Abstract: Queueing networks that do not fall under the BCMP product form are quite complex. One of the main challenges is inter-departure times, which are also the inter-arrival times of the next queue. To evaluate the distribution of the inter-departure times, we consider two customer types, which arrive from a Poisson process with different rates. Both customer types require exponential service but with different services. By decomposing inter-departure times to well define stochastic subcases, and then compose them together, we are able to obtain analytic expression to the inter-departure CDF. We further show that this method is both accurate and fast.

• Algorithms for queueing systems with reneging and priorities modeled as quasi-birth-death processes

Amir Rastpour*, Armann Ingolfsson, Burhaneddin Sandikci
Ontario Tech University; University of Alberta; University of Chicago

Abstract: We develop an iterative algorithm for a class of infinite level-dependent quasi-birth-and-death (LDQBD) processes. These LDQBDs can model the Erlang A system with two priority classes of impatient customers with different arrival, service, and abandonment rates. Our algorithm provides bounds for the level-dependent rate matrices and uses these bounds to endogenously truncate the system and to provide bounds on system performance measures. We show that existing algorithms for this class of LDQBDs either suffer from low accuracy or from long solution times.

• Reversed priority: Shift effect in emergency departments

Tianshu Lu*, Opher Baron, Dmitry Krass
University of Toronto

Abstract: We study how a self-interested physician in an ED allocates capacity between new patients and re-entrant patients, focusing on the time-dependent pattern. For the physician, we characterize her optimal strategy; for the ED manager, we show the undesirable its effect on TPIA. We analyze physician's strategy using MDP, and analyze its impact with a fluid model. In MDP, we show that physician's strategy has two phases: in the first, the physician is more willing to serve new patients, while re-entrant in the second. In the fluid model, we show that the p-th (p>50) percentile of TPIA becomes longer.

• Optimal control of a two-server flow-shop network

Yossef Luzon*, Yariv Marmor, Eugene Khmelnitsky
University of Toronto; ORT Braude College; Tel Aviv University

Abstract: In this talk we will suggest a simple method for scheduling jobs in a two-server flow-shop network (FSN) with the minimum makespan objective. Jobs of multiple types with corresponding constant service times arrive at the network at various times over a finite time interval. An analogous fluid network is proposed, its optimal fluid control policy is proven and used to suggest a new asymptotically optimal method for scheduling jobs in the original discrete FSN. The method is particularly attractive because it falls into the class of computationally inexpensive on-line algorithms which perform optimally in almost all numerical simulated instances.

• Variation approach to optimal capacity planning

Eugene Furman*, Adam Diamant
Schulich School of Business

Abstract: We analyze a cloud computing system where a provider wants to determine the optimal number of servers and the optimal retrial interval when all servers are busy. Servers in this setting represent components of a computer network and customers are jobs in the cloud. By modeling the system as a fluid queue and using a calculus-of-variations approach, we derive the optimal amount of service capacity in anticipation of time-varying dynamics as well as the optimal retrial interval. Using data collected from a real cloud service provider, we quantify the cost savings using our approach.

■ PRM2 TC 15:30- 17:00

Product pricing and release

Chair/Président: Xuan Zhao, Wilfrid Laurier University

• Pricing of demand-related products
Salma Karray*, Guiomar Martin-Herran, Georges Zaccour
Ontario Tech University; University of Valladolid; HEC Montréal

Abstract: This research studies pricing strategies of competing retailers offering substitutable products in multiple categories. We develop and solve a game-theoretic model that accounts for both within and cross-category effects. The results show that cross-category effects largely influence the retailers' pricing and profitability. In particular, intentionally ignoring cross-category effects leads to lower prices for categories that are either substitutable or highly complementary and to higher prices otherwise.

• Release time and price: Optimal delayed release with consumer learning in the Freemium Model
Xiaoyan Chen*, Weng Geng, Xuan Zhao
Southwest Jiaotong University [1, 2]; Wilfrid Laurier University [3]

Abstract: We consider a delayed release strategy based on the assumption of two dimensions of consumers' heterogeneity in valuation for the product and learning effect in the freemium business model. A free version is often released prior to the premium one to take the advantage of consumer learning. In a two-stage model, a consumer who uses the free version in the first stage will update her/his valuation in the second stage. A condition is first found to guarantee such a delayed release is desirable. The optimal time to launch the premium version and corresponding price are then obtained regarding different conditions.

• Simultaneous versus sequential product release
Hojat Abdolanezhad*, Ming Hu, Ningyuan Chen
University of Toronto [1,2]; University of Toronto Mississauga [3]

Abstract: We study a firm who has two digital products and decides on the release strategy of them into a market in order to maximize its expected total revenue. Consumers have uncertainty about the quality of the products and can learn about it through both private and social learning. The firm could play a crucial role in the learning process by facilitating the generation and dissemination of information through its release strategy. We provide a full characterization of optimal release strategy for different settings joint with the behavior of the optimal prices.

■ IND2 TC 15:30- 17:00

Analytics for decision-making in COVID-19 era

Chair/Président: Abelardo Mayoral,

• Case study of home care routing and scheduling problem
Francois Lacoursiere*
AlayaCare

Abstract: Alayalabs leveraged its beta scheduling and routing optimization algorithm and applied it to two specific use cases. The first is a full schedule reshuffle used for planning field supervisors visits for the next month that reduces travel time and increases the number of visits per day. The next is an optimized employee finder that allows coordinators to quickly search for the best match to fill a vacant visit or a series of visit recurrences based on ranked criteria. This schedule optimization module is available in beta version as part of the AlayaCare platform.

• Smoothing the required resources for immunizing the general public against COVID-19
Shaghaygh Akhtari*, Abelardo Mayoral Fierros
Fraser Health Authority

Abstract: Vaccination allocation for public is prioritized by age groups. The variability in population sizes of age groups together with the demand for second dose could lead to high variations in resource requirements. In order to minimize the variations in resource needs, an important decision is vaccination start and end dates of each group. We developed an optimization model to plan the dates for vaccination of different age groups while avoiding high peaks and deep valleys in resource needs. Compared with the initial plan, the plan from the model yields a 60% lower peak demand for the vaccine resource requirements.

• Impact of emergency department expansion on emergency department patient flow in standard and pandemic models of care – A simulation model
Shaghaygh Akhtari*, Abelardo Mayoral Fierros
Fraser Health Authority

Abstract: One of British Columbia's regional hospitals is undergoing a footprint expansion of its Emergency department (ED). Also, pandemic precautions have increased the space needs in many settings, including ED. We developed a simulation model to quantify the impact of different layout configurations for both Standard and Pandemic models of care at this particular hospital. The results show that the patient

flow and space utilization metrics are expected to increase in future due to projected increase the ED visits over time regardless of expansion. However, ED expansion would control the magnitude of the increase in patient flow and space utilization rates.

• **A stochastic heuristic for the operating rooms scheduling problem**

Florian Grenouilleau, Vincent Gatien*
HEC Montréal; Ivado Labs

Abstract: COVID-19 pressured the health care system and exposed opportunities for optimizing operating rooms/waiting lists. The pandemic delayed diagnosis and increased the number of patients awaiting surgery, as the number of intensive care unit beds for non-COVID-19 patients was drastically reduced. To cope with this situation, we developed a comprehensive framework integrating a surgeries' duration' predictor and a scheduling method while considering a hospitals' constraints. According to experiments run within the CHUM (Centre hospitalier de l'Université de Montréal), the proposed method improved by 6% the number of patients scheduled while reducing by 30% the error associated with surgery's duration' prediction.

■ ENRE2 TC 15:30- 17:00
Applications of AI

Chair/Président: Maryam Kamgarpour, University of British Columbia

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• **System level synthesis: Robust and optimal control as optimization**

Nikolai Matni*
University of Pennsylvania

Abstract: In this talk, we provide an introduction to the System Level Synthesis framework, a new approach to the robust and optimal control of linear dynamical systems. We show that by focusing on the closed loop maps from process noise to state and control input, i.e., the system responses, that classical problems in robust and optimal control can be reduced to familiar optimization problems. We then highlight use cases where this new perspective has allowed for tools from robust and distributed optimization to be leveraged with great success in the context of learning enabled and distributed control.

• **Analysis and design of distributed optimization algorithms over time-varying graphs**

Akhil Sundararajan, Bryan Van Scoy, Laurent Lessard*
University of Wisconsin-Madison

Abstract: Distributed optimization involves a coordinated effort by a collection of networked agents to solve a large-scale optimization problem. Many efficient algorithms have been proposed, but each comes with specialized ad hoc analyses, making algorithm selection and tuning difficult. In this work, we present a unified and efficient analysis framework that yields a worst-case convergence rate as a function of the condition number of the local objective functions, the spectral gap of the network graph, and the parameters of the algorithm. We also present a new algorithm that outperforms all known algorithms.

• **On learning Nash equilibria and regret minimization**

Maryam Kamgarpour*
University of British Columbia

Abstract: A challenge in control of large-scale systems such as the power grid and the transportation network is to address autonomous decision making of interacting agents while ensuring global system safety and performance. In this setting, a Nash equilibrium is a stable solution in the sense that no agent finds it profitable to unilaterally deviate from her decision. Due to geographic distance, privacy concerns or simply the scale of these systems, each agent can only base her decision on local information. I present our results on distributed algorithms for learning Nash equilibria in convex and non-convex games.

• **A system dynamics approach to earthquake early warning scenario analysis for resilience enhancement of gas pipelines**

Foad Esmaeili*, Fuzhan Nasiri
Concordia University

Abstract: Cities with a natural gas pipeline network are subject to risk of cascading fires resulting from gas leaks in case of earthquakes. Vancouver, as one of the most active seismic zones among Canadian cities, supplies a share of its end-use energy demand from natural gas. Vancouver benefits from an earthquake early warning system. A system dynamics approach is explored to model and analyze this system identifying design and operational scenarios for resilience enhancement.

• **Utilizing COVID-19 opportunities by agile Canadian forestry supply chains**

Davoud Ghahremanlou*, William Newell, Kelly Hawboldt
Memorial University of Newfoundland

Abstract: The Canadian Forestry Supply Chains (CFSCs) have been impacted by the COVID-19 pandemic,

from shifts in market demand to challenges in transportation. Ethanol from forestry biomass has typically been used as a biofuel, however the pandemic has created a potential market in hand sanitizers and other disinfectants. To shed light on this issue of a dynamic shifting market, we have developed a bi-objective two-stage stochastic programming model for the CFSC to incorporate uncertainties in the market. The CFSC accounts for new products and market development. We conduct a case study and analyze the results within the framework of sustainability.

Wednesday/Mercredi June 09

■ HC23 WA 10:00- 11:30

Managing healthcare operations during the COVID-19 pandemic - II

Chair/Président: Houra Mahmoudzadeh, University of Waterloo

• Radiotherapy patient scheduling during pandemics

Shamim Raeisi*, Ernest Osei, Johnson Darko, Houra Mahmoudzadeh
University of Waterloo [1, 4]; Grand River Regional Cancer Centre [2, 3]

Abstract: With the COVID-19 outbreak happening worldwide, clinically vulnerable people should be of concern, as they are more likely to be exposed to the virus. Cancer patients with weak immune systems are a group of aforementioned people that often have to go to hospitals for radiotherapy treatment sessions every day for several weeks. Therefore, special measures are to take place for more protection. Our research focuses on scheduling radiotherapy patients, using mixed-integer linear programming, minimizing the total number of potential interactions among patients and between staff members and patients. We use numerical examples to demonstrate the effectiveness of the proposed approach.

• Optimizing the operations of cancer centers during the COVID-19 pandemic

Arian Aminoleslami*, Ernest Osei, Johnson Darko, Houra Mahmoudzadeh, Hossein Abouee Mehrizi
University of Waterloo [1, 4, 5]; Grand River Regional Cancer Centre [2, 3]

Abstract: This paper studies the impact of COVID-19 pandemic on the operations of cancer centers, with the goal of minimizing the overall infection transmission and the consequent staff replacements. Our particular focus is on Radiation Therapy (RT) departments. Since COVID-19 is transmissible during its incubation period, it is extremely hard to identify infected staff members and patients. It is also impossible to regularly test all people present at the clinic. We will provide simulation, scheduling, and optimization tools to suggest staff scheduling policies during the pandemic so that the risk of infection transmission is minimized.

• PPE usage and preservation at the age of COVID-19

Kimia Ghobadi*, Cassandra Thiel
Johns Hopkins University; New York University

Abstract: With the rise of the COVID-19 pandemic and its impact on the economy and healthcare systems, access to Personal Protective Equipment (PPE) became a concern. In this talk, we investigate the resilience and sustainability of the healthcare supply chain under extreme stressors. We particularly focus on the impacts of PPE shortage on medical centers to gain a better understanding of their response and policies to better utilize the available PPE. We also aim to identify locations with possible severe shortages to inform efforts to meet the demand and find the optimal pathways to address them.

• Establishing a correlation between healthcare capacity attributes and the number of deaths due to COVID-19

Fardin Ganjkhanloo*, Farzin Ahmadi, Michael Lepori, Kimia Ghobadi
Johns Hopkins University

Abstract: We consider the question of different factors effective in the rate of spread and mortality of the novel coronavirus. Specifically, we study the correlation of healthcare capacity with the COVID-19 early stage mortality. We consider total hospital counts and bed counts on county level as two indicators of healthcare capacity, and analyzed the correlation between these indicators and the mortality in the early stages of the pandemic in each county over the general acute hospitals of the United States. Results show a positive correlation between healthcare capacity indicators and COVID-19 early-stage mortality.

■ HC5 WA 10:00- 11:30

OR applications in healthcare - I

Chair/Président: Amin Khademi, Clemson University

• Is it time to incorporate post-transplant survival in heart transplant allocation rules?
Farhad Hasankhani, Amin Khademi*
Clemson University

Abstract: The recent change in heart transplantation rule focused on dividing the sickest patient group further to three groups. We show via a validated simulation model that considering post-transplantation survival can significantly improve the quality adjusted life years of the patient population.

• Risk-sharing agreements in pharmaceutical industry under information asymmetry
M. Hosein Zare*, Greg Zaric
Ivey Business School

Abstract: We investigate risk-sharing contracts between a pharmaceutical company and a healthcare payer in the presence of asymmetric information. Our focus is on situations where the pharmaceutical firm does not reveal her actual manufacturing cost. We formulate the problem as a Stackelberg Game and we explore how the information asymmetry impacts the drug price, the rebate rate and the patient's coverage level compared to the complete information model. We show that providing full coverage is not necessarily advantageous to all types of manufactures. Also, our results show that not all manufacturers benefit from increasing the drug price under asymmetric information.

• A stochastic optimization approach for staff scheduling decisions at inpatient clinics
Sajjad Dehnoei*, Antoine Sauré, Onur Ozturk, Jonathan Patrick
University of Ottawa

Abstract: Staff scheduling is one of the important challenges in inpatient facilities. Typically, there is no easy way to estimate demand for services and patients can be discharged at any given time, affecting care-provider requirements. There are many other unpredictable factors such as seasonal patterns and staff leaves affecting the process as well. This research addresses a group of staff scheduling problems at inpatient clinics, where demand is stochastic. We have used a predictive Markov model to forecast patients' flow over time and a stochastic optimization approach (Sample Average Approximation), based on Monte Carlo Simulation, to find optimal staff schedule.

• To extend or not to extend? Dynamic shift lengths in workforce planning
Negar Ganjouhaghighi*, Marco Bijvank, Alireza Sabouri
University of Calgary

Abstract: In many service environments it is difficult to predict customer arrivals, whereas employees are scheduled a long time in advance. To ensure that enough employees are available to provide service in a timely fashion, we consider shift lengths to be dynamic: two hours before the end of a shift, the extension decision is made. The objective is to find an optimal policy for shift extensions such that wait times are minimized. We formulate this problem as an infinite horizon MDP and use stochastic dynamic programming to solve it. A case study from an ED is used to illustrate solution procedure.

■ HC19 WA 10:00- 11:30

Predictive modelling applications in healthcare

Chair/Président: Michael Carter, University of Toronto

• Machine learning applications to improve patient flow
Arun Dixit*, Michael Carter
University of Toronto

Abstract: Approximately 10% of patients visiting an Emergency Department (ED) in Ontario are admitted to a hospital bed. Between April and September 2018, the wait time between an admission decision and a patient leaving the ED for a ward represented 72% of the overall ED length of stay, when measured at the 90th percentile. Extended ED lengths of stay are associated with increased risk to patients and higher staff burnout. The objective of this study is to build a model capable of predicting a patient' need for admission based on data available after initial assessment by a physician.

• Patient flow forecasting: Mitigating medical surges
Ji Min Kim*, Michael Carter, Tammi Hawa, Michael Caesar, Andre D'Penha, Brenda Kenefick, Fayez Quereshy
University of Toronto [1, 2]; University Health Network [3, 4, 5, 6, 7]

Abstract: Healthcare expenditure has increased over the past few years due to aging populations, increased ambulatory costs, and most recently the global pandemic induced by the COVID-19 disease. While resources are bound by physical and budgetary constraints, hospitals have frequently experienced med-

ical surges, where their subprograms are near or at full capacity. Hospitals have adopted strategies to mitigate such a surge, however, the optimality of these decisions is currently unknown. This study proposes a data-driven medical surge decision support tool that suggests the optimal strategies based on the forecasted bed demand in the upcoming week at each program level.

• Predicting the number of beds that will require cleaning and staff requirements in the emergency department

Tahera Yesmin*, Michael Carter
University of Toronto

Abstract: Boarding inpatients is a major contributor to emergency department (ED) crowding, which can be seriously impacted by the delay in bed cleaning at the ED. Therefore, knowing the number of beds to clean will help reduce the bed turnover time and consequently will help to reduce the ED crowding. This research applied machine learning algorithms to predict the number of beds requiring cleaning. The results from the prediction model were used in a queuing model to determine the staff number. The outcome from this study will enable hospitals to proactively plan resources rather than being reactive during a crisis moment.

■ FRM7 WA 10:00- 11:30

Machine learning in financial engineering

Chair/Président: **Chi-Guhn Lee**, University of Toronto

• Risk-sensitive portfolio investment strategy selection with distributional reinforcement learning

Wentao Liu*, Chi-Guhn Lee, Yuri Lawryshyn
University of Toronto

Abstract: This presentation will focus on the topic of applying state-of-art distributional reinforcement learning to a portfolio management problem. Unlike traditional reinforcement learning algorithms, which focus on maximizing expected rewards, distributional reinforcement learning attempts to learn the whole distribution of all possible rewards at each state and action pair. This unique feature makes distributional reinforcement learning a superior tool for risk-sensitive portfolio management and creates possibilities for real-world applications. Portfolio managers could use this model to discover the intrinsic risk of certain investment actions and target specific risk tolerance. The risk-sensitive decision-making concept also has great potential in other research areas.

• Multiplex networks for credit risk measurement

Cristián Bravo*, María Óskarsdóttir
University of Western Ontario; Reykjavik University

Abstract: We present a methodology to leverage multiplex networks - those in which each node can be connected to another node by more than one type of edge – using a novel Multiplex Personalized PageRank algorithm, which we subsequently apply to credit risk assessment. Our model accounts for different connections between borrowers and allows for explicitly modelling the interaction between diversely connected borrowers. Our results show that multiplex networks are a powerful alternative to single-network approaches, and that they work best when otherwise fully connected networks would not arise naturally, such as in clique-prone environments.

• High-dimensional continuous reinforcement learning for finance

Amine Mohamed Aboussalah*, Chi-Guhn Lee
University of Toronto

Abstract: Reinforcement learning (RL) is the most appropriate ML approach for the portfolio management (PM) problem because of its ability to solve sequential decision-making problems, which is a key aspect of PM systems. RL has proven useful in domains such as game playing and robotics. However, the application of RL to PM is a challenging task due to several characteristics of the financial domain which we have identified and studied. We aim to leverage operation research and mathematical finance methodologies to tackle these issues and help to make intelligent, optimal RL decisions for PM.

• Cause and effect relationship of shareholder value creation and employee satisfaction for U.S. banks

Abbas Attarwala*, Stanko Dimitrov, Rob Duimering
University of Waterloo

Abstract: We study the causal relationship between shareholder value creation (SHVC) and employee satisfaction for U.S. banks. Prior research finds that financial markets do not entirely capture employee satisfaction of a firm when determining the price of that firm' stock. We contribute to this literature by using three different kinds of SHVC: (1) stock price, (2) TobinQ ratio, and (3) market capital and use the Toda Yamamoto causality test (TYCT) and examine the causal relationship of SHVC and employee satisfaction for U.S. banks. We conclude that there is a causal relationship

between employee satisfaction and some SHVCs for certain U.S. banks.

■ OPT16 WA 10:00- 11:30

Large scale optimization for routing and distribution problems - II

Chair/Président: Onur Ozturk, University of Ottawa

• **Solving the time index formulation of a scheduling problem by column generation**

Onur Ozturk*

University of Ottawa

Abstract: Time index formulations of scheduling problems tend to have strong relaxations. In this study, we develop a time index integer model for a parallel batch-scheduling problem in which jobs have release dates, different processing times and capacity requirements. The linear relaxation of the model is solved by column generation. The sub-problem is solved first by a heuristic algorithm. If the heuristic does not provide a negative reduced cost, then a dynamic programming algorithm is run in search for the smallest reduced cost value.

• **Distributed implementation of a hybrid algorithm for solving combinatorial optimization problems: The case of the traveling salesman problem**

Imene Benkalai*, Mohammed Yagouni

University of Quebec at Chicoutimi; University of Science and Technology Houari Boumediene

Abstract: This work presents a hybridization of heuristic methods for solving NP-hard optimization problems. It combines the complementary properties of solution-based and population-based metaheuristics in order to provide better quality solutions. A parallel-distributed scheme is used to implement the hybrid method and is tested on instances of the traveling salesman problem which is known to be a test problem for new methods and approaches. The numerical results show the efficiency of our method as well as its robustness; this is visible through the low gap between our solutions and the best-known solutions but also in the quasi-regularity of the method' performance.

• **A branch-and-price algorithm for a resource constrained vehicle routing problem with time window**

Neda Tanoumand*, Tonguc Unluyurt

University of Toronto; Sabanci University

Abstract: We consider the vehicle routing problem with resource constraints motivated by a home health care application. We propose a branch and price algorithm to solve the problem. In our problem, we consider different types of patients that require a nurse or a health aid or both where the patient have predetermined time windows. The number of nurses and health aids are limited. The aim is to find feasible routes to minimize the total distance travelled. The branch-and-price utilizes a label correcting algorithm with ng-relaxation. We demonstrate the effectiveness of our algorithm on random problem instances upto 100 patients.

• **Electric vehicle routing and charging/discharging under time-variant electricity prices**

Bo Lin*, Bissan Ghaddar, Jatin Nathwani

University of Toronto; Ivey Business School; University of Waterloo

Abstract: The integration of electric vehicles (EV) with the energy grid has become an important area of research due to the increasing EV penetration in today's transportation systems. This paper proposes the EV routing problem with time windows under time-variant electricity prices which optimizes the routing of an EV fleet delivering products to customers, jointly with its charging and discharging from/to the grid given the time-variant energy prices. A Lagrangian relaxation approach and a meta-heuristic are proposed to obtain high quality solutions. Numerical experiments and insights on the impacts of energy pricing, service time slots, and fleet size are presented.

■ OPT17 WA 10:00- 11:30

Optimization and machine learning applications - II

Chair/Président: Joe Naoum-Sawaya, Ivey Business School

• **Improving branch-and-bound using decision diagrams and reinforcement learning**

Augustin Parjadis*, Quentin Cappart, Louis-Martin Rousseau, David Bergman

Ecole Polytechnique de Montréal [1, 2, 3]; University of Connecticut [4]

Abstract: Combinatorial optimization is a mathematical field essential for industrial or fundamental decision making problems. Finding tight bounds on the objective function is crucial for combinatorial optimization, and remains a challenge. Recently, Decision Diagrams (DDs) provided new means of obtaining bounds for combinatorial problems that can be signifi-

cantly better than those obtained via traditional linear programming relaxation. The quality of DD bounds is directly linked to the quality of the ordering chosen to build the DD. In this work, we propose to study how a branch-and-bound algorithm can be improved using bounds that have been obtained with DDs and reinforcement learning.

• Learning a storage policy for e-commerce warehouses

Adrien Rimélé*, Philippe Grangier, Louis-Martin Rousseau, Michel Gamache, Michel Gendreau
Polytechnique Montréal [1, 3, 4, 5]; Element AI [2]

Abstract: Robotic Mobile Fulfillment Systems are a new type of automated warehouse in e-commerce that uses a fleet of robots to retrieve shelves from the storage area. After each picking, robots can dynamically choose any open storage location to adapt the layout in real-time to newly revealed orders. We model this problem as an MDP and propose to learn a dynamic storage policy (no batching of orders) which minimizes the average traveling time of the robots. We developed methods based on Reinforcement Learning and rollout strategies and validate their performance by simulation compared to standard decision rules.

• Deep Q-learning for simultaneous beam selection and trajectory optimization of CyberKnife treatment planning

Peyman Kafaei*, Quentin Cappart, Louis-Martin Rousseau, Nicolas Chapados
Polytechnique Montréal [1, 2, 3]; Element AI and Imagia [4]

Abstract: Radiation Therapy treatment planning is one the most common approaches for cancer treatment. One of the major difficulties to develop high-quality treatment plans is the selection of an ensemble of the beams to irradiate the patient through them. This is critical for CyberKnife system as the treatment is lengthy which causes discomforts for the patient and diminishes the quality of the treatment. Formulating the Beam Orientation Optimization as a Combinatorial Optimization problem leads to a highly nonconvex and complex problem which is shown to be NP-hard. Thus, we opt for the Deep Q-learning to select the favorable beams.

• Metaheuristics for the Euclidean location-allocation with unknown number of facilities

Jean-Paul Arnaout*
Gulf University for Science and Technology

Abstract: This study deals with the facility location-allocation problem with Euclidean distances and an unknown number of facilities. The problem is a harder variant of the NP-hard multisource weber problem where the number of facilities is known a priori. A worm optimization (WO) algorithm is developed for the problem, its parameters optimized using a custom design of experiments, and its performance assessed by comparing it to ant colony optimization and genetic algorithms. The computational results showed that WO performed better than the other two algorithms in terms of both solution quality and convergence time, with ACO performing second and GA last.

■ SMS3 WA 10:00- 11:30

Stochastic models in service operations - II

Chair/Président: Saied Samiedaluie, University of Alberta

• Public-private partnership to secure containerized supply chains

Mohammad Nikoofal, Morteza Pourakbar, Mehmet Gumus*
Ryerson University; Erasmus University; McGill University

Abstract: Carrying over 90% of the world's trade by sea, maritime transport has become vulnerable to disastrous security crisis. This led to governments initiating security programs that now have tens of thousands of members worldwide. This paper examines the value of a public-private partnership (PPP) in enhancing the security of containerized Supply Chains. Specifically, we develop a sequential game between government, firms, and terrorist to study the interaction between customs inspection capacity and the incentives offered in security programs.

• Competing on-demand platforms with heterogeneous time-sensitive customers

Setareh Farajollahzadeh*, Philipp Afeche, Azarakhsh Malekian
University of Toronto

Abstract: We study duopoly competition between symmetric ride-hailing platforms that serve a market of heterogeneous customers that differ in their time-sensitivity. We model the platform operations as queueing systems. The platforms select their service fees and capacity levels. Customers choose the platform that maximizes their expected utility. We characterize the equilibrium in the function of demand and supply parameters. Specifically, we show that when the potential demand of patient customers is moderate, the equilibrium is asymmetric, whereby each platform targets a different customer segment.

Otherwise, the equilibrium is symmetric. We further compare the duopoly and monopoly outcomes.

• **Approximate linear programming for a queueing admission control problem**

Saied Samiedaluie*, Dan Zhang, Rui Zhang
University of Alberta [1]; University of Colorado Boulder [2, 3]

Abstract: We study a classical queueing control problem with multiple classes of customers. The queue is a loss system; i.e., arriving customers are rejected if all servers are busy. When a server is available, the decision is whether to admit an arriving customer and collect a lump-sum revenue. We model this problem as a continuous-time infinite-horizon dynamic program and propose approximate linear programming methods to solve the problem under four approximation architectures: affine, finite affine, quadratic and separable piecewise linear. We numerically investigate these approximation architectures in terms of the quality of the bounds and the policy performance.

• **Data-driven quickest detection of customer churn**

Roozbeh Yousefi*, Jue Wang
Queen's University

Abstract: In many service industries, customers may stop returning for service without informing the service provider. It is important for the service provider to detect such soft churn as quickly as possible, so that appropriate retention can be made. We develop a churn detection model based on partially observable Markov decision processes in which both transition and observation probabilities are unknown. The optimal policy must balance churn detection with parameter learning. We characterize the structure of the optimal policy and show that the infinite-dimensional belief space can be collapsed to two-dimension, making the optimal policy computationally feasible.

■ AIML5 WA 10:00- 11:30

ML applications

Chair/Président: Elias Khalil, University of Toronto

• **Developing personalized treatment pathways of type 2 diabetes through predictive and prescriptive analytics**

Manaf Zargoush, Somayeh Ghazalbash*
McMaster University

Abstract: This research aims to use Machine Learning to identify patient-specific treatment plans for diabetic patients considering their chronic conditions and demographic characteristics. To this end, we used Bayesian Network modeling, for both predictive and prescriptive purposes, with the electronic health records of 17,773 Type II diabetic patients. First, we predicted the 30-day mortality risk for 24 patient groups based on their combinations of chronic conditions and demographic characteristics. Then, we identified the best treatment plans by minimizing the risk of 30-day mortality. Our results indicate various optimal medication therapy pathways for diabetic patients who had different characteristics.

• **Development of convolutional network architecture for detecting prohibited goods for aviation security**

Kim Woong*, Sungchan Jun, Chulung Lee
Korea University

Abstract: Aviation security X-ray equipment screens objects primarily and human screeners have to re-examine baggage and travelers to detect prohibited objects. Advancement of computer vision and deep learning technology can improve the accuracy of identifying dangerous goods such as guns and knives. Artificial intelligence-based aviation security X-rays can facilitate the high-speed detection of target objects while reducing the overall security search duration and the workloads of the screeners. An O-Net structure was designed through various learning rates and dense/depth-wise experiments as an improvement based on U-Net. The accuracy of O-Net is 6.56% higher than that of U-Net in extensive experimental results.

■ Tutorial WA 10:00- 11:00

Decision diagrams for optimization

Chair/Président: Adam Diamant , Schulich School of Business

• **Decision diagrams for optimization: Theory and application**

Andre Cire
Assistant Professor in Operations Management and Analytics, University of Toronto

Abstract: In this tutorial, we will study new methodologies for discrete and nonlinear optimization based on decision diagrams (DDs). A DD, in our context, is a graph-based extended formulation of an optimization problem, exposing network structure that can be leveraged explicitly in novel relaxations and exact solution methodologies. The tutorial will present the principles of DD modeling for combinatorial and nonlinear problems, discuss relaxations based on limited-width DDs, and develop the intrinsic connections between DDs and (approximate) dynamic programming. We will

also show novel decompositions techniques and recent applications in stochastic programming and cut-generation algorithms, which exploit new links with mathematical programming and polyhedral methods.

■ TL1 WA 10:00- 11:30

Sustainable city logistics planning

Chair/Président: Anjali Awasthi, Concordia University

• The reliable uncapacitated maximum covering location problem under disruption

Badr Afify, Anjali Awasthi*
Concordia University

Abstract: Maximum Covering Location Problem (MCLP) is an important problem because of its real-life application. The objective of MCLP is to optimize the location of the established facilities to maximize the total client demands that are located within a stated distance from the serving facilities. In the literature, the majority of approaches didn't consider facility failure and in this context we present a non-linear integer model for MCLP under disruption. The model considers heterogeneous facility failure, one layer of backup and fortification budget. The proposed approach involves a linearization to the proposed model and iterative approach for the fortification budget allocation.

• Pedestrian safety using computer vision and applications of Internet of things

Ujjwal Khanna, Anjali Awasthi*
Concordia University

Abstract: Pedestrian safety is a prime concern with the ongoing evolution in Urban cities. With the ongoing constructions and rapid increase in the number of vehicles on the streets the safety of the pedestrians is at a high risk. This paper aims to propose a technique that can enable us to identify the high risk points by identifying the density of pedestrians on the major intersections by collecting data using computer vision. Further, it identifies the problems that are faced by the pedestrians on the streets and provides with solutions using the Applications of Internet of things.

• A simulation study on the effective use of shared autonomous vehicle in supply chain network

Amir Zohouri, Anjali Awasthi*
Concordia university

Abstract: In the field of sustainable transportation system, numerous articles have been discussing that an effective shared autonomous vehicle can be used as a part of agile supply chain network. Continuous movement of material, continuous route optimization and reduction of empty trips can be numerated as the benefits of using SAV in freight transportation. In this research we aim to develop a simulation model to analyse a strategy to support the efficient use of SAV in a supply chain network. Our focus is to propose a flexible use of a networked SAV system for a delivery of foods

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• An optimal control policy for a facility under stochastic disruption using two inspection intervals

Negar Ghodsi*, Farnoosh Naderkhani, Anjali Awasthi
Concordia University

Abstract: Developing an optimal control policy for a facility plays a significant role in order to increase the efficiency and reliability. In this regard, we try to find an optimal control policy for a facility under stochastic disruption. A Markov chain Model with N states is developed to represent the health condition of a facility. The facility is inspected based on longer and shorter inspection intervals. The problem is formulated in a Semi Markov Decision Process (SMDP) in order to minimize the total cost by optimizing the length of inspection intervals and critical states as a switching state and control state.

■ OSM5 WA 10:00- 11:30

Emerging models of data-driven decision making

Chair/Président: Sheng Liu, University of Toronto

• Understanding the value of fulfillment flexibility in an online retailing environment

Levi DeValve, Yehua Wei*, Di Wu, Rong Yuan
University of Chicago; Duke University; JD.COM; Stitch Fix

Abstract: We propose a general method for understanding flexibility in online retailing fulfillment networks. Motivated by practical constraints, we introduce a model with local fulfillment constraints and customer abandonment, two features that are new to the fulfillment literature. We then propose a simple, adaptive, and intuitive class of spillover limit policy under our model. We show that the spillover limit policy is asymptotically optimal. From simulations, we estimate that a proposed fulfillment network with additional flexibility equates to a profit improvement on the order of tens of millions of U.S. dollars.

• Real-time delivery time forecasting and promising in online retailing

Nooshin Salari*, Sheng Liu
University of Toronto

Abstract: Delivery time promising is critical to managing customer expectations and improving customer satisfaction. We propose a data-driven framework to predict the distribution of order delivery time and set promised delivery time to customers in a cost-effective way. We adapt regression tree and quantile regression forests to generate distributional forecasts by exploiting the complicated relationship between delivery time and relevant predictors. Tested on a real-world data set, our proposed models deliver superior forecasting performance and have the potential to provide better promised delivery time in terms of both cost and accuracy, as compared to the conventional promised time.

• **Promotions in the presence of rewards programs**
Rim Hariss*, Georgia Perakis, Yanchong (Karen) Zheng
McGill University [1]; MIT [2, 3]

Abstract: We consider a retailer who offers both price discounts and a point-based rewards program to customers. We study the retailer' optimal promotion strategy over a finite horizon when demand is a general linear function with price and its coefficients are functions of customers' current point balance. We show a product is discounted only if the average customers' balance of points is above a certain threshold. We propose an approximation algorithm of the optimal dynamic promotion problem and leverage data from a fast food chain to assess the performance of both the algorithm and the optimal pricing strategy.

• **Mechanism design for workforce scheduling in on-demand platforms**
Omar Besbes, Vineet Goyal, Garud Iyengar, Raghav Singal*
Columbia University

Abstract: Motivated by the substandard drivers' welfare in on-demand platforms, we propose a mechanism design framework for workforce scheduling. The platform maximizes profit by gathering supply via an admission control policy, which allocates hourly slots ("right to drive") to drivers. Each driver maximizes her expected utility, which depends on her temporal preference regarding when to drive, the slots she receives, and the time she spends on-road. We use our framework to evaluate existing policies and show they can result in highly suboptimal effective wage. Then, we propose a mechanism and establish tight performance guarantees with respect to both profit and wages.

■ QUE7 WA 10:00- 11:30

Queueing applications in operations and logistics

Chair/Président: Sapna Isotupa, Wilfrid Laurier University

• **Unfairness under shortest-remaining-processing-time scheduling in energy-proportional speed-scaling systems**
Maryam Elahi*, Carey Williamson
Mount Royal University; University of Calgary

Abstract: CPU speed-scaling is an effective method for balancing performance and the associated cost of energy in computer systems. In energy-proportional speed-scaling, the power consumption is proportional to the queue length. The SRPT scheduling policy is shown to be robust and optimal for minimizing the linear combination of average response-time and power consumption in energy-proportional systems. However, speed-scaling magnifies unfairness under SRPT, where large jobs experience longer waiting times. We quantify the magnitude of this unfairness by presenting a lower-bound for the slowdown of the largest job under SRPT in comparison to the slowdown under the egalitarian Processor-Sharing scheduling policy.

• **Data-driven system simulation for healthcare applications**
Opher Baron, Dmitry Krass, Arik Senderovich, Sijia (Nancy) Li*
University of Toronto

Abstract: Queueing analysis is instrumental in optimizing processes to efficiently serve customers. The availability of emergency department data has enabled a data-driven simulation approach to mimic a patient' journey from arrival to departure, with some probability that the patient necessitates a specialist consult in the process. Our research goals are twofold. First, to mimic the system with high verisimilitude by developing a consult model and a sojourn time model using static patient characteristics and number of patients upon arrival. On top of this, to prescribe rules by shortening the sojourn time of consult patients in order to aid managerial decisions.

• **An M/M/1 queueing system with attached inventory**
S.K. Samanta, Sapna Isotupa, Akash Verma*
National Institute of Technology, Raipur [1, 3]; Wilfrid Laurier University [2]

Abstract: In this paper we analyze an M/M/1 queueing system with finite waiting space where items from inventory are used to provide service to customers. Each customer who arrives needs one item from in-

ventory and a server. When inventory level drops to the reorder point, s, and order of size Q is placed which arrives after a lead time. The lead times for orders are independently and identically distributed with a known distribution. The long-run expected cost rate is derived. Numerical illustrations of the results are also provided.

■ PRM7 WA 10:00- 11:30

Omnichannel applications in pricing

Chair/Président: Mahsa Mahboob-Ghodsi, HEC Montréal

• Omnichannel assortment optimization with two-stage decisions

Venus Lo*

City University of Hong Kong

Abstract: Suppose a retailer sells in a physical store and online. A customer visits the physical store and requests her favourite product. If it is available, then she purchases it and leaves. Otherwise, she examines the in-store assortment before proceeding online. She adjusts her preferences for the online products based their similarities with the in-store products, and she purchases according to MNL. Computing an in-store assortment which maximizes expected revenue over both stages and channels is NP-hard. I present a fully polynomial-time approximation scheme, which introduces a staircase strategy that can also improve the runtime of algorithms for other assortment problems.

• Should competing firms offer 'Buy n times, get one free' loyalty programs? A game-theoretic analysis

Amirhossein Bazargan*, Saeed Zolfaghari, Salma Karray

Fairleigh Dickinson University, Vancouver; Ryerson University; Ontario Tech University

Abstract: Despite the prevalence of loyalty programs, some researchers argue that they might be costly and inefficient in competitive markets. Applying a game-theoretical approach, we study a market where two competing firms consider whether to offer 'Buy n, get one free' LPs or not. The market demand is derived using an analytical choice model that incorporates customers' valuations of reward and time. The results show that under different market conditions, firms might face a prisoner dilemma or find that not offering an LP is a dominant equilibrium. These results apply when the firms are symmetric and when they are not.

• Inventory allocation strategies for omnichannel retailing

Mahsa Mahboob Ghodsi*, Mehmet Gumus, Necati Ertekin

HEC Montréal; McGill University; University of Minnesota

Abstract: Nowadays many retailers have started omnichannel fulfillment initiatives that allow customers to pick up online orders in-store or have online orders shipped to stores. To stay competitive, retailers need to choose the least costly and most efficient option to fulfill the orders while maintaining the highest profit levels. With omnichannel strategies retailers face a trade-off between allocating stocks to store inventory or distribution center inventory. In this project, we aim to understand what motives retailers to adopt different omnichannel fulfillment strategies and analyze under what conditions it is beneficial for a retailer to offer omnichannel fulfillment strategies.

■ IND7 WA 10:00-10:45

Applying OR to humanitarian operations

Chair/Président: Polly Mitchell-Guthrie, Kinaxis

• Applying OR to humanitarian operations

Koen Peters*, Anna Melchiori*

United Nations World Food Programme

Abstract: Humanitarian operations are becoming increasingly difficult to manage, and in the wake of COVID-19 the needs have never been higher. The United Nations World Food Programme, which provides food assistance to 97 million people across 88 countries, has made significant investments over the last decade to put planning and optimization at the forefront of tackling emergencies at WFP. Their efforts were recognized earlier this year with the prestigious Franz Edelman Award. During this session, speakers from WFP will reflect on what it takes to use data science to support humanitarian operations, with special focus on WFP' corporate optimization tool: Optimus.

■ ENRE4 WA 10:00- 11:30

Optimization of power systems - I

Chair/Président: Mehrdad Pirnia, University of Waterloo

• Applications of a reformulated unit commitment model

J. David Fuller*

University of Waterloo

Abstract: The optimal solution of the continuous relaxation of a reformulated single-hour unit commitment (UC) model has a simple structure: ranking

generators by their minimum prices to be profitable, the cheapest have on/off binary variables equal to 1; at most one has a binary variable between 0 and 1; the remainder have 0 binaries; and the market price is between the minimum price of the most expensive generator with a nonzero binary and the next most expensive generator. Possible applications are discussed, e.g., to pricing for solutions of the full multi-hour UC model.

• Optimal operation of electric storage for energy and reserve markets under uncertainty

Hassan Shavandi*, J. David Fuller, Mehrdad Pirnia
University of Waterloo

Abstract: We present several analytical results for a chance constrained model of electric energy storage participating in both the energy and reserve markets, alongside generation, in the context of a day-ahead unit commitment model. The main source of uncertainty, and thus the reason for a reserve market, is assumed to be imperfect forecasts of wind generation. By assuming the forecasted mean of wind as deterministic supply, we prove several properties of the deterministic model. Then the uncertain model is studied through chance constraint model and results are compared with deterministic model.

• Data driven model for generation expansion planning with approximate short-term operational constraints

Hassan Shavandi, J. David Fuller, Mehrdad Pirnia*
University of Waterloo

Abstract: Recent growth in intermittent renewable generation has increased the need to represent the capability for non-renewables to respond to rapid changes in daily loads, leading research to bring unit commitment (UC) features into generation Expansion Planning (GEP) models. Such models usually contain discrete variables which, along with many details, make computation times impractically long for analysts who need to develop, debug, modify and use the GEP for many alternative runs. We propose a GEP with generation aggregated by technology type, and with the minimal UC content necessary to represent the limitations on generation to respond to rapid changes in demand.

• Multi-stage stochastic optimization and GIS for planning of multiple microgrids

Enrique Gabriel Vera, Claudio Canizares, Mehrdad Pirnia*
University of Waterloo

Abstract: MGs are groups of Distributed generation sources (DERs) (such as Renewable energy resources (RES) and Energy Storage systems (ESSs)) and loads, that can provide access to cheaper, cleaner, more flexible and reliable electricity. MGs must be planned, which is achieved by formulating optimization problems to find the proper location and economical mix of generation and energy storage resources that are necessary to satisfy the end-user' energy requirements. We propose a multi-stage stochastic framework for multi-MGs planning within distribution networks, considering spatial characteristics of the planning locations as well as solar irradiation, wind speed, demand, and spatial uncertainties.

■ HC17 WB 13:30- 15:00

Optimization for cancer care

Chair/Président: Houra Mahmoudzadeh, University of Waterloo

• Generating the Pareto robust frontier in robust radiotherapy optimization problems

Fahimeh Rahimi*, Hossein Abouee Mehrizi, Houra Mahmoudzadeh
University of Waterloo

Abstract: The goal of radiation therapy is to deliver a prescribed dose of radiation to a tumour while trying to spare the surrounding organs, considering the uncertain changes in the anatomy. One of the frameworks to present this problem is robust. While robust optimization is often used to protect against the worst-case scenario of uncertainty, Pareto robust optimization ensures that non-worst-case scenarios are also accounted for, and the solution cannot be dominated for all scenarios. We present an algorithm to generate a Pareto frontier for any linear robust optimization problems. We also demonstrate an application of the algorithm for radiation therapy.

• An optimization model for sliding windows IMRT treatment planning

Rafiq Habib*, Johnson Darko, Ernest Osei, Houra Mahmoudzadeh
University of Waterloo [1,4]; Grand River Regional Cancer Centre [2, 3]

Abstract: Intensity-modulated radiation therapy (IMRT) with sliding windows is a form of radiation therapy that delivers precise radiation dosage to a tumor using a multi-leaf collimator to conform the shape of the radiation beam to the tumor regions. This dynamic treatment approach aims to deliver adequate radiation dosage to tumor regions while minimizing radiation delivery to healthy tissues. This paper proposes a linear optimization model for IMRT with slid-

ing windows, incorporating deliverability constraints to conform to physical limitations of the IMRT machine. We demonstrate the viability of this model using patient data and discuss the leaf motion proposed by our model.

• **Closed-form constraint generation for robust radiation therapy treatment planning**
Danielle Ripsman*, Houra Mahmoudzadeh
University of Waterloo

Abstract: Integrating uncertainty into fluence map optimization (FMO) models for cancer treatment can be time and memory-intensive. Previous work has incorporated motion uncertainty using a robust FMO (RFMO) model, made tractable with a robust counterpart (RC). The RC, however, is much larger than the FMO model, motivating more efficient constraint generation (CG) approaches for solving the RFMO problem. In this talk, we show that the CG approach can be further streamlined using a closed-form algorithm. We prove that our approach generalizes to any problem with the same class of polyhedral uncertainty, and demonstrate its benefits using clinical breast cancer data.

■ HC11 WB 13:30- 15:00
Healthcare decision modeling

Chair/Président: Majid Taghavi, Saint Mary's University

• **Siting primary care clinics to meet daytime and afterhour objectives**
John Campbell*, Majid Taghavi, Peter VanBerkel
Dalhousie University [1, 3]; Saint Mary's University [2]

Abstract: Location science is used to determine the optimal geographical placement of primary care resources with operations research models. In determining the optimal placement, we account for the objectives of both patients and physicians. Patients prefer to be close to clinics to ensure access and physicians typically prefer to have minimum panel sizes to ensure consistent appointments. These objectives and the methods used to address them differ between daytime and afterhours settings. The daytime and afterhours problem settings are solved independently, sequentially, and simultaneously. The models are generalized but will be applied to census data from Nova Scotia.

• **Predicting ambulance offload delay using a hybrid decision tree model**
Mengyu Li*, Xiang Zhong, Peter Vanberkel
University of Florida [1, 2]; Dalhousie University [3]

Abstract: Ambulance offload delay (AOD) is the delay between transferring an ambulance patient to a hospital emergency department (ED). It negatively affects the ability of the ambulance service to respond to future calls and reduce the efficiency of the system. Using integrated historical data from a partnering hospital and an Emergency Medical Services provider, we developed a decision-support tool using a hybrid decision tree model to predict the severity of AOD occurring within 1 to 5 hours. The proposed approach improved upon the basic classification and regression tree algorithm for classification accuracy, precision, sensitivity and specificity analysis

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• **An efficient optimization model to organ allocation problem under uncertainty**
Bahareh Kargar*
University of Ottawa

Abstract: Organ allocation is one of the most critical decisions in organ transplantation network because of the great demand rate for organs compared to its shortage rate of organs. This research proposes a multi-objective model for organ allocation problem considering medical and logistics uncertainty. The proposed model minimizes total transportation cost and maximizes the patient' survival rate. Subsequently, to solve the proposed model, an effective solution method based on goal programming approach is developed to find the desired compromise solution. The applicability and validity of the proposed model are demonstrated through a case study.

• **A study of pediatric Left Without Being Seen (LWBS) patients**
Julia Sarty*, Peter VanBerkel, Majid Taghavi, Katrina Hurley, Eleanor Fitzpatrick
Dalhousie University [1, 2, 4, 5] Saint Mary's University [3]

Abstract: Patients and their caregivers that seek care in an Emergency Department (ED) may ultimately choose to leave without being seen by a physician. This occurrence is labelled "left without being seen" (LWBS) and can account for up to 15% of all patient visits in an ED. Identifying which patients are more likely to LWBS may provide an opportunity to intervene and prevent a departure that poses a risk to the patient or others. This investigation focuses on a pediatric ED and uses descriptive analytics and machine learning methods to predict patients who are more likely to LWBS.

■ HC3 WB 13:30- 15:00

Healthcare supply chain management

Chair/Président: Michael Carter, University of Toronto

• **Reimagining the operating room inventory as a center of savings**
Tammi Hawa, Michael Carter*
University of Toronto

Abstract: Operating room inventories typically manage hundreds of surgical items. Currently most inventory managers rely on intuition to set inventory control parameters. We investigate the value of ordering policies improved with access to information on usage and lead time patterns and upstream visibility. Results show inventory policies generated based on the real environment which acknowledge usage patterns and take advantage of upstream visibility lead to cost savings when compared to expert intuition and classically proposed policies. We provide realistic actions hospitals can take to decrease disposable surgical supply inventory policy costs.

• **The value of advance surgery booking information for inventory management of surgical consumables**
Jacky Chan*, Vahid Sarhangian
University of Toronto

Abstract: Surgical procedures require a large number of consumable items and since shortage of supplies could lead to cancellation of surgeries, it is paramount to maintain appropriate inventory levels at the hospital. In this work, we (i) investigate the value of utilizing advance booking information (ABI) for elective surgeries in improving replenishment decisions and reducing inventory costs; and (ii) propose practical policies to use this information effectively. By conducting a case study using data from a hospital in Ontario, we demonstrate that using only a few days of ABI can lead to significant reduction of inventory costs.

• **A newsvendor approach to design of surgical preference cards**
Berk Gorgulu*, Vahid Sarhangian
University of Toronto

Abstract: Surgical procedures require a large number of supplies that need to be picked and prepared before the surgery. A surgical preference card (SPC) specifies the required supplies for each surgery and their fill/open quantities. We formulate the problem of determining the fill and open quantities as an optimization problem aiming to minimize the expected total operational and wastage costs incurred for the surgery and show that the optimal solution has the same structure as that of the Newsvendor problem. We demonstrate the potential value of designing SPCs based on our optimization approach using data from a hospital in Ontario.

• **Integrated supply chain management and healthcare service delivery**
Esam Mustafa*
Athabasca University

Abstract: Healthcare organizations should integrate with suppliers and customers to improve service delivery and performance. This study investigates the effect of integrated supply chain management on healthcare service delivery in healthcare organizations. A random sample of 150 healthcare specialists from over 15 different healthcare organizations were collected using questionnaires and statistically analyzed. The findings indicate that integrated supply chain management has strong effect on healthcare service delivery. These findings help healthcare organizations to use integrated supply chain management to enhance their service.

■ FRM8 WB 13:30- 15:00

Quantitative finance

Chair/Président: Christoph Frei, University of Alberta

• **Generalized risk parity portfolio optimization: An ADMM approach**
Giorgio Costa, Roy Kwon*
University of Toronto

Abstract: We consider a generalized risk-parity model. First, we set an objective that seeks to maximize the portfolio expected return while minimizing portfolio risk. Second, we relax the risk parity condition and instead bound the risk dispersion of the constituents. This allows an investor to prescribe a desired risk dispersion range, yielding a portfolio with an optimal risk–return profile that is still well-diversified from a risk-based standpoint. We propose an algorithm based on the alternating direction method of multipliers. Numerical results show that this algorithm converges to a higher quality optimal solution when compared to the competing non-convex problem.

• **Dynamic portfolio decisions with uncertainty about climate change**
Alexey Rubtsov*, Sally Shen
Ryerson University [1]; Global Risk Institute [1, 2]

Abstract: We study the effect of investment horizon on the optimal stock-bond-cash portfolio in a dynamic

model with learning and uncertainty about climate change. The stock risk premium is assumed to be an affine function of global temperature change and an unobserved factor which is estimated via Bayesian learning. It is further assumed that probability distribution of future global temperature change is uncertain. The optimal investment strategy robust to the uncertainty about climate change is derived in closed form and analyzed for returns on S&P500 stock index.

• **E-backtesting risk measures**
Ruodu Wang*
University of Waterloo

Abstract: Testing statistical hypothesis is usually done in sciences using p-values. Recently, e-values have gained attention as potential alternatives to p-values as measures of uncertainty, significance and evidence. We use e-values to construct a model-free backtest of the Expected Shortfall, the most important risk measure in finance and insurance.

• **Traditional and digital currencies in over-the-counter markets**
Christoph Frei*, Qianhong Huang
University of Alberta

Abstract: We introduce a search and bargaining model where agents transact in traditional and digital currencies. Our model features the fundamental trade-off between (i) lower transaction costs of the digital currency and (ii) the reluctance of part of the population to use the digital currency. While participants in the digital currency benefit from welfare gains, people unwilling or unable to use the digital currency suffer from fewer trading opportunities and bear a higher share of transaction costs. We characterize the agents' distribution in the steady state, and explicitly determine when participants of the digital currency cease to trade with non-participants.

■ OPT23 WB 13:30- 15:00

Large scale optimization for routing and distribution problems - III

Chair/Président: Sheng Liu, University of Toronto

• **Investigating the use of range-constrained rotary-wing UAVs for target search applications**
Kyle E. C. Booth*, Chiara Piacentini, Sara Bernardini, J. Christopher Beck
University of Toronto [1, 2, 4]; Royal Holloway University of London [3]

Abstract: We study a range-constrained variant of the multi-UAV target search problem in which rotary-wing UAVs are deployed alongside mobile recharging vehicles (MRVs) that can travel to meet up with, and recharge, a UAV. We propose a pipeline for representing the problem over realistic road networks and solve the problem using mixed-integer linear programming (MILP) and constraint programming (CP). A computational assessment of our methods using real-world data indicates that CP provides better solutions than MILP and that the routing of MRVs improves the performance of the UAV fleet.

• **Multi-period dispatching and assignment for on-time last-mile delivery**
Sheng Liu*, Zhixing Luo
University of Toronto; Nanjing University

Abstract: Motivated by a large meal delivery company, we model and solve a multi-period driver dispatching and assignment problem for the last-mile delivery system where the on-time performance is the main target. Based on a novel approximation scheme, we are able to reformulate the problem with efficient exact algorithms. Extensive numerical studies on both synthetic and real data sets validate the superior performance of our algorithms.

• **Team orienteering with time-varying profit**
Qinxiao Yu, Yossiri Adulyasak*, Louis-Martin Rousseau, Ning Zhu, Shoufeng Ma
Tianjin University [1, 4, 5]; HEC Montréal [2]; Polytechnique Montréal [3]

Abstract: We consider the team orienteering problem where the arrival time and service time affect the collection of profits which can be applied in the contexts of urban search and rescue, or tourist trip planning. The problem is formulated as a mixed integer non-concave programming model. A Benders branch-and-cut algorithm, along with valid inequalities for tightening the upper bound, are developed to solve the problem. To tackle large-scale instances, we introduce a hybrid heuristic that integrates a modified coordinate search (MCS) into an iterated local search, which proven to be highly efficient compared to other benchmark approaches.

• **An optimization model for a capacitated multi-vehicle covering tour problem on a road network graph and an application to waste collection**
Vera Fischer*, Meritxell Pacheco Paneque, Antoine Legrain, Reinhard Bürgy
University of Fribourg [1, 2, 4]; Polytechnique Montréal [3]

Abstract: We consider a bi-level waste collection problem in which each resident brings the waste to a

collection site of their preference located in the neighborhood and trucks collect the waste there. Given a set of (potential) collection points, the goal is to select a subset of (actual) collection points so that each resident has one in their neighborhood and the resulting total collection time is minimized. We propose a compact mixed-integer linear programming formulation that exploits the sparsity of the road network and compare it with a formulation relying on the classical network representation in vehicle routing problems.

■ OPT31 WB 13:30- 15:00

Robust and stochastic optimization - II

Chair/Président: Narges Sereshti, HEC Montréal

• Multi-stage stochastic lot sizing with substitution

Narges Sereshti*, Merve Bodur, James Luedtke, Raf Jans, Yossiri Adulyassak
HEC Montréal [1, 4, 5]; University of Toronto [2]; University of Wisconsin [3]

Abstract: We consider the lot sizing problem with stochastic demand and the possibility of product substitution. Considering different production costs, the use of substitution can increase the revenue and customer satisfaction specially when the demand is uncertain. The goal is to minimize the total expected cost while satisfying a predetermined service level. In our model, we consider the Î± service level which limits the probability of stock outs, defined as a chance constraint. We investigate different solution policies for this chance-constrained multi-stage stochastic model and derive some managerial insights for the problem.

• An adaptive robust approximation for the lot-sizing problem under yield uncertainty

Paula Metzker Soares*, Alexandre Dolgui, Yossiri Adulyasak, Simon Thevenin
IMT Atlantique [1, 2, 4] HEC Montréal [3]

Abstract: This work addresses a linear approximation of the adaptive robust lot-sizing problem with backlog under yield uncertainty. In the light of the robust optimization, the adaptive approximation ignores the quadratic term that makes the adaptive robust model difficult to solve. The developed approximation achieves to the minimization of costs, while meet demands efficiently and with good quality products. Numerical experiments demonstrate that the approximation achieves satisfactory results that are free of strong assumptions about the disturbance in the worst case scenario, even if only a partial perspective of the robustness of the optimal solution is addressed by our approximated model.

• Robust appointment scheduling using min-max optimization

Tasmia Tumpa, Fazle Baki*, Ahmed Azab
University of Windsor

Abstract: Appointment scheduling is an increasingly challenging problem for service-centers, healthcare, production and transportation sector due to the difficulty to optimize between underutilization and idle time. The problem becomes more complicated in the presence of processing time uncertainty, varying from customer to customer. We develop a Robust Appointment Scheduling model using Min-max Optimization which provides appointment dates with the objective to minimize the cost of the worst-case scenario. Heuristic approaches are provided for solving larger instances of the problem. Two case studies, a Dentist' clinic and VIA Rail Canada are performed.

• Constrained stochastic blackbox optimization with MADS and the progressive barrier

Kwassi Joseph Dzahini*, Michael Kokkolaras, Sébastien Le Digabel
Polytechnique Montréal [1, 3]; McGill University [2]

Abstract: This work introduces StoMADS-PB, a direct-search method using a progressive barrier approach for constrained stochastic blackbox optimization. The objective function and all the constraints values can only be computed with random noises following unknown distributions. Since the deterministic computable version of the blackbox is unavailable, StoMADS-PB uses probabilistic estimates of the objective and constraints values, required to be accurate with high but fixed probabilities. Using Clarke calculus and martingale theory, the sequences of feasible and infeasible points produced by StoMADS-PB are shown to converge respectively with probability one, to Clarke stationary points of the unknown problem.

■ FOR4 WB 13:30- 15:00

Forest harvest planning

Chair/Président: Luc Lebel, Université Laval

• The effect of uncertainty on harvesting decisions by private non-industrial woodlot owners

Jules Comeau*, Michel Soucy
Université de Moncton

Abstract: Neuro dynamic programming has been used to solve stochastic forest stand management problems. In this study, we use this method to explore the impact of sources of uncertainty such as stumpage fees and natural disasters on decision making by private non-industrial woodlot owners in New Brunswick.

We discover that, even under unlikely extreme natural disaster scenarios, there are very little changes if any in what would be an optimal age to harvest softwood plantations. We then discuss the next step in understanding why these woodlot owners are not harvesting at optimal ages.

• Optimization of harvest scheduling at operational level

Rohit Arora*, Taraneh Sowlati
University of British Columbia

Abstract: A mixed-integer linear programming model will be developed to schedule the forest harvest activities at the operational level to minimize the total cost. Total cost includes operating cost, fixed cost of using an equipment piece, and equipment movement cost between harvest areas. The precedence relationship between harvest activities, the possibility of using the same piece of equipment for more than one harvest activity, and the possibility of assigning more than one equipment piece for each harvest activity at each harvest area will be considered in this model. This model will be applied to a real case study in BC.

• Integrated forest harvest planning and road building model with consideration of economies of scale

Azadeh Mobtaker*, Julio Montecinos, Mustapha Ouhimmou, Mikael Rönnqvist
CanmetENERGY [1]; École de technologie supérieure [2, 3]; Université Laval [4]

Abstract: We studied the tactical forest harvest planning problem with an extension of forest road building planning. The model decides which harvest areas to cut in specific period, the log allocation to wood-processing facilities operating and which roads to build in each period to have access to harvest areas that have not been connected to the network. The objective of the model was to minimize the total transportation and road building cost, subject to budget constraints. We aimed to assess the potential benefits of incorporating the notion of economies of scale in road construction. Our results showed cost reduction of 5.3%.

• A method to design the best-suited harvest system for fragmented forests

Luc LeBel*
Université Laval

Abstract: Forests in Canada offered opportunities for large and homogeneous harvesting blocks. Today, increased fragmentation makes operation planning more difficult. The systems used for forest operations in Canada are limited and represent a fraction of existing alternatives. Among all systems that could operate in Canada, we verified if one could outperform those currently found. This presentation offers a comprehensive review of existing harvest machines. The design of an MCDA methodology based on the PAPRIKA method is described. Seven systems topped the ranking. Four included solutions not used in Canada. Finally, an optimization-simulation model allowed to compute performance indicators for each system.

■ SE1 WB 13:30- 15:00

Sports analytics - I

Chair/Président: Kent Kostuk, Applied Decisions Systems

• Intention vs execution: Quantifying the loss in value due to player inaccuracies in tennis using MDPs

Craig Fernandes*, Timothy Chan, Doug Fearing, Stephanie Kovalchik
University of Toronto [1, 2]; Zelus Analytics [3, 4]

Abstract: The widespread utilization of value functions in sports helps determine the optimal strategy to employ. However, the efficacy of these suggested policies relies on players being able to accurately perform the desired task. We seek to tackle this disparity in the context of tennis by using detailed, simulated ball and player tracking data. We apply a clustering approach to determine a collection of similar shots in order to parse out the likely intended shot. Utilizing this inferred intention and the size/shape of each cluster, we can measure a player' shot value using MDPs, and how it varies with player inaccuracies.

• Do NHL goalies get hot in the playoffs? A multilevel logistic regression analysis

Likang Ding*, Armann Ingolfsson, Ivor Cribben, Monica Tran
University of Alberta

Abstract: The Hot Hand theory states that an athlete who has performed well in the recent past will perform better in the present. We use multilevel logistic regression to test this theory for National Hockey League playoff goaltenders, controlling for a variety of shot-related and game-related characteristics. Our data consists of 48,431 shots for 93 goaltenders in the 2008-2016 playoffs. Using a wide range of shot-based and time-based windows to quantify recent save performance, we consistently find that good recent save performance has a negative effect on the next-shot save probability, which contradicts the Hot Hand theory.

• **Value functions in curling: Analyzing curling as a Markov model**
Ji Tong (Michael) Yin*, Timothy Chan
University of Toronto

Abstract: We explore the generation of value functions in curling. The location and colour of rocks are extracted from a dataset of 130,000 shot images of professional curling matches. Clustering techniques reduce the dimensions of this image feature set, then used to develop a four-dimensional finite-horizon Markov reward process. The state reward represents the definite gain or loss of points at that state; using recursive logic, the value function representing the expected gain or loss of points over the rest of the game is calculated. This value function provides a metric in evaluating play and answering questions regarding optimal strategies.

• **The remarkable similarity of the female/male velocity ratios of Olympic champions in swimming, rowing, speed skating, and running**
Raymond Stefani*
California State University Long Beach

Abstract: Although swimming, rowing, speed skating and running appear to have little in common, using kinesiology and physics, the equation for expected female/male velocity ratio of Olympic champions, assuming equal training and efficiency, equals the Lean-to-Weight ratio for running and speed skating and the 8/9th power of that ratio for swimming and rowing. Olympic champion swimmers, rowers and speed skaters were within tenths of a percent of the value from the LTW ratio while for running the velocity ratio of champions was 1% lower than expected, due to a striding inefficiency. Women and men are therefore equally trained and technically efficient.

■ QUE8 WB 13:30-14:15

Three perspectives on arrival modeling to queues

Co-Chairs/Présidents: Opher Baron, University of Toronto
Co-Chairs/Présidents: Amir Rastpour, Ontario Tech University — Featuring

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• **Three perspectives on arrival modeling to queues**
Peter W. Glynn
Stanford University

Abstract: A fundamental element in data-driven queueing applications is the specification and estimation of the associated exogenous arrival stream to the system. In this talk, we will give an overview of some of the issues arising in this context. We will first talk about alternatives to renewal process modeling that are based on plausible models of customer behavior, specifically the settings of scheduled traffic and randomly scattered arrivals. We will then discuss what limit theory developed for queues tells us about the scales over which arrival data needs to be accurately represented within an analytical or simulation model that is calibrated to real-world data. Our third perspective comes from looking at real-world arrival data, and studying what the data itself tells us about how queue performance is impacted by various features of the data.

■ PRM3 WB 13:30- 15:00

Assortment optimization in revenue management

Chair/Président: Sanjay Dominik Jena, Université du Québec à Montréal

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• **Two-stage assortment optimization with product recommendations**
Venus Lo*
City University of Hong Kong

Abstract: A customer requests a product which may or may not be in the retailer' assortment, following the independent demand model. If her requested product is in the assortment, she purchases it and leaves. Otherwise, the retailer recommends a subset of his assortment as substitute products, which is customized according to the customer' initial request. The customer' preferences for the other products depend on her initial request. She chooses among the substitute products or an outside option according to MNL. I show that computing the optimal first and second stage assortments is APX-hard, and present a FPTAS when customers are semi-heterogeneous.

• **A partially-ranked choice model for large-scale data-driven assortment optimization**
Sanjay Dominik Jena*, Andrea Lodi, Hugo Palmer, Sole Claudio
Université du Québec à Montréal [1]; Polytechnique Montréal (2, 4] Bla Bla Car [3]

Abstract: The product assortment of a store directly impacts the sales and is among the most important decisions of store managers. Ranking-based choice models have been acknowledged for representing well high-dimensional product substitution effects, and therefore well reflect consumer preferences. We extend this concept to additionally allow for indifference for a subset of products on which the consumer does not have a strict preference. We show how to learn

those structures from historical data via column generation. The subproblems are efficiently solved using a growing tree that represents partially ranked preferences, allowing for training and optimizing assortments on thousands of products.

• On the estimation of rank-based discrete choice models with irrational customer behaviors

Claudio Sole*, Sanjay Dominik Jena, Andrea Lodi
Polytechnique Montréal [1, 3]; Université du Québec à Montréal (UQAM) [2]

Abstract: Random Utility Maximization (RUM) is arguably the most adopted framework for modeling human choice. This framework, however, is unable to capture complex choice behaviors such as halo effects. In this talk we propose an estimation method for the recently proposed Generalized Stochastic Preference choice model, which subsumes the RUM framework and can account for halo effects. Our results show that incorporating irrational behaviors in the learning process can lead to significant improvements in predictive accuracy.

• Assortment optimization under choice model ambiguity

Öykü Naz Attila*, Sanjay Dominik Jena, Walter Rei
Université du Québec à Montréal

Abstract: Assortment optimization is typically carried out on a discrete choice model, which represents the customers' buying behavior and is estimated based on historical data. Unfortunately, several sources of noise may result in different choice models, leading to different assortments with varying performance. This creates uncertainty when applying assortment optimization (i.e., the risk of using an ill-suited discrete choice model). We tackle this issue by using stochastic and robust optimization models based on a finite set of choice models instead of a nominal one. We evaluate these models by comparing the stochastic and robust models to their deterministic variants.

■ ENRE5 WB 13:30- 15:00

Optimization of power systems - II

Chair/Président: Sara Séguin, UQAC and GERAD

• An optimization model to maximize generation efficiency in short-term hydropower unit commitment

Maissa Daadaa, Sara Séguin*, Kenjy Demeester, Miguel F. Anjos
UQAC [1, 2]; Rio Tinto; University of Edinburgh

Abstract: We present a linear mixed-integer formulation to solve the short-term hydropower unit commitment problem. It determines the pair of maximum efficiency points of water discharge and the power produced at the maximal storage for all possible combinations of turbines. The goal is to maximize total energy for all periods. The objective function is calculated using the correction between the power produced at the current volume and the maximal storage and penalizes unit start-ups. Computational results are presented.

• Application of the theorems of "Content" and "Co-Content" for power flow distribution in complex transmission networks

Naser Moosavian*, Ziad Shawwash, Douglas Robinson
University of British Columbia [1, 2]; BC Hydro [3]

Abstract: We introduce a novel algorithm for analysis of power flow in complex power systems. The algorithm follows the Theorems of "Content" and "Co-Content" developed by Millar to minimize energy system losses subject to nodal balance equations. The method of Lagrange multipliers was used to enhance the BC Hydro Generalized Optimization Model (GOM) to efficiently optimize the power distribution in the BC Hydro's transmission network. GOM uses linear programming to optimize hydropower system operations and electricity trade in the US and Alberta electricity markets. The results show that the proposed method successfully approximates the power flow distribution in complex transmission networks.

• Reinforcement learning for hydropower optimization under chance constraints

Florian Mitjana*, Kenjy Demeester, Michel Denault, Dominique Orban
HEC Montréal [1, 3]; Rio Tinto [2]; Polytechnique Montréal [4]

Abstract: In the context of hydropower management, the optimization of reservoir operation is one of the most challenging tasks. One main difficulty is to deal with the uncertainties of the inflows, especially in a northern region like Canada. We define chance constraints on the water storage and apply a reinforcement learning (RL) approach, where a policy gradient method is combined with so-called "backoffs" in order to maximize the generated electricity with respect to the chance constraints. Stochastic dynamic programming is used as a benchmark.

• Using game theory in multi-agent coordination of BC Hydro resources

Farah Rawas*, Ziad Shawwash
University of British Columbia

Abstract: In British Columbia, the coordination of

hydropower generation is an essential but complex task that involves solving multi-decision-maker problems of multiple generation plants. Competitive and cooperative game theory has been increasingly used to solve multi-agent, central coordination systems as opposed to conventional, single-objective optimization techniques. We propose and test game-theoretic algorithms to coordinate and optimize the multi-reservoir system of BC Hydro. The model can be used to inform operational decisions for the Columbia and Peace river systems, on storage operations, and purchases and sales in the electricity market.

■ EDUC5 WB 13:30-15:00

In view of AI/ML usefulness and popularity, does OR education require an overhaul?

Chair/Président: Daniel Frances, University of Toronto

• In view of AI/ML usefulness and popularity, does OR education require an overhaul?

Please join our panelists

Emma Frejinger, Université de Montréal

Lauren Cipriano, Ivey Business School

Samir Elhedhli, University of Waterloo

Timothy Chan, University of Toronto

to discuss the question "In view of AI/ML usefulness and popularity, does OR education require an overhaul?" in a live panel. Prior to the panel, we would like to know what you think. Please participate in the following quick one-question anonymous poll at https://forms.gle/3NsesFKzCckd9QMA6.

For your reference, we provide below the Oxford Dictionary entries for these terms:

• **Analytics**: The systematic computational analysis of data or statistics.

• **Machine learning**: The use and development of computer systems that are able to learn and adapt without following explicit instructions, by using algorithms and statistical models to analyze and draw inferences from patterns in data.

• **Artificial Intelligence (AI)**: The theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages.

■ JOB WB 13:30- 15:00

Panel Discussion — Job search

Chair/Président: Stanko Dimitrov, University of Waterloo

Description: In this job-panel session four individuals with advance degrees will provide insight on how to position yourself for success after graduation. Hear from individuals developing and applying advanced operations research methods in public and private organizations. Have your previously asked questions answered and pose new questions in this live job-panel session.

Panel members:

Richard Chen, Flexport
Ned Dimitrov, StackAdapt
Saeid Molladavoudi, Statistics Canada
Anne Robinson, Kinaxis

■ NSERC/NRC WC 15:30- 17:00

Chair/Président: Fatma Gzara, University of Waterloo

• Collaborating for innovative logistics and transportation solutions: National Research Council Program

Margaret McKay, Program Leader
NRC AI for Logistics

Abstract: The National Research Council (NRC) is the Government of Canada's largest research and development organization. With over 100 years of experience, NRC works with its partners to deliver a national platform for innovation. NRC delivers value to Canada in two ways:

1. Through NRC's national network of researchers and facilities, who perform research and technical services with partners; and,

2. Through the Industrial Research assistance Program (IRAP), which provides advice and funding to leading small- and medium-sized technology companies

Since 2018, NRC has been developing ways to enhance collaboration opportunities between its own researchers and colleagues in academia, the private, and public sectors. As a part of this initiative, NRC has established collaborative R&D programs enhancing NRC's ability to collaborate with academic and private-sector partners. This presentation will discuss NRC's collaborative R&D programs in general, and specifically the AI for Logistics program, which is centered on the use of artificial intelligence to improve the transportation of civilian goods.

• NSERC – News

Katherine MacLean (Program Officer, Research Grants

and Scholarships, NSERC) Natalie Weiskopf (Team Leader, Program Officer, Research Grants and Scholarships, NSERC)

Description: The presentation will deliver a brief overview of NSERC news highlighting key program and policy updates. This will be followed by NSERC's latest response to the impacts of COVID-19 to provide continued support and funding across programs.

■ HC13 WC 15:30- 17:00

Optimization of cancer treatment

Chair/Président: Houra Mahmoudzadeh, University of Waterloo

• **Clinical implementation of automated radiotherapy treatment planning using expedited constrained hierarchical optimization (ECHO): Over 3000 patients**

Masoud Zarepisheh*, Linda Hong, Gourav Jhanwar, Ying Zhou, Qijie Huang, Jie Yang, Hai D. Pham, Joseph O. Deasy

Memorial Sloan Kettering Cancer Center

Abstract: This study automates IMRT radiotherapy treatment planning by formulating that as a hierarchical constrained optimization problem (also known as prioritized optimization). This technique has been clinically implemented and being used in our institution daily clinical routine with over 3000 patients treated to-date. We explain some optimization and implementation challenges and solutions, including: 1) non-convexity of DVH constraints, 2) computational challenges with large-scale no-linear constrained optimization problems, 3) dose discrepancy between optimization and final dose calculation, and 4) integration with an FDA-approved clinical system.

• **A two-stage column-and-constraint generation approach for direct aperture optimization in intensity modulated radiation therapy**

Amirhossein Vaeztehrani*, Houra Mahmoudzadeh

University of Waterloo

Abstract: In radiation therapy, the goal is to irradiate the tumor while sparing the adjacent healthy tissues. Deliverability constraints, which guarantee an "aperture" feasibility, are often formulated as a mixed-integer programming problem. We propose a column generation algorithm to solve this large-scale MIP model, where the master problem optimizes the current apertures' intensity, and the sub-problem generates new eligible apertures. There is no guarantee that a small number of apertures are positive in our CG optimal solution, which results in a significant increase in delivery time. Thus, we develop different cutting policies to limit the number of positive apertures.

• **Imputing radiobiological parameters of the linear-quadratic dose-response model from a radiotherapy fractionation plan**

Archis Ghate*

University of Washington

Abstract: The objective in cancer radiotherapy is to maximize tumor-kill and limit toxic effects of radiation on nearby organs-at-risk. Planners wish to find a dosing sequence that achieves this goal. This is called the fractionation problem. Formulations of this optimization problem utilize the linear-quadratic (LQ) dose-response framework. This yields a nonconvex quadratically constrained quadratic program. The optimal dosing plan in this forward problem depends on the LQ parameters. These parameters are unknown. The clinical literature is includes debates about what parameter values will make specific dosing plans effective. I will present an inverse optimization approach to solve this problem.

• **Adaptive liver stereotactic body radiotherapy**

Marina Epelman*, Victor Wu, Martha Matuszak, Daniel Polan

University of Michigan [1,3, 4]; LLamasoft, Inc. [2]

Abstract: In abdominal stereotactic body radiation therapy (SBRT), the patient may come in for treatment with a geometry that is drastically different from the planning one. On the day of a treatment, the patient may have a CT to update their geometry, but fully re-optimizing on the day of treatment is too operationally taxing. We propose a treatment planning model in which possible geometries at each fraction are estimated, and we optimize a set of plans based on biologically effective dose – one for each potential geometry – before the patient arrives, and deploy the plan appropriate to the day-of geometry.

■ HC15 WC 15:30- 17:00

Optimization of healthcare delivery under uncertainty

Chair/Président: Amir Ardestani-Jaafari, University of British Columbia

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• **Analysis and improvement of Alternate Level of Care (ALC) patients**

Ya-Tang Chuang*, Manaf Zargoush, Saied Samiedaluie

McMaster University [1, 2]; University of Alberta [3]

Abstract: Alternate Level of Care (ALC) patients are hospitalized patients who no longer require hospital resources yet have not been discharged because bed resources in lower intensity organizations are very limited. This problem has resulted in two major issues: 1) The large number of ALC patients prevent access to care for other patients needing intensive care; 2) ALC patients do not receive an appropriate level of care, which negatively affect their health outcomes. Our objective is to determine an optimal discharge rule to alleviate hospital congestion by using jointly advanced data analytics and optimization techniques.

• **Multi-period pattern-based home health care planning and scheduling: Models, decompositions, and a novel branching algorithm**

Bahman Naderi*, Mehmet Begen, Gregory Zaric, Vahid Roshanaei
University of Windsor [1]; Western University [2, 3]; University of Toronto [4]

Abstract: We study a multi-period pattern-based home health care planning and scheduling (HHCPS) problem. We formulate the HHCPS problem as a novel mixed-integer program (MIP). Using a dataset from the literature, we demonstrate that our MIP achieves 10%lower optimality gap, on average, than another MIP that we develop based on the widely-used routing decisions (35% versus 45%). Then, we develop two exact techniques for the problem: (i) a logic-based Benders decomposition (LBBD) and (ii) a LBBD-based branching-decomposition. We show that our novel BD algorithm can (i) guarantee optimality in 25% of instances and reduce the optimality gap to an average 3.6%.

• **Improving stroke routing protocol**

Amir Ardestani-Jaafari*, Beste Kucukyazici
University of British Columbia; Michigan State University

Abstract: Stroke is a medical emergency and must be treated immediately. However, transporting patients to the closest stroke hospital may not be the best solution. It often causes congestion in some hospitals, while underutilization in others. We study patients' routing protocol under congestion.

• **Variable neighborhood search algorithm for multiple objective elective surgery planning problem**

Xiankai Yang*, Yuvraj Gajpal, Srimantoorao Appadoo
University of Manitoba

Abstract: Operating scheduling is a crucial part in a hospital. It is related to both patient satisfaction and hospital performance. This paper considers elective surgery scheduling problem on tactical level. There are multiple objectives like minimizing overdue patients and maximizing performance etc. All the objectives are fulfilled under the resource limitation like surgeons and operating rooms. Moreover, downstream resources like wards and beds are considered in the model. We use variable neighbourhood search algorithm to solve the problem. Numerical experiment is performed in the randomly generated date set to evaluate the effectiveness of the proposed algorithm.

■ HC18 WC 15:30- 17:00

Stochastic modelling applications in healthcare

Chair/Président: Faith Erenay, University of Waterloo

• **An MDP model for optimizing screening policies for hospital-acquired infections applied to MRSA surveillance among the exposed roommates**

Esma Akgun*, Fatih Safa Erenay, Sibel Alumur Alev
University of Waterloo

Abstract: The optimal screening time and method for the exposed roommates of Methicillin-Resistant Staphylococcus Aureus (MRSA) carriers are unknown. We build a Markov Decision Process to i) capture the stochastic MRSA propagation and progression, and ii) optimize the screening policy (using culture and/or PCR tests) based on QALYs, total cost, number of colonized patients, and number of missed MRSA cases. Considering the spread of the infection within the room structure of a hospital makes the proposed model applicable to other hospital-acquired infections. The optimal policies from the MDP model are compared with the current practice via a discrete event simulation model.

• **Optimal planning of catheter administration sequence using MDPs in the neonatal intensive care unit**

Cansu Dagsuyu*, Fatih Safa Erenay, Ali Kokangul, Nejat Narl*f*±
University of Waterloo [1, 2]; University of Cukurova [3, 4]

Abstract: Catheter use during invasive treatment procedures is a source of high infection risk, especially in newborns. There are different catheter types with different infection rates and change dates (i.e., lifetime after placement). Infection rates also depend on the order of catheter type use. Using clinical data, we developed a novel Markov Decision Process that consider

remaining treatment duration and catheter use history to determine the optimal catheter placement strategy for minimizing wasted catheter lifetime and infection risk under resource constraints. We determined the optimal policy from the MDP model and compared it with the current practice using discrete-event simulation.

• Stochastic modeling of drug wastage in cancer care

Krishna Sabareesh Rajangom*, Fatih Safa Erenay, Qi Ming He, Avram Denburg
University of Waterloo [1, 2, 3]; SickKids Hospital [4]

Abstract: High wastage of left-over cancer drugs is a major concern given ever-increasing drug costs. Left-over drug occurs when dose demands based on patients' body surface area or weight do not match the available drug vial sizes. The wastage can be reduced through vial sharing, increased vial size variety, and better inventory management under restrictions such as a six-hour time-window for sharing the left-over drug. We developed a stochastic model to analyze the expected wastage under different operating conditions and wastage mitigation methods. The model, which is built and validated using medical data, assumes random patient arrivals and random dosage requirements.

■ FRM9 WC 15:30- 17:00

Advances in mathematical finance

Chair/Président: Dena Firoozi, HEC Montréal

• Robustness in the optimization of risk measures

Paul Embrechts, Alexander Schied*, Ruodu Wang
ETH Switzerland [1]; University of Waterloo [2, 3]

Abstract: We study issues of robustness in the context of Quantitative Risk Management and Optimization. Depending on the underlying objectives, we develop a general methodology for determining whether a given risk measurement related optimization problem is robust. Motivated by practical issues from financial regulation, we give special attention to the two most widely used risk measures in the industry, Value-at-Risk (VaR) and Expected Shortfall (ES). We discover that for many simple representative optimization problems, VaR generally leads to non-robust optimizers whereas ES generally leads to robust ones.

• Optimal trading with differing trade signals

Ryan Donnelly*, Mathew Lorig
King's College London; University of Washington

Abstract: We consider the problem of maximizing portfolio value when an agent has a subjective view on asset value different from the traded market price. We also consider several agents interacting and trading simultaneously when they have a subjective view of the asset value. Two cases are considered: one in which they all share the same information, and one in which they all have an individual signal correlated with price innovations. We take a mean-field game approach which remains tractable. After classifying the mean-field equilibrium we compute the dependence of price distribution on the amount of shared information among the agents.

• Convergence of deep fictitious play for stochastic differential games

Ruimeng Hu*
University of California, Santa Barbara

Abstract: This talk focuses on the convergence analysis for deep fictitious play (DFP), a novel machine-learning algorithm for finding Markovian Nash equilibrium of large N-player asymmetric stochastic differential games. By incorporating the idea of fictitious play, the algorithm decouples the game into N sub-optimization problems, and identifies each player' optimal strategy with the deep BSDE method parallelly and repeatedly. I will show the algorithm's convergence to the true Nash equilibrium, and show that the strategy based on DFP forms an ϵ-Nash equilibrium. Numerical results of large population games are presented showing the empirical convergence of the algorithm beyond the technical assumptions.

• Solar renewable energy certificate (SREC) markets: A mean field game approach

Dena Firoozi*, Arvind Shrivats, Sebastian Jaimungal
HEC Montréal [1]; University of Toronto [2, 3]

Abstract: Solar renewable energy certificate (SREC) markets can be viewed as a large-population stochastic game with heterogeneous agents, where agents interact through the market price of the certificates. We study this stochastic game by solving the mean-field game limit, where firms optimize costs accounting for trading frictions, generation cost, SREC nonlinear penalty, and generation uncertainty. We characterize firms' optimal actions as the solution to a McKean-Vlasov (MV) FBSDE which yield an Epsilon-Nash equilibrium for the market, and determine the equilibrium SREC price using the market clearing condition. We numerically solve the MV-FBSDEs and conclude by illustrating how firms behave in equilibrium.

■ OPT4 WC 15:30- 17:00

Optimization and machine learning ap-

plications - III

Chair/Président: Ian Zhu, University of Toronto

• Inverse mixed integer optimization: Polyhedral insights and trust region methods

Ian Yihang Zhu*, Merve Bodur, Timothy Chan
University of Toronto

Abstract: Inverse optimization – determining parameters of an optimization problem that render a given solution optimal – has received increasing attention in recent years. In this talk, we present a new set of theoretical insights and algorithms for the general class of inverse mixed integer linear optimization problems. Specifically, a general characterization of optimality conditions is established and leveraged to design new cutting plane solution algorithms. Through an extensive set of computational experiments, we show that our methods provide substantial improvements over existing methods in solving the largest and most difficult instances to date.

• Sparsity-agnostic lasso bandit

Garud Iyengar, Min-hwan Oh*, Assaf Zeevi
Columbia University

Abstract: We consider a stochastic contextual bandit problem where the feature vectors are potentially high-dimensional, however, only a sparse subset of features affect the reward function. Essentially all existing algorithms for sparse bandits require a priori knowledge about the value of the sparsity parameter. This knowledge is almost never available in practice, and misspecification of this parameter can lead to severe deterioration in the performance of the existing methods. The main contribution of this work is to propose the first algorithm which does not require a priori knowledge of sparsity and establish tight regret bounds under relatively mild conditions.

• Learning manipulation through dissemination

Jussi Keppo, Michael Jong Kim, Xinyuan Zhang*
NUS Business School [1]; University of British Columbia [2, 3]

Abstract: We consider the problem of optimally manipulating a Bayesian learner through adaptive provisioning of information. The problem is motivated by settings in which a firm can disseminate possibly biased information, to influence the public's belief about a hidden parameter related to the firm's payoffs. For example, firms advertise to sell products. We study a sequential optimization model in which the firm dynamically decides on the quantity and content of information sent to the public. We solve the associated Bayesian dynamic programming equation and characterize the optimal manipulation policy in closed-form. We also encode the evolution of the public's belief.

• A prescriptive approach to surgical inpatient discharges

Taghi Khaniyev*, Kyan Safavi, Martin Copenhaver, Ana Cecilia Zenteno Langle, Bethany Daily, Peter Dunn, Retsef Levi
Massachusetts Institute of Technology [1, 7]; Massachusetts General Hospital [2, 3, 4, 5, 6]

Abstract: We trained a neural network model to accurately predict next-day' surgical patient discharges. EMR data included in the model was represented based on whether it indicated a clinical or administrative barrier to discharge which was defined as an event that may postpone the patient' discharge. Discharge predictions were categorized as NO/MAYBE/YES. An optimization model was developed to select the minimal subset of barriers for each patient that needs to be resolved in order to move a patient to YES category. This minimal list was intended to serve as a prioritized action list for each patient.

■ OPT33 WC 15:30- 17:00

Machine learning and optimization for COVID-19 and healthcare applications

Chair/Président: Shobeir Amirnequiee, Ivey Business School

• Improving medical services through a combination of an optimized deep learning and the blockchain technology

Chinedu Egbuonu*, Anjali Awasthi
Concordia University

Abstract: This study aims to build a Smart Medical System, by developing a cross-intersectionality between AI and the Blockchain technology. It observes a patient' medical record and existing health condition and using an optimized activation function of the deep learning, it will be able to predict if a patient will have a particular kind of illness or not within a given time period. By utilizing the blockchain technology it protects a patient' medical records and makes them easily accessible. The result of our work is the development of an AI model with a high accuracy result used in medical diagnosis.

• Surgical ward multi-objective planning and scheduling for elective patients

Yasaman Fallahpour*, Majid Rafiee
Khatam University; Sharif University of Technology

Abstract: Operating Rooms planning and schedul-

ing is essential in Healthcare centers. In this paper, a Mixed Integer Programming has been provided for minimizing idle and waiting time, and maximizing the allocation points of high priority patients. Constraints related to upstream and downstream units are considered. For solving, an improved version of eps-constraint has been used. To the best of our knowledge this is the first time eps-constraint has been used for a Multi-Objective problem in this field. The idea of Occupancy Level Coefficient of ICU has been provided because it was a bottleneck. The results represent that the method is suitable.

• **Optimization of inpatient care unit resources during COVID-19 pandemic**
Manas Ghosh*, Elkafi Hassini
McMaster University

Abstract: Hospitals and the health care system faced an unprecedented challenge during the COVID-19 pandemic. Health care managers needed to develop optimal resource utilization plans to serve the maximum number of patients. In this paper, we will investigate optimal resource utilization under a given budget where patients are allowed to be transferred among hospitals in a health care system. We will also investigate a policy where a hospital may be designated as a dedicated COVID-19 facility. We carried numerical experiments to investigate the effect of patient arrivals, waiting time, and unmet demand during the COVID-19 pandemic.

• **PPE distribution during the COVID-19 pandemic: A two-stage stochastic program**
Jordan Kiss*, Samir Elhedhli
University of Waterloo

Abstract: We consider the problem of distributing critical personal protective equipment (PPE) during the COVID-19 pandemic by acquiring distribution and storage resources from multiple independent carriers. Given the uncertainty, the limited supply, and the severity of the pandemic, we propose a two-stage stochastic program with recourse. We test on a case study based on real data from Ontario and provide detailed analysis and insights.

■ SMS8 WC 15:30- 17:00

Stochastic models in healthcare operations

Chair/Président: Hossein Abouee Mehrizi, University of Waterloo

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• **Data-driven advance scheduling of patients with different priority levels and service requirements**
Hossein Abouee Mehrizi*, Mohammad Hossein Eshraghi, Vahid Sarhangian
University of Waterloo [1, 2]; University of Toronto [3]

Abstract: We consider advance scheduling of multi-class multi-priority patients where different classes have different service durations. We assume that, on any given day, the scheduling calendar is open only for the next fixed number of days, and patients who are not scheduled on the day of their arrivals will be waiting to be scheduled in the future. We provide a discrete-time data-driven model of the problem in a finite horizon setting. We analyze the proposed model and provide an analytical gap between the wait cost of different priority levels under the optimal offline policy and a class of online scheduling polices.

• **Data-driven platelet inventory management**
Hossein Abouee-Mehrizi, Mahdi Mirjalili*, Vahid Sarhangian
University of Waterloo [1]; Univeristy of Toronto [2, 3]

Abstract: Determining the ordering quantities for platelet units at hospitals is a challenging task due to high uncertainty in daily usage and short shelf-life of platelets. We propose a data-driven approach to determine ordering quantities for hospitals that order platelets from a central supplier and hence the age of received orders is subject to uncertainty. The approach is data-driven in the sense that it only relies on historical values of usage and other relevant "features". We evaluate the performance of our approach based on the resulting wastage and emergency orders using data from a network of hospitals in Hamilton, ON.

• **Split liver transplantation: An analytical decision support model**
Yanhan Tang*, Alan Scheller-Wolf, Sridhar Tayur, Emily Perito, John Roberts
Carnegie Mellon University [1, 2, 3]; University of California, San Francisco [4, 5]

Abstract: Split liver transplantation (SLT) is a procedure that saves two lives using one liver. Despite SLT' potential to relieve the acute shortage of donated livers, SLT is rarely used in the US. Barriers to increase SLT utilization include surgical expertise, geography, and the complexities of donor-recipient matching. We analytically model the deceased-donor liver allocation system incorporating both SLT and fairness concerns. We formulate a multi-queue fluid system, incorporating the specifics of donor-recipient size matching and dynamically changing Model for End-Stage Liver

Disease scores. Our formulation enables us to find the optimal matching and evaluate the performance of different allocation policies.

• **Joint appointment and reentry scheduling: Mitigating onsite overcrowding in outpatient services**
Xinyun Chen, Jim Dai, Yichuan Ding*, Pengyi Shi, Linger Sun
Chinese University of Hong Kong (Shenzhen) [1, 2, 5]; McGill University [3]; Purdue University [4]

Abstract: We study outpatient scheduling in the presence of both walk-in arrivals and patient reentry for an integrated care unit. We develop a novel iterative algorithm to efficiently solve the joint appointment time and reentry time scheduling problem, with provable bounds. Our algorithm deals with endogeneity between the schedule and system parameters, which is usually overlooked in the literature. Collaborating with a large teaching hospital in Shenzhen, China, we use real data to demonstrate that our algorithm reduces patient delay by 13% ~ 18% compared to the current policy.

■ EDUC3 WC 15:30-16:30

Tutorial — An introduction to SAS optimization: Solving the cutting stock problem using column generation

Chair/Président: Ari Zitin, SAS Institute Inc.

• **Tutorial — An introduction to SAS optimization: Solving the cutting stock problem using column generation**
Ari Zitin
Analytical Training Consultant, SAS Institute Inc.

Abstract: In this tutorial we will explore the syntax and functionality of SAS Optimization by introducing and solving a simple cutting stock problem. We use a nested approach that takes advantage of the linear programming solver and the integer linear programming solver in SAS Optimization. A key goal in the workshop is to learn how to use the syntax in SAS Optimization to read data, formulate optimization problems, and solve them in an efficient way. We will finish the workshop by taking a quick look at some of the more modern tools in SAS Optimization, including a derivative-free optimization algorithm that takes advantage of distributed computing.

■ FOR5 WC 15:30- 17:00

Wildfire management

Chair/Président: David Martell, University of Toronto

• **Integrating wildfire resistance into a multicriteria approach for Portuguese forest management**
Liliana Ferreira*, Miguel Constantino, José Guilherme Borges, Susete Marques, Brigite Botequim
Escola Superior de Tecnologia e Gestão [1]; Universidade de Lisboa [2, 3, 4, 5]

Abstract: Although forest sector plays a key role in the Portuguese economy, the absence of active management is harmful for its development. Portugal faced catastrophic wildfires in 2017 with tremendous consequences to forest sector and society. Afterwards, it became obvious that alternative forest management should be explored. Nowadays decision makers are forced to address the impacts of uncertainty caused by natural disturbances on forest projections. Thus, this research aims at presenting a multicriteria approach for forest ecosystem management that considers spatial optimization in order to include wildfire resistance as one of the criteria chosen to optimize by the forest stakeholders.

• **Estimating the treatment effect of initial attack activities in wildfire suppression**
Mostafa Rezaei*, Ilbin Lee, Jen Beverly
University of Alberta

Abstract: Requirements: This tutorial will be introductory, so attendees are not expected to have a background in SAS programming.

• **Managing flammable forest landscapes inhabited by woodland caribou**
Nicolo Fellini, David Martell*, Emmet Snyder
University of Toronto

Abstract: The boreal forest region of Canada is an important source of industrial fibre but much of it also serves as habitat for Woodland caribou which is classified as being threatened under Canada' Species at Risk Act. Forest managers are challenged by the need to develop forest management strategies that will deliver sustainable economic timber supplies and provide undisturbed areas that can serve as caribou habitat. That fire is a natural component of boreal forest landscapes complicates such planning. We describe our efforts to apply mathematical programming and stochastic programming methods to this important landscape management problem.

■ TL2 WC 15:30- 17:00

Emerging logistics optimization for smart cities

Chair/Président: Sheng Liu, University of Toronto

• **Stall economy: The value of mobility and precision deployment of retail on wheels**
Junyu Cao, Chen Ma, Wei Qi*
University of Texas, Austin [1]; McGill University [2, 3]

Abstract: Urban open space emerges as a new territory to embrace retail innovations. Selling products in public spaces with wheeled stalls can potentially become ubiquitous in our future cities. Transition into such a "stall economy" paradigm is being spurred by the recent global pandemic, but has been scarcely studied. This paper provides models, algorithms, and managerial insights to understand how to deploy and operate wheeled stalls in cities to scale up the stall economy. In a broader sense, this work demonstrates an expanded scope of retail operations reshaped by the pandemic and big data.

• **Urban TSP estimation: A dataset and software tool for operations and transportation researchers**
Peter Zhang, Hai Wang, Hao Hao*
Carnegie Mellon University

Abstract: We create a software tool to comb through major urban networks in the world, to estimate TSP coefficients based on an improved version of the BHH formula. This would allow transportation researchers and city planners to have an accurate closed-form estimation in various TSP setups, enabling them to do fast calculations for urban planning and analytical study. In addition, our analysis shows that the estimation is sample-efficient in the online setting (e.g., with stochastic gradient descent), implying that data from real trips can be used to quickly update the coefficients during actual operations.

• **Capacity allocation for electric vehicle charging stations considering congestion and waiting times**
Omer Burak Kinay*, Fatma Gzara, Sibel Alumur Alev
University of Waterloo

Abstract: We introduce a new methodology to design the charging infrastructure for electric vehicles that decides on the capacities of charging stations. Our mathematical model determines the number of power outlets (parallel servers) at each charging station within a joint simulation-optimization framework. A Benders decomposition-based solution methodology is developed to solve this problem where the resulting complex queuing network subproblems are evaluated by simulation. Computational experiments are performed to derive managerial insights on cost and congestion tradeoffs under various problem settings.

• **Assessing the efficiency of transit-oriented development based on the concept of compactness**
Nasim Rabiei*, Fuzhan Nasiri
Concordia University

Abstract: Transit-oriented development (TOD) is a compact mixed-use sustainable development around transit stations. The success of TODs is assessed regarding sustainable principles: destination accessibility, distance to transit, density, diversity, and design (5D). An efficient TOD area has the maximum destination accessibility, density, diversity, and design in the minimum distance to transit. Distance to transit represents the TOD area and is measured in a 400-800 meter circular buffer of stations. In this research, the first 4Ds are taken as outputs and distance to transit as the input of a Data Envelopment Analysis (Fuzzy-DEA) to address the uncertainties in defining the service area.

• **Research in matching and pricing models for shared transportation platforms: A systematic literature review**
Marjan Padidar*, Samira Keivanpour, Maha Ben Ali
Polytechnique Montréal University

Abstract: The increasing complexity of transportation chains triggered the emergence of resource-sharing platforms. These platforms aim to manage the allocation and pricing the mobility services. Various objectives are considered for the matching problems from maximizing profits to minimizing the total traveled distance depending on different factors like the acceptance level among customers. Furthermore, there are different pricing strategies as a result of the dynamics and complexity of two-sided market platforms. The purpose of this study is to present a systematic literature review on different mathematical models and algorithms for matching as well as pricing strategies and provides future research directions.

■ SE2 WC 15:30- 17:00

Sports analytics - II

Chair/Président: Kyle Maclean, Western University

• **Observed versus expected COVID-19 infections among National Football League players during the 2020 season**
Tom Bliss*
National Football League

Abstract: To mitigate COVID-19 risk among players and staff, the National Football League and National

Football League Players Association implemented a set of strict protocols for the 2020 season. Using county-level test data from each team location, we county-specific baseline distributions of infection rates that would have been expected to occur in a population similar in age to NFL players were the league not to have a season. Over a five-month period (from August 1st, 2020 to January 2nd, 2021), positive NFL player infections (n = 256) were roughly 50% lower than expected when compared to like cohorts from the population.

• **Parenthood and labour productivity: Evidence from the MLB**

Kyle Maclean*
Ivey Business School

Abstract: Parenthood and its impact on labour productivity has been a widely studied problem. In this presentation, I seek to tackle two research questions: How does career stability impact the likelihood of taking paternity leave, and how the eventual status of parenthood does (or does not) impact productivity. The current literature on both of these questions is limited by poor or highly lagged productivity measures. Utilizing a novel Major League Baseball dataset combining in-season paternity leaves, we investigate if career stability impacts the likelihood of taking a paternity leave, as well as if parenthood impacts productivity of players.

• **An inverse optimization analysis of the fourth down decision in football**

Nathan Sandholtz*, Yifan Wu, Martin Puterman, Timothy Chan
University of Toronto [1, 4]; Simon Fraser University [2]; University of British Columbia [3]

Abstract: The fourth down decision in football has been primarily studied as an optimization problem. In this work, we approach the fourth down decision from an inverse optimization perspective. We assume coaches' observed decisions are optimal; our goal is to infer the latent optimization model driving their behavior. In our framework, the latent aspect of the optimization model is the optimality criterion governing the decision rule. Using the quantile function as a function space for the optimality criterion, we find that coaches optimize over low quantiles with respect to the uncertainty in the next state value, which corresponds to conservative preferences.

■ SCM9 WC 15:30- 17:00

Competition and collaboration in supply chain management

Chair/Président: Amirmohsen Golmohammadi, Laurentian University

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• **Quality-to-price scoring: Information sharing in competitive supply chains**

Hedayat Alibeiki*, Mehmet Gumus
California State University San Marcos; McGill University

Abstract: Considering a supply competition in which the buyer uses a quality-to-price scoring rule to allocate the order, we investigated the impact of quality score information sharing. Our results reveal the circumstances under which the buyer is better off to share this information with the suppliers.

• **Governments' strategies for setting environmental standards**

Amirmohsen Golmohammadi*, Tim Kraft, Seyed Amin Monemian
Laurentian University [1, 3]; Poole College of Management [2]

Abstract: The acceleration of global warming has forced governments to further monitor and regulate the greenhouse gas emissions of industry. One of the most common approaches that governments use to reduce firms' emissions is to set an environmental standard for firms to comply with before a specific deadline. we examine how a government should set the deadline for a new standard in a market with two competing firms, both of whom make technology development and production decisions. Our work takes the perspective of the government and emphasizes the timing of her decision, a critical and yet understudied dimension in the literature.

• **Supply chain information sharing with prediction markets**

Majid Karimi*, Nima Zaerpour
California State University San Marcos

Abstract: Information sharing is one of the key enablers of supply chain integration, yet it is often underutilized. In this study, we use an information aggregation tool called prediction markets to address many of the challenges that prevent the adoption of supply chain information sharing. An analytical model of a decentralized supply chain is considered. The supply chain consists of a supplier who sells to a procure-to-stock retailer in which both partners receive demand forecast updates. We analyze the partners' profit structure under various information sharing schemes and show the Pareto improvement of employing prediction markets for supply chain information sharing.

■ ENRE8 WC 15:30- 17:00

Contributed papers

Chair/Président: Olivier Bahn, HEC Montréal

• Implications of EMF 34 scenarios on carbon abatement in Canada: Insights from NATEM

Olivier Bahn*, Kathleen Vaillancourt
HEC Montréal; ESMIA

Abstract: This paper proposes a detailed analysis of the evolution of Canadian energy systems under some selected EMF 34 scenarios. Our analysis is based on NATEM, a bottom-up energy model. NATEM shows that imposing different renewable penetration constraints for electricity generation has limited impacts outside the electricity sector. Conversely, the imposition of a carbon tax has broader impacts on Canadian energy systems and on GHG emissions that are almost stabilized. However, the level of the carbon tax envisions by the EMF 34 study is not high enough to trigger a decrease of GHG emissions over time as mandated by Canadian policies.

• Robustness assessment in energy transition models: An application to the North American Northeast

Jesus Rodriguez-Sarasty*, Michel Denault, Pierre-Olivier Pineau
HEC Montréal

Abstract: Decarbonizing the electricity sector involves deep uncertainties such as future load levels, technology costs and deployment of energy policies. Therefore, assessing the risk and robustness of investments supporting energy transition plans is essential to increase their political and social acceptability. Considering uncertainty and ambiguity aspects, we apply multiple optimization models (deterministic, stochastic, min-max cost and min-max regret) for planning the future electricity sector in the North American Northeast under emission reduction targets. We are able to show how to improve the robustness of grid decarbonization investments under decision makers' ambiguity and uncertainty.

• A robust simulation-optimization approach for designing hybrid renewable energy systems

Pardis Pourmohammadi*, Ahmed Saif
Dalhousie University

Abstract: Stand-alone hybrid renewable energy systems (HRES) provide a viable alternative to satisfy energy demand in remote and isolated communities. We consider a PV/Wind/Diesel/Battery HRES and propose a cost-minimization design approach that uses a finite number of supply and demand scenarios with uncertain probabilities, extracted from limited data through k-means clustering. Using an ambiguity set based on phi-divergence, a novel robust simulation-optimization approach that estimates a surrogate objective function through Response Surface Methodology (RSM) is proposed. Results obtained from implementing the proposed approach on a real case study show that it outperforms classical risk-neutral methods on external data samples.

• Potential of electric bicycle deliveries in the Montreal region

François Sarrazin*, Bernard Gendron, Martin Trépanier, Suzanne Pirie
Université de Montréal [1, 2]; École Polytechnique de Montréal [3, 4]

Abstract: In urban context, several deliveries could be transferred to low GHG emission modes. However, there is a lack of data and methods to identify them. In this study, to estimate the overall truck movements portrait, simulations covering multiple scenarios were carried out using data from all establishments for the census metropolitan area of Montreal and using the FRETURB model. We use these results to estimate the potential of transferring deliveries made by truck to electric cargo bikes, especially for short distances and low volumes. Finally, an optimization model is proposed to minimize GHG emissions that include the potential trips.

Thursday/Jeudi June 10

■ HC21 ThA 10:00- 11:30

Healthcare planning and process improvement

Chair/Président: Felipe Rodrigues, Western University

• A survival analysis approach to ICU capacity planning based on length-of-stay probabilities using MODS and NEMS

Lori Murray*, John Wilson, Felipe Rodrigues, Greg Zaric
Western University

Abstract: In Canada, the Multiple Organ Dysfunction Syndrome (MODS) score and the Nine Equivalents of Nursing Manpower Use Score (NEMS) are used to quantify severity of patient illness and nursing workloads, respectively. We developed a survival-analysis based model utilizing MODS and NEMS to estimate patient length-of-stay (LOS) probabilities in order to forecast Intensive Care Unit (ICU) occupancy with a 7-day planning horizon. The capacity planning model incorporates an ARIMA model that forecasts patients arriving in the ICU. Although survival analysis is used in many areas of medicine, its use in this area is novel.

• **Updating the efficiency metrics for Ontario cancer treatment centres: A sequential DEA model**
Tiffany Bayley, Felipe Rodrigues, Steven Habbous, Mehmet Begen*, David Barrett
Ivey International Centre for Health Innovation [1]; Western University [2]; Ontario Health (Cancer Care Ontario) [3]; Western University [4, 5]

Abstract: Ontario cancer treatment centres are measured by Ontario Health/Cancer Care Ontario (CCO) against the same provincial targets, despite differences in scale, scope, financial resources and patient demographics. We analyze CCO data and formulate a sequential data envelopment analysis model (DEA) in which the output of a previous stage becomes the input of the next. In this particular case: planning, delivery, and quality of treatment stages, respectively. We then compare the updated model with previous versions. Furthermore, we use the results of the DEA model to discuss the inherent scale and specialization trade-offs faced by cancer treatment centres.

• **Funding reform for cerebrovascular stroke in Ontario, Canada - a queuing game perspective**
Felipe Rodrigues*, Salar Ghamat, Norine Foley, David Barrett, Matthew Meyer
Western University [1, 4, 5]; Wilfrid Laurier University [2]; London Health Sciences Centre [3]

Abstract: Acute care, followed by rehabilitation, are two of the most significant stages of the Cerebrovascular stroke care pathway. In Ontario, Canada, there is empirical evidence that rehabilitation centers' current funding model lacks the financial incentives to reduce treatment wait times and prevent costly Alternate level of care (ALC) options. We extend our queuing game-theoretical model to include loss systems and information asymmetry. We proceed to propose policies based on treatment intensity, cost sharing and vertical integration. Using aggregate secondary data we are able to further demonstrate the potential efficiency gains and cost savings of such policies.

• **Factors influencing care complexity in emergency department**
Marco Bijvank*, Seung-Yup Lee
University of Calgary; Vanderbilt University Medical Center

Abstract: While the Canadian Triage and Acuity Scale (CTAS) has been a well-established triage tool developed and applied for Canadian Emergency Departments (EDs), it does not involve any consideration of the level of care complexity. To many healthcare providers, the notions of urgency and complexity are mixed and sometimes used interchangeably. Care complexity is known to influence operations and behaviors in ED care delivery. However, there is a lack of study on what factors influence care complexity. We investigate both clinical and non-clinical factors affecting the determination of care interventions in four EDs.

■ HC14 ThA 10:00- 11:30
Healthcare operations management

Chair/Président: Saied Samiedaluie, University of Alberta

• **Wait time prediction for mental health outpatients**
Amir Rastpour*, Megalai Thavakugathasalingam, Carolyn McGregor, Beth Brannon
University of Ontario Institute of Technology [1, 2, 3]; Ontario Shores Centre for Mental Health Sciences [4]

Abstract: The demand for mental health services is increasing and the transparency of wait time is becoming increasingly important while managing and reducing wait times is becoming increasingly difficult. A key challenge is predicting accurate estimate wait times for individuals. We empirically investigate factors that impact different components of the waiting time, from referral until the first visit. We focus on five different types of mental health patient populations and thoroughly investigate the waiting time profiles of these patient groups. We propose statistical models to predict the wait times and validate our models using empirical data.

• **Models of the impact of triage nurse standing orders on emergency department length of stay**
Vera Tilson, Armann Ingolfsson, Saied Samiedaluie*
University of Rochester [1]; University of Alberta [2, 3]

Abstract: Standing orders allow a triage nurse, under certain conditions, to order tests or treatments that would normally be ordered by a physician in an emergency department (ED). Several empirical stud-

ies in the medical literature have shown that standing orders have the potential to decrease the ED length of stay. Using analytical and simulation models we examine the impact of using standing orders in an ED and identify the situations in which initiating orders/treatments early decreases the length of stay for all patients. We also propose policies that perform close to optimal and are simple enough to be used in practice.

• **Coordinating referral and scheduling policies in a centralized intake system for specialized healthcare services**

Amin Mahmoudian Dehkordi*, Michael Pavlin
Wilfrid Laurier University

Abstract: We study patient access to specialized services under centralized and decentralized referral schemes. In this project, we define a bi-level optimization problem to determine optimal policies for players in a centralized system. Results include characterizing optimal centralized referral decisions and contrasting outcomes with those expected from a decentralized system.

■ HC26 ThA 10:00- 11:30

Optimization and forecasting in healthcare logistics under uncertainty

Chair/Président: Hossein Hashemi Doulabi, Concordia University

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• **Operating room planning with multiple downstream units**

Arian Andam*, Hossein Hashemi Doulabi
Concordia University

Abstract: In this paper, we have developed a mixed-integer programming model for an operating room planning problem, which addresses multiple downstream units including wards, and ICUs. The proposed model allocates the patients to different operating rooms over a planning horizon while minimizing the sum of the opening cost of operating rooms, overtimes, and the cost of refusing patients, and the waiting cost of patients. The proposed model also addresses some side features such as time windows for surgeries. We carried out some computational results and have performed an extensive sensitivity analysis on various cost parameters and the capacity of each downstream.

• **Integrated physician and patient scheduling problem**

Setareh Sadat Lajevardi*, Hossein Hashemi Doulabi
Concordia University

Abstract: This research presents an integrated physician and patient scheduling problem in multidisciplinary clinics. Using a two-stage stochastic mixed integer programming, we took into consideration the uncertainty of patient demand and visiting durations. In the first stage, we assigned shifts to physicians considering their availabilities, preferences and fairness. In the second stage we determined appointment times for different types of patients. The objective is to minimize patients' waiting times, postponements and reschedules along side physicians' idle times with respect to their preferences. We propose a sample average approximation (SAA) method and report extensive computational results.

• **A reinforcement learning-based algorithm for prediction of COVID-19 pandemic**

Soheyl Khalilpourazari*, Hossein Hashemi Doulabi
Concordia University

Abstract: Prediction of the COVID-19 pandemic is of great importance, and it will help policymakers develop efficient plans to limit community transmission and optimize resource utilization. In this research, we propose a new reinforcement learning-based algorithm to solve global optimization problems. We apply our algorithm to the most recent data from Quebec, Canada, to model and predict the COVID-19 pandemic. We generate several scenarios for deepening our insight into pandemic growth. We determine essential parameters and deliver various managerial insights to help policymakers and healthcare professionals plan future social distancing measures.

■ FRM5 ThA 10:00- 11:30

Quantitative risk management methods in actuarial science

Chair/Président: Jun Cai, University of Waterloo

• **Insurance supply in the presence of multiple policyholders**

Carole Bernard, Fangda Liu*, Steven Vanduffel
Grenoble Ecole de Management; University of Waterloo; Vrije Universiteit Brussel

Abstract: The insurance business is based on diversification benefits that arise when pooling many insurance policies. Due to phenomena such as medical progress, longevity risk, and natural or man-made disasters, insurance claims tend to be correlated. In this paper, we investigate the impact of the systematic risk on insurance supply. We first show that all individuals receive coverage when risks are independent. However, in the case of interdependent insurance policies, it may become optimal for the insurer to refuse

to sell insurance to some individuals, and this decision is driven by the individuals' attitudes towards risk and their risk exposure characteristics.

• Distributionally robust reinsurance with Value-at-Risk and conditional Value-at-Risk

Haiyan Liu*, Tiantian Mao
Michigan State University; University of Science and Technology of China

Abstract: We study a weighted comonotonic risk sharing problem among multiple agents with distortion risk measures under heterogeneous beliefs. The explicit forms of optimal allocations are obtained, which are Pareto-optimal. A necessary and sufficient condition is given to ensure the uniqueness of the optimal allocation, and sufficient conditions are given to obtain an optimal allocation of the form of excess-of-loss or full insurance. The optimal allocation may satisfy individual rationality depending on the choice of the weight. When the distortion risk measure is VaR or TVaR, an optimal allocation is generally of the excess-of-loss form.

• Distributionally robust optimization under distorted expectations

Jun Cai, Jonathan Yumeng Li, Tiantian Mao*
University of Waterloo; University of Ottawa; University of Science and Technology of China

Abstract: In this paper, we propose to address a decision maker's risk attitude in Distributionally Robust Optimization (DRO) by following an alternative scheme known as "dual expected utility". We distinguish DRO based on distorted expectations by terming it "Distributionally Robust Risk Optimisation'" (DRRO), and show that DRRO can be equally, if not more, tractable to solve than DRO based on utility functionals. Our tractability results hold for any distortion function, and hence our scheme provides more flexibility to capture more realistic forms of risk attitudes. We characterize the worst-case distributions and discuss their implications.

• Optimal insurance contracts with ambiguity aversion

Wenjun Jiang*, Marcos Escobar-Anel, Jiandong Ren
University of Calgary [1]; Western University [2, 3]

Abstract: This paper presents analytical representations for an optimal insurance contract under distortion risk measure and in the presence of model uncertainty. We demonstrate that, under model uncertainty, ambiguity aversion results in a distortion on the decision maker's subjective probabilities assigned to the possible models. Our results illustrate that a more ambiguity-averse decision maker (DM) would demand more insurance coverage. In addition, we study in great details a framework with two states of possible loss distributions under Value-at-Risk. Explicit solutions for the optimal insurance indemnity functions are derived.

■ OPT28 ThA 10:00- 11:30
Optimization problems at Canadian Tire

Chair/Président: Michael Pavlin, Wilfrid Laurier University

• Ocean container optimization tool

Nourredine Hail, Wael Nassief*, Armaghan Alibeyg
Canadian Tire Corporation

Abstract: In this talk, we present a strategic optimization tool that facilitates yearly negotiations of rates for the Ocean Container Request for Proposal (OC-RFP) process. The OC-RFP optimization tool takes into account the yearly forecast of inbound shipments, carriers' rates, vessels' transit times and constraints, with the objective of minimizing the transportation cost. The OC-RFP provides a generic template for various stakeholders along with a budget and minimum quantity commitments (MQCs) to track. We present a generic mixed-integer program to solve this problem with various constraints.

• Promotional plan and delivery schedule for Canadian Tire stores

Nourredine Hail*
Canadian Tire Corporation

Abstract: In this talk, we present an optimization problem in which the plan and delivery days of each Canadian Tire store are determined when it comes to promotional products during certain events. Special deals or promotions are flagged beforehand and have 2 weeks to be delivered, while stores receive their regular shipments that are already scheduled. This problem is known in Canadian Tire as PHOTO (Pick and Hold Optimization Tool). PHOTO aims to balance deal and regular volume at the distribution centers while respecting store and transportation requirements. A generic multi-stage mixed-integer programming-based heuristic is used to solve this problem.

• Short-week optimization tool

Armaghan Alibeyg*
Canadian Tire Corporation

Abstract: Canadian Tire Supply Chain needs a master

template that defines the Plan and Delivery days from each Distribution Centre (DC) to every store. Short-week optimization tool (SWOT) is designed to assign plan and delivery days for the weeks with stat holidays. Having the master template for regular weeks, SWOT creates a modified template that addresses the needs for weeks that can have one or multiple stat holidays. Mathematical programming techniques has been used to model this optimization problem and it is solved using a commercial solver (CPLEX).

• Plan and delivery template for Canadian Tire stores

Nourredine Hail*
Canadian Tire Corporation

Abstract: In this talk, we present an optimization problem that consists of determining plan and delivery days template for Canadian Tire stores such that each distribution center workload is balanced while fulfilling store requirements and minimizing transportation costs. This problem is known as GDAP (Group Day Alignment Problem); it is formulated as a mixed integer programming. The various store and transportation constraints make it difficult to solve within 2 hours, which is a business requirement. We used different techniques (e.g. warm-start, sparsity, symmetry elimination) to reduce the optimality gap, while keeping the runtime under 2 hours to find a good solution.

■ OPT30 ThA 10:00- 11:30

Inverse optimization - II

Chair/Président: Houra Mahmoudzadeh, University of Waterloo

• Optimality-based clustering: An inverse optimization approach

Zahed Shahmoradi, Taewoo Lee*
University of Houston

Abstract: We propose a new clustering approach, called optimality-based clustering, which clusters data points based on their encoded decision preferences. We assume each data point is a decision made by a rational decision maker and cluster the data points by identifying a common objective function of the optimization problem for each cluster such that optimality gap for the data points within each cluster is minimized. We use inverse optimization to formulate the problem and show that our approach outperforms a naive approach where data points are clustered via traditional k-means and inverse optimization finds the objective function for each cluster post-hoc.

• Inverse learning: A data-driven framework to infer optimizations models

Farzin Ahmadi*, Fardin Ganjkhanloo, Kimia Ghobadi
Johns Hopkins University

Abstract: We introduce Inverse Learning as a data-driven framework for learning optimal solutions and recovering linear optimization problems. We build on existing inverse optimization models to learn optimal solutions directly given a set of observed decisions. Existing methodologies for Data-Driven Inverse Linear Optimization are either limited to obtaining extreme points as solutions or are computationally heavy. We show that our model provides better and more stable optimal solutions. The model is tested on a dataset in the diet recommendation problem setting. Results show that our model can obtain personalized daily diets that preserve the trends in the original data.

• Emulating human decision-making under multiple constraints

Farzin Ahmadi*, Tinglong Dai, Kimia Ghobadi
Johns Hopkins University

Abstract: In many real-world environments, the details of decision-making processes are not fully known. Conventional learning models are unable to grasp all parameters in play because either they are not suited for data-driven settings or they are not fitted to constrained problems. We develop a novel methodology (called MLIO) that combines machine learning and inverse optimization techniques to recover the utility functions of a decision-making process. MLIO is specifically developed with data-intensive decision-making environments in mind. We evaluate our approach in the context of personalized diet recommendations for patients and show MLIO recovers the underlying criteria that patients had in mind.

• Imputing the objective of parametric linear programs

Yingcong Tan, Andrew Delong, Daria Terekhov*
Concordia University

Abstract: In this work, we study the problem of imputing unknown parameters in the objective of a parametric linear program (PLP) from optimal decisions. We present three mathematical models and test their performance on a wide range of IO instances.

• Inverse optimization for promotion pricing

Saeide Bigdellou*, Houra Mahmoudzadeh, Shirin Aslani, Mohammad Modarres
Sharif University of Technology [1, 3, 4]; University of Waterloo [2]

Abstract: Sales promotion planning consists of finding the timing and pricing of promotions over a time

horizon so as to increase demand and maximize the overall profit. On the contrary, consider a retailer wishing to use promotions during specific periods over the time horizon. We use inverse optimization to determine the promotion prices that make the given promotion timing optimal. Two different goals of maximizing the profit and the demand, are separately addressed. We consider a linear demand function and demonstrate that the profit is a linear function of the promotion timing. We use numerical examples to demonstrate the proposed approach.

■ SMS12 ThA 10:00- 11:30
Advances in stochastic optimization

Chair/Président: Saeed Ghadimi, University of Waterloo

• Minimax-optimal off-policy evaluation with linear function approximation
Yaqi Duan*, Mengdi Wang
Princeton University

Abstract: The work studies the statistical theory of off-policy evaluation with linear function approximation in batch data reinforcement learning. We consider regression-based fitted Q-iteration, show that it is equivalent to a model-based method that estimates a conditional mean embedding of the transition operator, and prove that this method is information-theoretically optimal and has nearly minimal estimation error. The policy evaluation error depends sharply on a restricted chi-square-divergence over the function class between the long-term distribution of target policy and the distribution of past data. This restricted chi-square-divergence characterizes the statistical limit of off-policy evaluation and is both instance-dependent and function-class-dependent.

• Stochastic zeroth-order discretizations of Langevin diffusions for Bayesian inference
Abhishek Roy*, Lingqing Shen, Krishnakumar Balasubramanian, Saeed Ghadimi
University of California, Davis [1, 3]; Carnegie Mellon University [2]; University of Waterloo [4]

Abstract: Discretizations of Langevin diffusions provide a powerful method for sampling and Bayesian inference but require the gradient of the potential function. Sometimes obtaining gradient might be computationally expensive, even impossible. Here we provide sample complexity analysis of stochastic zeroth-order discretizations of overdamped and underdamped Langevin diffusions under various noise models to obtain an ϵ-approximate sample in Wasserstein distance. Our approach uses Gaussian Stein's identity based gradient-estimator, widely-used in stochastic optimization. We also propose a variable-selection technique based on zeroth-order gradient-estimator and establish its theoretical guarantees. Our contributions extend the practical applicability of sampling algorithms to noisy black-box and high-dimensional settings.

• Optimal algorithms for convex nested stochastic composite optimization
Zhe Zhang*, Guanghui Lan
Georgia Tech

Abstract: Recently, convex nested stochastic composite optimization (NSCO) has received considerable attention for its application in reinforcement learning and risk-averse optimization. However, In the current literature, there exists a significant gap in the iteration complexities between these NSCO problems and other simpler stochastic composite optimization problems (e.g., the sum of smooth and nonsmooth functions) without the nested structure. In this paper, we close the gap by reformulating a class of convex NSCO problems as "min-max...max" saddle point problems under mild assumptions and proposing two primal-dual type algorithms with the optimal $O1/\epsilon^2$ (resp., $O1/\epsilon^2$) complexity for solving nested (resp., strongly) convex problems.

■ EDUC4 ThA 10:00- 11:30
Experiences in teaching OR

Chair/Président: Daniel Frances, University of Toronto

• Unlocking student learning potential with escape room inspired problem-solving sessions
Tiffany Bayley*, David Wheatley, Ada Hurst
Western University; Wilfrid Laurier University; University of Waterloo

Abstract: We describe student-led solving of well-structured problems in a gamified environment for a second-year analytics course. The learner is challenged to solve a series of problems at their own pace and must find the correct solution to the first problem to unlock and progress to the next problem, and so on. We present the results of our controlled study in which we systematically measured student outcome and experience. We also discuss opportunities to increase student engagement, along with considerations for adapting this gamified problem-based learning approach to virtual settings.

• Active learning in operations research education

Daniel Frances* , Daria Terekhov
University of Toronto; Concordia University

Abstract: In this presentation we will share our experiences in applying several active learning techniques in teaching operations research. These techniques include allowing access to software during exams, use of real client projects, self-learning online courses, and having students identify alternate reasonable assumptions as part of model formulation. We discuss the value of these innovations as well as the challenges encountered during their implementation.

• How on-line experience during COVID can inform course redesign post-pandemic
Carolyn Busby*
University of Toronto

Abstract: We have all redesigned courses to rapidly move on-line. In some cases, the on-line version of a course was simply a poor substitute for what we do in-person, but in some cases, changes made to move on-line offered advantages over in-person learning. I discuss the course redesign of two very different Operations Research courses and highlight parts of the redesign that can continue to enhance learning when students return to campus post-pandemic.

• Data analytics: is it Industrial Engineering reborn?
Samir Elhedhli*, Mohammed Omar, Ali Bouabid
University of Waterloo [1]; Khalifa University [2, 3]

Abstract: The emerging field of Data Analytics has attracted the attention of academia and industry over the past years. Its promise of creating competitive advantages from data is appealing to all vital sectors of the economy, and its focus on extracting knowledge from data is reviving classical techniques in statistics, operations research, and computer science. In this work, we unveil the links between the field of Industrial Engineering and the emerging field of Data Analytics in an attempt to identify the boundaries of each and to use it to advance the training and education in Industrial Engineering.

■ SG1 ThA 10:00- 11:30
Homelessness and resettlement

Chair/Président: Andre Cire, University of Toronto

• Fair and efficient allocation of scarce resources based on predicted outcomes: Implications for homeless service delivery
Amanda Kube*, Sanmay Das, Patrick Fowler
Washington University in St. Louis

Abstract: We consider possible improvements to the allocation of homelessness services by optimizing over predicted outcomes (re-entry probabilities) given limited resources. We discuss the importance of counterfactual reasoning in predicting outcomes for different types of households given existing administrative datasets, as well as issues of equity and fairness in allocation.

• AI for underserved communities
Amulya Yadav*
Pennsylvania State University

Abstract: The potential of Artificial Intelligence to tackle challenging problems that afflict society is enormous, particularly in healthcare. In the first part of my talk, I will describe my work on developing new influence maximization algorithms which can handle various uncertainties in social network structure, influence models, etc., that commonly exist in real-world social networks. In the second part of my talk, I will discuss the real-world deployment of my algorithms to spread awareness about HIV among homeless youth in Los Angeles. Finally, I will also talk about other kinds of societally relevant problems, e.g., drug abuse prevention among homeless youth.

• Risk-averse placement optimization in refugee resettlement
Narges Ahani*, Alex Teytelboym, Andrew C. Trapp
Worcester Polytechnic Institute [1, 3]; University of Oxford [2]

Abstract: Refugees are resettled into communities in many ways, including recent well-designed analytical approaches. The refugee resettlement software Annie^{TM} MOORE uses predictive modeling of past refugee placement and outcomes data to estimate the likelihood of employment of new refugees in communities. While these estimated match quality scores are then used for offline optimal matching of arriving refugees into communities, inherent uncertainty exists with respect to the quality score estimation, to which the optimized outcomes may be sensitive. We study this uncertainty and propose optimization models to modulate the sensitivity of outcomes to quality score estimation error. Encouraging computational results are presented.

■ TL5 ThA 10:00- 11:30
Humanitarian and maritime logistics

Chair/Président: Hassan Sarhadi, Acadia University

• Optimal deployment of drone charging stations

for last-mile distribution in humanitarian operations

Boualem Rabta*
WU Vienna University of Economics and Business

Abstract: Drones are becoming popular in humanitarian operations. They provide access to isolated areas in post-disaster situations. However, the capacity of the battery limits their payload and their operating range. Charging stations installed at selected locations make it possible to extend the operating range of drones and to cover a wider area. They can be installed or deployed in the immediate response phase. We provide a Mathematical Model for optimal deployment of charging stations in a disaster-prone area, so that all demand locations are covered and connected to the depot via one or more charging stations while minimizing the total cost.

• **Marine search and rescue operations: A distributionally robust optimization approach**

Hassan Sarhadi*, Ahmed Saif
Acadia University; Dalhousie University

Abstract: Search and Rescue (SAR) operation is an essential component of marine transportation as it reduces the loss of life, injury, and property damage following marine incidents, thereby mitigates the risks involved with marine transportation activities. This research aims to study and formulate the problem of allocating SAR vessels to response facilities considering the uncertain nature of incidents. To this end, a distributionally robust optimization approach is proposed to properly deal with the underlying uncertainty of this problem.

• **A two-stage stochastic optimization approach for locating disaster relief resources under distributional ambiguity and congestion**

Ahmed Saif*, Noreen Kamal, Mahsa Pouraliakbarimamaghani
Dalhousie University

Abstract: We propose a two-stage stochastic programming model for disaster relief network design that considers response network disruptions, coverage requirements and the effect of congestion in emergency response centers. To account for the distributional ambiguity of disaster scenarios, we employ a robust optimization approach based on phi-divergence. The problem is reformulated as a large-scale mixed-integer second-order cone program with SOS type-2 variables. We used the proposed approach to design an earthquake relief network based on real data from Iran.

• **Risk assessment of low probability high consequence marine oil tanker accidents**

Atiq Siddiqui, Hassan Sarhadi*, Manish Verma
University of Dammam; Acadia University; McMaster University

Abstract: In this research, the management of low probability high consequence (LPHC) oil spill risks faced by global oil supply operations is investigated. To this end, a risk assessment methodology based on conditional value-at-risk (CVaR) is first developed to model the downside risk of oil spill accidents. Then, the developed risk measure is used to model the routing of a fleet of oil tankers to meet the demand for crude oil. Finally, the developed risk assessment methodology and model are used in a case study to manage risks and costs associated with routing of oil tankers.

• **Maritime SAR vessel location-allocation with effectiveness measures**

Alireza Forouzangohar*, Ronald Pelot
Dalhousie University

Abstract: In this research, we propose a location-allocation model for optimizing maritime Search and Rescue vessels, with a case study in Atlantic Canada. The non-linear multi-objective model optimizes access time, asset costs, and effectiveness, while minimizing failure probability of vessel dispatch to demand grids. A stochastic approach is used to address the uncertainty over incident occurrence, using historical data to obtain the probability distribution in each grid. A rating scale has been defined to reflect the capability of each response vessel type for dealing with each sort of incident. Dynamic programming along with metaheuristic approaches are used to solve this problem.

■ SCM11 ThA 10:00- 11:30

Supplier selection in supply chain management

Chair/Président: Samiul Islam, Ryerson University

• **Enhanced logic-based benders decomposition for stochastic production planning in the printing industry**

Karim Pérez Martínez*, Yossiri Adulyasak, Raf Jans
HEC Montréal

Abstract: This work addresses the production planning problem with minimum overproduction waste in the context of the printing industry. The main decisions include determining the configuration of the printing templates and the printing frequency for each template considering uncertain demands. This problem is modeled as a two-stage stochastic program where the first stage involves the design of templates

and the second stage involves the production decisions. We developed a logic-based Benders decomposition method as well as algorithmic enhancements which allow us to solve problems with a large number of scenarios. The proposed approach yields significant reduction in overproduction waste.

• Relationship value-based framework for supplier selection

Sepehr Sepehri*, Anteneh Ayanso
Brock University

Abstract: The primary focus of academic research in relationship management in the supply chain has been on the downstream side of it (customer). Moreover, traditional approaches and specific methods used for supplier selection and supplier relationship management are not scalable and often not effective. However, the complexity of today' supplier network, as well as the criteria often used to assess and select a trusted portfolio of suppliers have made this domain increasingly important. This research attempts to fill the gap by developing a framework for supplier relationship management by incorporating relationship value, and network properties, as well as machine learning techniques.

• Finding circular dependencies in supply networks

John Howat*
Kinaxis

Abstract: A frequent issue that arises when dealing with supply networks is the unintentional introduction of circular dependencies. In a manufacturing process, this might mean that an assembly X requires a component Y, while at the same time, an assembly Y also requires a component X. Unfortunately, not all circular dependencies are as obvious: the length of the cycle might be much larger and intertwined throughout an otherwise valid network, and there are a variety of domain-specific rules about what constitutes a cycle beyond the traditional graph theoretic definition. In this talk, we describe a solution to detect such cycles.

• A prediction-based optimization model for efficient supplier selection and order allocation planning

Samiul Islam*, Saman Hassanzadeh Amin
Ryerson University

Abstract: Supplier selection and order allocation for future timespans is a complex problem when product demands are volatile. This study presents a two-phase supplier selection and order allocation process. In the first phase, demand is forecasted using a new relational forecasting method, and the results are compared with two well-known forecasting methods. Then, the forecasted demand is used in the second phase where a mathematical model is developed to select the prospective suppliers and respective order quantities. Efficient solutions are obtained by using weighted-sum and Îµ-constraint methods. The proposed model is tested using a real dataset, and the results are discussed.

■ ENRE6 ThA 10:00- 11:30

Environmental sustainability - I

Chair/Président: Wei Qi, McGill University

• Scaling up electric vehicle battery swapping services in cities

Wei Qi*, Yuli Zhang, Ningwei Zhang
McGill University [1]; Beijing Institute of Technology [2, 3]

Abstract: Battery swapping for electric vehicle refueling is reviving and thriving in our cities. Some cities are embracing an emerging infrastructure network in which decentralized swapping stations replenish their inventory of charged batteries from centralized charging stations that are colocated with grids of sufficient capacity. In this paper, we model this new infrastructure network to understand its cost and environmental implications. In a broader sense, this work deepens our understanding about how mobility and energy are coupled in future smart cities.

• Energy mix optimization for northeastern American power markets

Julien Côté-Massicotte*
Artelys Canada Inc.

Abstract: In a world of transition, planning the future of our power system becomes a key issue. What amount of renewable energies, storage, distributed resources, thermal resources will compose the future generating portfolio, in order to satisfy a growing need for electricity, accompanied with energy efficiency measures? To answer these questions, Artelys develops tools enabling the use of advanced analytics in the energy field, such as Artelys Crystal, a high level optimization platform. This session will introduce Artelys Crystal platform and the on-going work on the Northeast power markets.

• Sustainability of the Open Architecture Products (OAPs): A conceptual framework

Fatemeh Mirzaei*, Samira Keivanpour
Polytechnique Montréal

Abstract: By emerging the open architecture prod-

ucts (OAPs) in response to the changing customers' needs, and variations in international market, improving the sustainability performance of these products is of importance. Considering the features of OAPs which are individualized products with a high variety of unknown personalized modules defined by customers, it is required to evaluate environmental impacts of these modules. This study discusses integrating computer-aided design (CAD) and life cycle assessment (LCA) tools to assess the environmental impacts of personalized modules to help customers to visualize the environmental impacts of their design choice and make decision towards a greener design.

■ Plenary 11:30- 12:30

Plenary Lecture by Georgia Perakis

Chair/Président: Timothy Chan, CORS2021 Program Chair (University of Toronto)

• A taste of the role of analytics in the fight of the COVID-19 pandemic

Georgia Perakis
William F. Pounds Professor of Management, MIT

Abstract: In this talk I will discuss how the field of Analytics has been playing a key role in the fight of the COVID-19 pandemic. In particular, I will discuss the work of my team related to COVID-19 this past year. I will discuss the MIT-Cassandra model that is a suite of models that are part of an ensemble method for COVID-19 case and death prediction. I will discuss the individual methods and what motivated them and then the ensemble method and show how they perform with actual data in the US.I will discuss how these models are comparing relative to other models also used by the CDC. I will further connect these predictions with detecting true infection (also referred to as prevalence). Finally, I will discuss how these methods and results can be used to distribute vaccines in different counties (or areas) within a state (or country) to a heterogeneous population, through optimization, ensuring fair distribution among the different counties. We will show how the proposed optimization model performs in the different counties in the state of Massachusetts. (The MIT-Cassandra team includes my students (current and former): Amine Bennouna, David Nze-Ndong, Boyan Peshlov, Divya Singhvi, Omar Skali-Lami, Yiannis Spantidakis, Leann Thayaparan, Asterios Tsiourvas, Shane Weisberg)

■ HC4 ThB 13:30- 15:00

OR applications in healthcare - II

Chair/Président: Hossein Piri, University of British Columbia

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• Setting patient wait time targets in a multi-class clinical setting

Vusal Babashov*, Antonie Saure, Onur Ozturk, Jonathan Patrick
University of Ottawa

Abstract: We propose an approach to analytically study the determination of wait time targets for multiple types of patients. Advance patient scheduling models in the literature typically assume that wait time targets are given a priori and aim to reduce patient delays based on priority-specific target parameters. However, we claim that often wait time targets are poorly determined and force patients to wait longer than needed for no meaningful benefit to clinics in terms of resource management. We present model and numerical results.

• Subsidies or public provision: Optimal government interventions on mitigating drug shortages

Hongmei Sun*, Gregory S. Zaric, Hubert Pun
York University [1]; Western University [2, 3]

Abstract: Drug shortages have been a significant issue in many countries. Despite current mitigating actions, shortages are still prevalent even for some life-saving and common drugs, raising the need for more government interventions to mitigate drug shortages. Our study analyzes two government interventions to mitigate drug shortages: 1) providing subsidies to supply chain parties; and 2) producing drugs at public manufacturer. We construct a game theoretical model to capture the interactions among three players: a pharmaceutical manufacturer, a wholesaler, and a government. Our study reveals the advantages and disadvantages for each intervention and proposes optimal government intervention under different circumstances.

• Individualized dynamic patient monitoring under alarm fatigue

Hossein Piri*, Tim Huh, Steven Shechter, Darren Hudson
Sauder School of Business [1, 2, 3]; University of Alberta [4]

Abstract: ICUs are rife with alarms, many of which are false. This leads to "alarm fatigue," in which clinicians may inadvertently ignore alarms. We develop a model to dynamically set alarms for patient's vital signs, to balance the risks of false positives and negatives. We incorporate the "cry wolf" effect by reducing alarm response probabilities with increasing prior false alarms. We consider patient heterogeneity in safety limits for vital signs, which are initially

only known through a population-based prior, and the model performs Bayesian updates during a patient's ICU stay. We present structural properties and comparative statics of the optimal solution.

• **The value of a musculoskeletal screener for osteoarthritis patients' surgical consultations**

Toni Tagimacruz*, Diane Bischak, Deborah Marshall
University of Calgary

Abstract: We explore the operational benefits, in terms of patient waiting time and specialist utilization, of employing a musculoskeletal (MSK) screener for osteoarthritis (OA) patients requesting consultation with an orthopedic surgeon for possible joint replacement surgery. We model the flow of patients as a network of queues and incorporate into the model an assumed patient's OA severity progression function. We compare a consultation system with and without an MSK and the impact of the difference between the threshold for surgical intervention of the MSK screener from that of the surgeon's.

■ HC6 ThB 13:30- 15:00

Healthcare analytics - II

Chair/Président: Martin Cousineau, HEC Montréal

• **A novel undersampling density-based approach in the classification of type 2 diabetes in Canada**

Azam Dekamin*, M. I. M. Wahab, Aziz Guergachi, Karim Keshavjee
Ryerson University [1, 2, 3]; University of Toronto [4]

Abstract: Diabetes Mellitus is becoming one of the biggest concerns in Canada. Also, eleven million individuals are experiencing diabetes or prediabetes in Canada, and it is predicted to be almost fourteen million within the next seven years. In terms of predicting diabetes type 2, machine learning techniques are widely applied to electronic medical records, which are mostly imbalanced. To balance a Canadian diabetes dataset, a novel undersampling method, based on feature importance and a distribution density plot, is proposed.

• **A value of information analysis of hypertension management**

Manaf Zargoush*, Mehmet Gumus, Vedat Verter, Stella Daskalopoulou
McMaster University [1]; McGill University [2, 4]; Michigan State University [3]

Abstract: The traditional technique for blood pressure (BP) measurements involves noise. Moreover, patients exhibit short-term and long-term variabilities in their BP. Estimating the patient' true underlying blood pressure, based on which the prescription decisions are made, will involve some degrees of the physician' subjectivity. Such a noisy, stochastic, and subjective environment, however, constitutes the basis for hypertension management. We present an analytical framework, which is a combination of Machine Learning and Dynamic Optimization, to characterize the optimal treatment policies in the above environment. We present several interesting results regarding the optimal prescription policies and the value of information.

• **A prototype for the recommendation of treatment-resistant depression treatments**

Martin Cousineau*, Laurent Charlin, Vedat Verter
HEC Montréal [1, 2]; CIRRELT [1]; MILA [2]; Michigan State University [3]

Abstract: This work consists of a prototype for the personalized recommendations of treatment-resistant depression treatments using recommender systems. After characterizing our dataset, we explore in this work the performance of a factorization machine with two different treatment definitions as well as different variables describing the patients and treatments.

• **The effect of visibility on forecast and inventory management performance during the COVID-19 pandemic**

Kaveh Dehkhoda*, Valerie Bélanger, Martin Cousineau
HEC Montréal and CIRRELT

Abstract: During the COVID-19 pandemic, healthcare organizations suffered a shortage of essential medical supplies such as personal protective equipment, which resulted in severe consequences. The goal of this study is to assess the impact of one potential factor for this shortage, i.e., the lack of visibility over the inventory and consumption. To do so, different forecasting and inventory management methods are tested with real and simulated data. This talk presents preliminary results for this study.

■ HC27 ThB 13:30- 15:00

Simulation modelling applications in healthcare

Chair/Président: Michael Carter, University of Toronto

• **DES modelling of emergency department staffing**

Megan Chan*, Jenya Doudareva, Michael Carter
University of Toronto

Abstract: Crowding leads to a prolonged length of stay (LOS) and wait times in the Emergency Department (ED). This research describes the development of a Discrete Event Simulation model of a large Toronto community hospital ED. It evaluates the impact of altering nurse and doctor schedules on LOS and staff workload, as denoted by resource utilisation and wait times for healthcare providers. Scenario testing revealed that decreases in LOS and patient queue times are mostly attributed to alterations in doctor staffing, whether through increased staffing levels or shifted schedules. Moreover, it was discovered that nurse utilisation fluctuates accordingly with doctor schedules.

• **The development of a generic emergency department (ED) discrete event simulation model**
Evgueniia (Jenya) Doudareva*
University of Toronto

Abstract: We created a novel generic discrete event simulation (DES) model for Emergency Departments (EDs) that can be applied globally. While DES is common in ED modeling, the literature on the use of generic ED DES models is limited. Our model was validated using the data of seven Ontario sites, one Alberta site, two UK sites, and one US site. Our results show that a generic approach to ED DES modeling is possible, can be deployed rapidly, is customizable, and can produce meaningful insights into ED bottlenecks with accuracy comparable to single-site models.

• **Post COVID-19 patient throughput simulation for surgical resource allocation**
Natalie Ash*, Peter VanBerkel, Noreen Kamal, Geoff Porter, Michael Dunbar, Jo-Anne Douglas, Glen Richardson
Dalhousie University [1, 2, 3]; Nova Scotia Health [4, 5,6, 7]

Abstract: In response to COVID-19, many elective surgical procedures in Nova Scotia were cancelled increasing the waitlist. A discrete event simulation approach may provide strategies for waitlist management. Descriptive analytics of two years (2018-2020) of surgery data informed the model development. The model facilitated scenario analysis of recovery strategies, increased bed capacity and operating room (OR) hours, as well as the COVID-19 effects on room turnaround and demand. The scenario that quantified the largest waitlist decrease was scheduling ORs on weekends. The largest threat is the potential surge in demand resulting from the suspension of additional procedures during subsequent COVID-19 waves.

• **Simulation modelling of computed tomography and magnetic resonance imaging patient wait times**
Selena Celic*, Guoqing Zhang
University of Windsor

Abstract: Due to world-wide increasing population and life expectancy, the number of patients requiring hospital services is growing. Hospital services are extremely important and expensive – particularly for Computed Tomography (CT) and Magnetic Resonance (MRI) diagnostic imaging. Ontario hospitals follow a public healthcare system with four patient priority levels, and target times for the four priority levels which need to be met. This paper focuses on developing a simulation model for an Ontario hospital to determine how improvements in the system can be made to have a higher percentage of patients from all priority levels meet their anticipated waiting target times.

■ FRM11 ThB 13:30- 15:00
Preference robust utility and risk optimisation

Chair/Président: Huifu Xu, Chinese University of Hong Kong

• **Multiattribute quasiconcave preference robust optimization: Characterization and numerical methods**
William Haskell*
Purdue University

Abstract: Preference robust optimization (PRO) is concerned with problems where the decision maker' preferences are ambiguous, and the optimal decision is based on a robust choice function with respect to a preference ambiguity set. In this paper, we propose a PRO model to support choice functions that are: (i) monotonic (prefer more to less), (ii) quasiconcave (prefer diversification), and (iii) multi-attribute (have multiple objectives/criteria). We show that the robust choice function can be constructed efficiently by solving a sequence of linear programming problems. Then, the robust choice function can be optimized efficiently by solving a sequence of convex optimization problems.

• **Active preference elicitation via adjustable robust optimization**
Phebe Vayanos*, Duncan McElfresh, Yingxiao Ye, John Dickerson, Eric Rice
University of Southern California [1, 3, 5]; University of Maryland [2, 4]

Abstract: We consider the problem of designing policies for prioritizing individuals experiencing homelessness for scarce housing resources in a way that

meets the value judgements of policymakers. We elicit preferences over policy characteristics by using a moderate number of pairwise comparisons. We investigate the cases where all queries are made at once or selected adaptively over time. We propose exact robust optimization formulations of these problems which integrate the elicitation and recommendation phases, study their complexity, and provide efficient solution procedures. Our experiments on both synthetic and real data show that our framework outperforms the state-of-the-art techniques.

• **Utility preference robust optimization: piecewise linear approximation, error bounds and stability**

Huifu Xu*, Shaoyan Guo
Chinese University of Hong Kong; Dalian University of Technology

Abstract: We propose a piecewise linear approximation (PLA) scheme for solving maximin utility preference robust optimization (PRO) problem. To justify the PLA approach, we derive an error bound for the approximated ambiguity set of utility functions and the optimal value of the resulting maximin problem. We derive some stability results which quantify the change of the ambiguity set against variation of problem data and its impact on the PRO model. Finally, we carry out some numerical results to examine the performance of the numerical schemes as the number of piecewise linear functions and/or information on the true utility function increases.

• **Optimizing aspirational preferences when the choice of a measure is ambiguous**

Jonathan Li*, Erick Delage
University of Ottawa; HEC Montréal

Abstract: Aspirational preferences describe a general class of preferences over random payoffs where diversification is preferred for payoffs satisfying certain aspiration levels and concentration is preferred otherwise. While such class of preferences is potentially more realistic (than pure diversification preferences), it is unclear how to find a numerical function that accurately captures such preferences for individuals. In this work, we consider the case where some preference information can be elicited from individuals and propose a robust performance criterion that is fully consistent with the available preference information. We show how such robust measures can be amenable to large-scale optimization.

■ OPT34 ThB 13:30- 15:00

Exact and heuristic methodologies for challenging optimization problems

Chair/Président: Allyson Silva, Université Laval

• **A parallel memetic iterated tabu search to the quadratic assignment problem and variants**

Allyson Silva*, Leandro C. Coelho, Maryam Darvish
Université Laval

Abstract: We develop a parallel memetic iterated tabu search (PMITS) to solve the Quadratic Assignment Problem (QAP) and some of its variants. PMITS is an evolutionary metaheuristic where solutions evolve using a biased crossover until convergence is reached. The search is intensified using a tabu search with a simplified tabu list and long-term memory that stores previous solutions to speed up the run. Computational experiments using the hardest QAPLIB benchmark instances attest PMITS competitiveness compared to state-of-the-art methods, sequential and parallel, to solve the QAP. Also, PMITS significantly outperforms the best methods for all variants considered, significantly updating their literature.

• **Making a site optimal: The inverse p-median problem**

Jaehwan Jeong*, Joyendu Bhadury
Radford University

Abstract: Economic development often necessitates the improvement of existing infrastructure such as roads to make preselected sites (e.g., data centers or power plants) the optimal locations. This is an inverse case of traditional p-median problems. We formulate a model to solve the inverse p-median problem as a mixed binary nonconvex quadratic program (NP-hard). Although its size grows exponentially per the network size, we show that the model is solvable using a bilinear program solver. We also show that the model is solvable as a mixed binary linear program in the case of 1-median.

• **Inverse Bayesian optimization: Learning human search strategies in a sequential optimization task**

Nathan Sandholtz*
University of Toronto

Abstract: In this paper, we explore the inverse problem of Bayesian optimization; we seek to estimate an agent's latent acquisition function, or search strategy, based on observed search paths. We introduce a probabilistic solution framework which provides a principled framework to quantify the both variability with which the agent performs the optimization task and the uncertainty around their estimated acquisition function. To illustrate our methods, we analyze human

behavior from an experiment which forced subjects to balance exploration and exploitation in search of an invisible target location, finding that upper confidence bound acquisition functions offer the best fit for most subjects.

• TOPSIS method with PSO algorithm: A real case on plastic injection problem

Luis Pérez-Domínguez*, Dynhora Danheyda Ramirez, Jorge Macias García, Erwin Martínez Gómez, Roberto Romero Lopez
Universidad Autónoma de Ciudad Juárez

Abstract: Nowadays the companies are facing closer and optimal decisions related to competitive spirited. In this mode it can adapt to changes in the market and technologies demand. Hence, it is important to consider background to deal with optimization issues and trends that affect injection plastic industry. For this reason, a system is proposed to evaluate the situation and improve research, through the TOPSIS method and PSO algorithm. In this sense, we can provide robust solutions to injection plastic companies. Finally, a numerical case on Plastic Injection problem was carry out in order to validate the proposal.

■ OPT18 ThB 13:30- 15:00

Session in tribute to the memory of the late Raymond G Vickson

Chair/Président: George Zhang, Simon Fraser University

• Analysis of queues with changeable service rates and strategic customers

George Zhang*, Siping Su, Ruiling Tian
Simon Fraser University; Western Washington University; Yanshan University

Abstract: We consider the customers' equilibrium strategy and socially optimal strategy in a single server Markovian queueing system with changeable service rates controlled by a threshold. The optimal joining strategies of customers are studied under two information scenarios- observable and unobservable queues. We analyze the steady-state distribution and performance measures of the system and derived the equilibrium strategy. Finally, we compare the equilibrium strategy with socially optimal strategy via numerical examples. The insights obtained from our analysis have been verified by simulation for more general settings.

• A polynomially solvable case of the maximum weighted independent set problem for the setup carryover assignment problem

Nusrat Chowdhury, Mohammed Baki*, Ahmed Azab
Bemidji State University [1]; University of Windsor [2, 3]

Abstract: We introduce the Setup Carryover Assignment Problem (SCAP), which consists of determining the setup carryover plan of multiple items for a given lot size over a finite planning horizon with the objective of maximizing setup cost savings. We show that the straightforward linear programming (LP) formulation of the problem provides a fractional solution. However, we propose an alternative integer linear program (ILP) and show that it has a completely unimodular property and thus yields an integer solution. Therefore, SCAP is solvable in polynomial time.

• A survey of Ray Vickson's contributions to the OR/MS literature

Mahmut Parlar*
McMaster University

Abstract: From the early 1970s until his retirement in the mid-2000s, Dr. Ray Vickson made important contributions to mathematical finance, stochastic inventory theory, scheduling and optimal control theory. Ray was also a Maple expert and he was a competent LaTeX user. He was my PhD supervisor between 1976 and 1979, and we kept in touch until his retirement. In this survey I will talk about Ray' contributions to the literature and I will also show a few pictures from the early days when I was a PhD student in Waterloo.

• A Benders decomposition approach to product location in carousel storage systems (and more)

Raymond Vickson, Elkafi Hassini*, Nader Azad
University of Waterloo; McMaster University; Ontario Institute of Technology

Abstract: As a commemoration of the work of Raymond G. Vickson we present one of his latest research studies: the problem of locating items within carousel bins to minimize the average carousel rotational distance per retrieval. We consider a single two-dimensional carousel and a group of two one-dimensional carousels and formulate the corresponding problems as mixed-integer programs. We apply Markovian performance evaluation methods to write the objective functions in a simple linear form. We define a set of uniqueness constraints that significantly reduces the size of the solution space and apply a Benders decomposition algorithm to solve both problems.

■ BDA1 ThB 13:30- 15:00

Business and data analytics - I

Chair/Président: Mohammad Iman Zadehnoori, Ryerson University

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• Forecasting of furniture sales based on neural networks

Saman Hassanzadeh Amin*, Yasaman Ensafi
Ryerson University

Abstract: Forecasting of sales is an important issue in practice. In this presentation, the applications of several forecasting methods for prediction of furniture sales based on a real dataset are discussed. Many forecasting methods including some classical time-series forecasting methods (e.g., Seasonal Autoregressive Integrated Moving Average (ARIMA) and Triple Exponential Smoothing), and some advanced methods (e.g., Prophet, Long Short-Term Memory (LSTM) and Convolutional Neural Network (CNN)) are applied. In addition, the performances of the models are compared. Then, the results are discussed.

• Hybrid Machine Learning (ML) models to predict credit scores

Marcos Machado*, Salma Karray
Ontario Tech University

Abstract: Predicting a customer's credit score is an important challenge faced by all banks and financial institutions. Traditionally, statistical models, such as logistic regression, have been used to assess customer's credit risk. Although simple and intuitive, these models cannot handle very large amounts of customer data and have a relatively poor prediction power when compared with sophisticated Machine Learning (ML) algorithms. This research presents hybrid ML-based models to cluster, assess, and predict Canadian commercial customer's credit scores, incorporate past scores information, and compare the different hybrid and individual models implemented.

• A prioritized fraud detection model for subscription-based businesses platform with a minimal labelled data

Dewan F. Wahid*, Elkafi Hassini, Stevie Yap, Kris Heidler
McMaster University [1, 2]; FreshBooks Inc. [3, 4]

Abstract: Many businesses are moving towards the subscription-based model to deliver services directly to consumers. Fraudsters are using these platforms for different malicious activities. Identifying fraudsters is challenging for many companies due to the limitation of resources. However, an automated fraud-detection-model (FDM) also creates risks of true-negative identifications. We develop a Prioritized-Fraud-Detection-Model (PFDM) that generates a prioritized list of fraud-risk-accounts by using a minimum labeled dataset. This model consists of an unsupervised clustering and a neural network classifier. We use this model to identify frauds in online subscription-based business data. Our model shows promising results in terms of practical use cases.

• A data-driven startup cohort formation method

Mohammad Iman Zadehnoori*, Morteza Zihayat Kermani
Ryerson University

Abstract: One of the critical steps in any startup accelerator is to choose the right set of startups (i.e., cohort) in each round. In this study, we introduce the new problem of data-driven cohort formation. We design a machine learning based framework to consider several factors (e.g., startup information, fundraising data, cohorts history, startup founders' personality) to form a cohort effectively. The framework builds an information graph based on the collected data from different data sources (e.g., Crunchbase, SeedDB) and applies different machine learning and NLP techniques to find the best set of startups as a cohort.

■ SG2 ThB 13:30- 15:00

Improving access in times of need

Chair/Président: Feyza G. Sahinyazan, Simon Fraser University

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• Improving schooling access for the refugee children in Turkey

Sebnem Manolya Demir, Bahar Yetis-Kara, Feyza G. Sahinyazan*
Bilkent University [1, 2]; Simon Fraser University [3]

Abstract: In 2021, 3.6 million Syrian refugees are registered in Turkey, and 48% are in the compulsory education age. Although the Syrian refugee children have the right to enroll in Turkish schools, the process does not run smoothly due to the lack of infrastructure. Arabic-speaking teachers (AST) is a very scarce resource in Turkey, assigned only to some selected schools. Alternatively, Turkey operates "Temporary Education Centers" (TECs), but this centralized approach increases schooling commute significantly. This paper focuses on the allocation of ASTs, the locations of the TECs, and the school bus routes to enable access to education.

• Renewable energy solutions for off-grid communities: Opportunities and challenges

Asligul Serasu Duran*, Feyza Sahinyazan
University of Calgary; Simon Fraser University

Abstract: Following the recent advances and cost reductions in renewable technologies, governments, the

private sector, and non-profit organizations started investing in rural electrification projects through renewable mini-grids, some of which were reported to have been unsuccessful. The findings and the lessons learned from these projects remain highly compartmentalized across different studies, making it significantly challenging to derive evidence-based insights and know-how on clean rural electrification for investors and practitioners. This study aids in closing this gap by collecting project-level information on 104 renewable energy mini-grids installed across the globe and identify the factors contributing to mini-grid projects' costs and success.

• Predictive and optimization models for food aid prepositioning: The case of the World Food Programme in South Sudan

Eeshaan Asaikar*, Marie-Ève Rancourt, Valérie Bélangér, Feyza Sahinyazan
HEC Montréal [1, 2, 3]; Simon Fraser University [4]

Abstract: In a multi-modal humanitarian logistics network, variability in demand and accessibility between nodes could have an adverse impact on logistics cost as well as access to beneficiaries. This study proposes a two-stage approach for addressing this problem. First, the demand for food aid is predicted using a classical demand prediction model, followed by an assessment of uncertainty in road closures using historical data. Next, a finite number of network scenarios are generated for solving a two-stage, multi-period stochastic optimization model. This methodology is tested on the actual case of the World Food Programme' (WFP) operations in South Sudan.

■ TL11 ThB 13:30- 15:00
Routing problems

Chair/Président: Maryam Darvish, Université Laval

• Logic-based Benders algorithms for a time-dependent vehicle routing problem

Pedro Castellucci, Leandro Coelho, Maryam Darvish*
Federal University of Santa Catarina [1]; Université Laval [2, 3]

Abstract: Vehicle Routing Problem is one of the most popular applications in the optimization literature. One of its extensions that has been gaining attention more recently is the Time-Dependent Vehicle Routing Problem (TDVRP). In this talk, we discuss how the time travel between stops is not constant along the planning horizon. We present two models for the TDVRP and their respective reformulations suitable for the Logic-Based Benders decomposition framework. The computational experiments revealed the decomposition framework's potential in finding feasible and optimal solutions against the use of a black-box solver.

• Multi-product production routing problems with big and small time buckets

Masoud Chitsaz, Jean-François Cordeau, Raf Jans*
Kinaxis [1]; HEC Montréal [2, 3]

Abstract: We consider the problem of integrating the lot sizing problem with outbound distribution planning using routes. We consider that the plant can make multiple product types. For the lot sizing problem, we consider both big and small time buckets. Furthermore, we present a formulation that allows the time buckets to be different for the lot sizing part and the routing part. We present several valid inequalities which are used in a Branch-and-Cut approach, and we also present a heuristic approach. Both approaches are tested in extensive computational tests.

• Location-routing models for aerial parcel delivery

Pierre Gautreau*, Borzou Rostami
Wilfrid Laurier University

Abstract: We study network design problems for autonomous aerial parcel delivery. We evaluate leading location-routing models proposed in the literature against real-world examples using major Canadian cities as a case study. By comparing cities, we show that cities' geographic makeup must be considered when designing this type of network.

• GPU-based algorithms for real-time dial-a-ride problems

Ramesh Ramasamy Pandi*, Yossiri Adulyasak, Louis-Martin Rousseau, Jean-Francois Cordeau
HEC Montréal [1, 2, 4]; Polytechnique Montréal [3]

Abstract: We study the Real-time Dial-a-ride problems (RT-DARP) and discuss how state-of-the-art GPU technology can be employed to solve RT-DARP. In this problem, the requests arrive dynamically, customers expect quick responses, and vehicles keep moving while computing assignments. Most transportation studies focus on sequential algorithms. In this work, we design a GPU-based Adaptive Large Neighborhood Search in a rolling-horizon framework for RT-DARP. The idea is to perform compute-intensive neighborhood explorations in GPU while retaining the control-intensive statements in CPU. We conduct experiments on benchmark instances from the literature and show the effectiveness of GPU on generating high-quality solutions in real-time.

■ SCM12 ThB 13:30- 15:00

Data-driven and smart supply chain management

Chair/Président: Guoqing Zhan, University of Windsor

• Data-driven operations and supply chain management: Established research clusters from 2000 to early 2020

Duy Tan Nguyen*, Yossiri Adulyasak, Jean-François Cordeau, Silvia I. Ponce
HEC Montréal

Abstract: Scholars and practitioners have long recognised the importance of data-driven operations and supply chain management (OSCM). Given the impressive development of big data analytics (BDA), there are many BDA papers in OSCM, possibly indicating a focus shift in OSCM studies. Nevertheless, research finds that firms struggle with BDA adoption, suggesting gaps in literature. We systematically synthesise the research on data-driven OSCM from 2000 to early 2020 to identify established research clusters and literature lacunae. Our co-citation analysis by open-source software, factor analysis and multidimensional scaling finds six research clusters on data-driven OSCM, whose themes are identified by keyword co-occurrence analysis.

• Smart supply chain management under Industry 4.0: A review

Guoqing Zhang*, Yiqin Yang, Guoqing Yang
University of Windsor [1, 2]; Hebei University [3]

Abstract: This paper uses an integrated method to analyze the current developments of smart supply chains, the impacts of industry 4.0 and related technologies. National strategies, research status of new technologies from the major national research councils in North American region, and a systematic review of both academic and practice literature are conducted to summarize the research progress and practice.

• Solving multi-echelon inventory problems with deep reinforcement learning

Qihua Zhong*, Yossiri Adulyasak, Martin Cousineau, Raf Jans
HEC Montréal [1, 2, 3, 4]; CIRRELT [3]

Abstract: Multi-echelon inventory models aim to minimize the system-wide total cost in a multi-stage supply chain by applying a proper ordering policy to each of the stages. When backorder costs are incurred at more than one stage, there are no known optimal policies even in a serial system. We applied several deep reinforcement learning algorithms (e.g. DQN, A2C, T3D) and found that the results are comparable or better than the best known heuristics. We also propose a mechanism to reduce the training time by incorporating known heuristics into the exploration process of the deep reinforcement learning algorithms.

• Order picking optimization with rack-moving mobile robots and multiple workstations

Yanling Zhuang*, Yun Zhou, Yufei Yuan, Xiangpei Hu, Elkafi Hassini
Dalian University of Technology [1, 4]; McMaster University [2, 3, 5]

Abstract: This paper focuses on determining the order and rack sequences at multiple workstations of robotic mobile fulfillment systems. We formulate a comprehensive multi-workstation order and rack sequencing problem as a mixed-integer programming model that accounts for workload balancing and rack conflicts. We propose an adaptive large neighborhood search method, which builds on a newly developed data-driven heuristic and simulated annealing. We show that our proposed approach performs well on both small-scale problem instances and a large-scale real-world dataset. In the latter case, it can save up to 62% in rack movements compared to the company's current practice.

■ AD-I ThB 13:30- 15:00

Analytics Day - I

Chair/Président: Fredrik Odegaard,

• Analytics Day - I: Leveraging analytics to manage supply chain disruptions

Anne G. Robinson*, Benny Mantin, Achille Ettorre
Kinaxis; Luxembourg Centre for Logistics and Supply Chain Management; GTA Equipment Rentals

Abstract: Supply chain planning can be challenging under the best of circumstances and even more difficult during disruptions. One of the keys to navigating such challenges is effectively leveraging a balance of analytics and human intuition for agile response. Agility is essential to absorb the volatility we cannot predict. Disruptions cause huge volatility, so we will discuss challenges and best practices observed during the current pandemic and the importance of analytics and agility in ensuring continued supply chain success.

■ ENRE7 ThB 13:30- 15:00

Environmental sustainability - II

Chair/Président: Samar Garrab, Royal Military College of Canada

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• **Evolutionary farsightedness in environmental agreements with signatories as game leaders**
Samar Garrab*
Royal Military College of Canada

Abstract: We study in this paper the impact of the leader-follower equilibrium concept on International Environmental Agreements (IEA). We assume that countries that are part to the IEA are called signatories and play a leader role when deciding about their emissions, while all the other countries are called defectors and take the leader' announcement as given to take their emission strategies. In a dynamic discrete-time, infinite-horizon setting, we investigate the impact of the leader-follower equilibrium concept on the stability and the main outcomes of an IEA.

• **Edge computing and environmental sustainability**
Chialin Chen*
National Taiwan University

Abstract: Edge computing, which is a distributed computing paradigm that brings computation and data storage closer to the location where it is needed to improve response times and save bandwidth, has changed the way today's companies use computing technology. In this paper, we use Systems Dynamics to construct models to analyze the economic and environmental impacts of edge computing and its technological counterpart, cloud computing. A simulation model with VisSim is developed to understand the systems behaviors of edge computing and cloud computing as well as to quantify and compare the resulting economic and environmental costs and benefits.

• **Finding trends and insights in environmental science and engineering research using topic modeling**
Yazwand Palanichamy*, Mehdi Kargar, Hossein Zolfagharinia
Ryerson University

Abstract: Advancements in environmental science and engineering (ESE) research is needed towards ensuring an environmentally conscious society. We apply topic modelling analysis on over 3,000 recent abstracts collected from top-tier ESE academic journals. We use the latent Dirichlet allocation (LDA) model to infer twenty trending topics (e.g., environmental impact assessments, waste management, and lead pollution). We then detect hot and cold topics, and aggregate results based on countries and journals. Our observations demonstrate that both countries and journals display clearly distinguishable patterns. Environmental scientists, and engineers will benefit from our results to identify promising topics for research collaborations.

■ FRM12 ThC 15:30- 17:00
Predictive analytics in financial and insurance risk management

Chair/Président: Chengguo Weng, University of Waterloo

• **Do jumps matter in the long run? A tale of two horizons**
Jean-François Bégin*, Mathieu Boudreault
Simon Fraser University; Université du Québec à Montréal

Abstract: In the context of life insurance and pension plans, economic scenario generators must replicate both short- and long-term stock price dynamics consistently as (1) the resulting liabilities are long-lived and (2) the short-term performance of the assets backing these liabilities may trigger significant losses. In this study, we show that jump-diffusion models cannot replicate higher moments if estimated with the maximum likelihood. Using the generalized method of moments, on the other hand, we find that simple jump-diffusion models or regime-switching models have an excellent fit for various moments observed at different time scales. Finally, we investigate three typical applications.

• **DSA algorithms for mortality forecasting**
Liqun Diao, Yechao Meng, Chengguo Weng*
University of Waterloo

Abstract: It has been well recognized that borrowing information from populations with similar structural mortality patterns and trajectories is helpful to the mortality forecasting of a target population. One crucial step to gain enhanced forecasting accuracy lies in the selection of a proper group of populations. In this talk, I will present a flexible framework for the selection of populations from a given candidate pool to assist a target population in mortality forecasting. The defining feature of the framework is the deletion-substitution-addition (DSA) algorithm, which is entirely data-driven and versatile to work with any multiple-population model for mortality prediction.

• **Financial stability analysis via an online predictive analytics platform**
Rogemar Mamon*, Xing Gu, Heng Xiong, Thibaut Duprey
University of Western Ontario [1, 2]; Wuhan University [3]; Bank of Canada [4]

Abstract: A multivariate hidden Markov model (HMM) is developed to capture the regime-switching characteristics of certain indices pertinent to financial stability. Such indices mirror the systemic stress levels in the financial and business cycles. Multivariate filters in recursive forms are derived, which in turn, provide optimal estimates for the state of the Markov chain and other related processes. Parameters are updated instantaneously, through the filters, when new information becomes available. An implementation to actual data is considered. Early-warning signals are generated as alerts before the occurrence of some financial-crisis events.

■ OPT32 ThC 15:30- 17:00

Optimization applications in operations and supply chains

Chair/Président: Chourouk Gharbi, Université du Québec à Trois-Rivières

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• A multi-objective model for warehouse storage assignment problem

Kyle Armstrong*, Guoqing Zhang
University of Windsor

Abstract: Order picking is the most labour intensive operation in a warehouse. Motivated by a real-world problem, we develop a multi-objective model for warehouse storage assignment problem, which assigns SKUs to storage locations such that the travel distance to pick a set of orders and the cost of damages associated with the order picking are minimized.

• A multi-objective decision support tool for managing vessel routing

Chourouk Gharbi*, Jean-François Audy, Mikael Ronnqvist
Université de Québec à Trois-Rivières [1, 2]; Université Laval [3]

Abstract: Optimizing a vessel transit is a complex task as many aspects affect transit costs like the number of pilots and fuel consumption. Some restrictions may also increase transit costs, e.g., vessels sometimes should wait for the tide rises to moor ports or for the tide decreases to avoid obstacles at a height above the water. We present a multi-objective decision support tool for managing vessel routing. It is to follow detailed rules, restrictions, and guidelines to provide a trade-off between many objectives. We use transit requests on the Saint-Lawrence River to test our methodology and compare it with the status-quo.

• Group purchasing of bundles of items with time and shipping cost consideration

Zahra Sadat Hasanpour Jesri*, Kourosh Eshghi, Majid Rafiee
Sharif University of Technology

Abstract: Group purchasing has gained much attention in recent decades. However, studies in the field of group purchasing with bundles of items are still in infancy. So, we have proposed a group purchasing structure that each purchaser is willing to buy only a part of items from a bundle. The purchasing power of buyers is assumed as a function of time and bundles expiration dates. Moreover, shipping cost is also considered that its amount depends on whether that the shipping day is an exceptional day (such as holidays) or not. To solve the proposed problem, a genetic algorithm is developed.

• A new formulation and a hybrid subgradient method for aircraft maintenance routing problem

K. Gulnaz Bulbul*, Refail Kasimbeyli
Eskisehir Technical University

Abstract: Aircraft maintenance routing is an important phase in airline operations planning and scheduling process, subsequent to flight scheduling and fleet assignment phases. In this context, we propose a new integer programming model for the aircraft maintenance routing problem, and develop a new Lagrangian relaxation based hybrid solution method to solve the problem. The method combines the feasible value based modified subgradient algorithm which is based on the sharp augmented Lagrangian duality scheme, and the ant colony optimization algorithm which is used to solve subproblems. The performance of the proposed method, is demonstrated and analyzed through detailed computational experiments.

■ OPT21 ThC 15:30- 17:00

Large scale optimization for routing and distribution problems - IV

Chair/Président: Kianoush Mousavi, University of Toronto

• Stochastic last-mile delivery with crowd-shippingand mobile depots

Kianoush Mousavi*, Merve Bodur, Matthew Roorda
University of Toronto

Abstract: We propose a two-stage stochastic integer programming formulation for a last-mile delivery operation with crowd-shipping and mobile depots, with uncertainty in crowd-shipper availability. The model optimally selects mobile depot locations in advance of full information about the availability of crowd-shippers, and then transfers packages to crowd-

shippers for the final shipment to the customers. We develop branch-and-cut and cut-and-project frameworks as a solution algorithm. We compare a risk-averse approach against a risk-neutral approach by assessing conditional-value-at-risk for a case study on the City of Toronto.

• Last mile delivery routing with drone resupply and dynamic demand

Zeynep Bulbul*, Bissan Ghaddar, Fatma Gzara
University of Waterloo [1, 3]; Ivey Business School [2]

Abstract: In this research we consider an integrated vehicle-drone delivery system for same-day and instant delivery service applications. In this delivery system, as the vehicle provides delivery to customers, the drone resupplies the vehicle with orders arriving dynamically. We introduce a mixed integer programming (MIP) formulation for the static case with given set of orders to be delivered in the immediate and future periods, and propose a periodic reoptimization approach for the dynamic problem which repeatedly solves the MIP formulation. We evaluate the performance of the proposed delivery system for three service strategies and compare to the conventional vehicle-only delivery.

• Dynamic matching with driver compensation guarantees in crowdsourced delivery

Aliaa Alnaggar*, Fatma Gzara, James Bookbinder
University of Waterloo

Abstract: Sharing economy platforms for on-demand services have enabled the prompt provision of service at reasonable costs to consumers. Those platforms rely on freelance workers, who typically get compensated per task and receive little guarantees for their earning amount while they are ready to work. We study the problem of designing a dynamic matching policy, in a crowdsourced delivery system, that guarantees a particular level of utilization and earning for active workers. We model the problem as an MDP and utilize approximate dynamic programming techniques to efficiently obtain good solutions, given the high dimensionality of the solution space.

• A time-dependant location-routing problem of hazardous material transportation with edge unavailability and time window

Saeed Tasouji Hassanpour*, Ginger Ke, David Tulett
Memorial University of Newfoundland

Abstract: This paper explores the application of robust optimization in hazmat location-routing problems with edge unavailability, time-dependent parameters, and delivery time window. To be specific, random disruptions are formulated as a scenario-based robust optimization model, which is integrated with a vehicle routing problem with time windows, and then solved by an augmented epsilon constraint method. In applying the robust optimization, variabilities in cost and risk functions have been introduced as critical indicators for designing robust and reliable transportation plans. In the end, the model is applied to a real-world hazmat transportation network, from which practical insights are derived.

• A variable neighborhood search to solve migratory beekeeping routing problem

Xintong Qiu*, Yuvraj Gajpal, Srimantoorao Appadoo
University of Manitoba

Abstract: Commercial apiculture plays an important role because its contributions to reducing poverty and conserving biodiversity. Based on this, a migratory beekeeping routing problem (MBRP) is studied to optimize total profit of beekeepers, comprehensively considering nectar source allocation, flowering periods, nectar environment capacity, price of bee product and so on. A variable neighborhood search method (VNS) is proposed to solve the complicated MBPR and computational instances is utilized to test the validity and feasibility of proposed method.

■ BDA2 ThC 15:30- 17:00

Business and data analytics - II

Chair/Président: Fadaeefath Abadi, Concordia University

• Customer churn prediction by integrating Principal Component Analysis (PCA) and classification techniques

Zahra Vazifeh, Shohre Khoddami*, Fereshteh Mafakheri
Concordia University

Abstract: Customer churn is the loss of customers when they stop receiving product or service from a company. In this study, customer churn is predicted by applying five classification algorithms including Decision Trees, Random Forest, NaÃve Bayesian, Logistic Regression, and K-Nearest Neighbors using a dataset containing 14 continues attributes in the telecommunication industry. The principal component analysis (PCA) has been applied to find the correlated variables and reduce the dimensionality. The prediction results of all algorithms on both reduced-dimension dataset and the initial one is compared by metrics such as Recall, Precision, and F-measure as well as training time needed.

• **Short-run Johansen frontier-based industry models: Methodological refinements and empirical illustration on fisheries**

Kristiaan Kerstens, Jafar Sadeghi*, Ignace Van de Woestyne, John Walden
IESEG School of Management; Ivey Business school; KU Leuven; NOAA/NMFS Northeast Fisheries Science Center

Abstract: This contribution focuses on extending the current state of the art in the short-run Johansen industry model in two ways. First, instead of only considering output-oriented plant capacity, we allow for alternative plant capacity concepts. In particular, we introduce an input-oriented plant capacity concept, and an alternative attainable output-oriented plant capacity concept that corrects a major empirical issue in the traditional output-oriented plant capacity notion. Second, we correct a long-standing issue of the correct choice of weight variables on the capacity distribution by guaranteeing that these weights determine production combinations that belong to the original production technology.

• **Environmentally friendly tour recommendations using sustainable transporters**

Mehdi Kargar*, Jaroslaw Szlichta, Morteza Zihayat
Ryerson University [1, 3]; Ontario Tech University [2]

Abstract: Traveling and tourism are popular activities for numerous people around the world. A prominent aspect of traveling is to form the trip itinerary. However, it is not trivial how the tour should be formed. We design a tour recommendation system that first takes the points of interest from tourists. Then, based on the tourist preferences, it generates a sequence of points in each day that optimizes the overall travelling distance and time. We presume tourists commute with a sustainable personal transporter, such as, electric scooter or bike. Hence, this minimizes the carbon emission leading to environmentally friendly daily tours.

• **Interconnection between psychological elements and their influential channels are potential accelerators to comprehend people's inclination towards AV**

Aishwary Pramodrao Nipane*, Anjali Awasthi
Concordia University

Abstract: In product development, most focus is on technical solutions to an endless cycle that takes a prolonged time and many companies' resources. However, questions remain of its acceptance, people's willingness (APW) to use them and human aspects' involvement make it complicated, and autonomous vehicles (AVs) considerably resemble them. However, the factors triggering and influencing APW resides in psychological elements and their interconnections. Our literature review perception describes comprehensively& presents an observed pattern and theoretical Comparative Estimation table (CET). We believe it gives insights into tackling APW challenges productively and supports researchers in developing better APW survey questionnaires about AVs.

• **Reliability analysis of the vapor compression refrigeration system for office building applications**

Mohammad Hosseini Rahdar, Masoud Rezaei, Mostafa Fadaeefath Abadi*, Fuzhan Nasiri
Concordia University

Abstract: Reliability analysis has been conducted on the Vapor Compression Refrigeration System (VCRS) in an office building for evaluating system reliability (including components and subsystems). VCRS is typically used in Heating, Ventilation, and Air Conditioning (HVAC) systems in residential and industrial sections. VCRS includes several components that are presented and defined. The reliability data, including probability distributions and parameters, are collected to perform the analysis. The optimum distribution parameters have been obtained by using optimization techniques to maximize system' reliability. A comparison between basic and optimized systems (with new distribution parameters) over their lifetime is achieved to illustrate system' improvement percentage.

■ SG3 ThC 15:30- 17:00

Fairness in OR

Chair/Président: Swati Gupta, Georgia Institute of Technology

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• **Secretary problems under bias**

Jad Salem*, Swati Gupta
Georgia Institute of Technology

Abstract: Optimization and machine learning algorithms often use real-world data that has been generated through complex socio-economic and behavioral processes. This data, however, is noisy, and naturally encodes unquantifiable systemic biases. In this work, we model and address bias in online hiring. We assume that utilities of candidates are scaled by unknown bias factors, perhaps depending on demographic information, and show that bias-agnostic algorithms are suboptimal in terms of utility and fairness. We propose bias-aware algorithms that achieve demographic parity (i.e., equal probability of selection across groups), while obtaining competitive ratios for maximizing util-

ity of hired candidates in several settings.

• **Can tax incentives induce donation of fresh goods?**
Armagan Ozbilge*, Elkafi Hassini, Mahmut Parlar
McMaster University

Abstract: In this paper, we study the operational planning problem of a food-retailer for a continuously deteriorating inventory over two periods. The market demand is both price- and quality-dependent, and the length of the selling season is characterized by the shelf-life of the goods. The retailer's operational planning comprises of inventory and pricing decisions, where she plans not only for the purchase of the goods but also for donating them. We incorporate the actual tax deduction policy for food donations implemented by the U.S. government into the retailer' after-tax profit function to gain some policy insights for both parties.

• **Modelling for decision making under uncertainty: Ethical issues and practical guidelines**
Jesús A. Rodríguez-Sarasty*
HEC Montréal

Abstract: With the growing availability of data and computational tools, mathematical models and algorithms are rapidly expanding their scope for supporting decisions with direct impact in people's lives. However, such real-world decisions face multiple sources of uncertainty. This talk focuses on two questions. First, what are some ethical consequences of uncertainty in mathematical modelling? And second, how can we mitigate such consequences in practical applications? In response to those questions, we discuss issues around uncertainty and we summarize some good practises for real-world modelling. We argue that both ethical and technical aspects of uncertainty must be accounted for in practical applications.

■ TL7 ThC 15:30- 17:00

Truckload and less-than-truckload operations

Chair/Président: Hossein Zolfagharinia, Ryerson Unviversity

• **A routing problem for a mixed fleet of electric and conventional vehicles**
Afsane Amiri*, Hossein Zolfagharinia, Saman Hassanzadeh Amin
Ryerson University

Abstract: Due to environmental concerns, electric vehicle routing problems have drawn remarkable attention recently. The goal of the problem is to minimize the total cost of constructing the routes over the demand points and a subset of charging stations. In this presentation, we introduce a variant of the problem with conventional and electric trucks, which use different levels of chargers and swapping batteries. We develop a mixed-integer linear programming model and we solve it by applying two metaheuristic algorithms. Lastly, sensitivity analyses are provided, and the obtained results are discussed.

• **Drivers and barriers affecting trucking companies' adoption of green initiatives in Canada**
Nina Jovanovic, Hossein Zolfagharinia*, Konrad Peszynski
Ryerson University [1, 2] RMIT University, Australia [3]

Abstract: To-date, ample scholarly literature has focused on the application of environmental sustainability in manufacturing, with scant attention on the logistics industry – particularly in Canada. Given the lack of research on the topic in Canada and the significant negative environmental impact of trucking transportation in the country, we use case study methodology to uncover: (1) the types of green initiatives that have been adopted by Canadian trucking companies, and (2) the drivers and barriers that can affect trucking companies' adoption of green initiatives. The results illustrate that the implementation of green initiatives in trucking is at an early stage.

• **Developing a mathematical model to utilize imperfect advance load information for truckload carriers**
Mehdi Najafi*, Hossein Zolfagharinia
Ryerson University

Abstract: In this study, we first develop a deterministic mathematical model for truckload carriers to address advance load information. We then extend this model using a stochastic dynamic programming approach to capture imperfect advance load information (IALI). After designing a set of experiments, both models are employed using a dynamic implementation mechanism to assess the benefits of IALI. Conducting a statistical analysis reveals that (1) utilizing IALI can significantly improve carriers' profits, (2) the impact of IALI can be affected by other factors (e.g., network size), and (3) the profit improvement can be as high as almost 30% on average.

• **Environmental goal misalignment between logistics service providers and shippers: A power perspective**
S.M. Mehdi Jourabchi*, D. Marc Kilgour, Michael

Haughton, Mojtaba Araghi
University of Lethbridge [1]; Wilfrid Laurier University [2, 3, 4]

Abstract: We study the interface between a logistics service provider and a shipper to analyze their environmental decisions within a decentralized supply chain. Our game-theoretic analysis examines the impacts of consumers' environmental preferences, regulatory measures, and the parties' relative share of green investment on the environmental consequences of product logistics. We characterize the parties' target environmental levels according to who holds the channel power over the joint environmental decision, explicating the matches and gaps between their environmental targets. We further characterize each party's optimal contribution to green logistics investment, which may be determined by either party or by negotiation.

■ SCM13 ThC 15:30- 17:00

Supply chain and manufacturing

Chair/Président: Yinong Yang, Polytechnique Montréal

• A multi-objective optimization model to design a sustainable beverage container closed-loop supply chain

Babak Mohamadpour Tosarkani*, Saman Hassanzadeh Amin
University of British Columbia (Okanagan); Ryerson University

Abstract: The closed-loop supply chain network design (CLSCND) has received growing attention for two reasons. First, government policies and environmental regulations have urged producers to hold eco-friendly business frameworks. Second, companies can highlight environmentally friendly attributes of their products by adopting recovery activities and waste management. We demonstrate a multi-objective optimization model to design a sustainable multi-echelon beverage container CLSCN. In practice, multiple sources of uncertainty exist in optimization models based on the type of parameters (fuzzy and random parameters). Therefore, a hybrid possibilistic method is employed to investigate such imprecise parameters in a CLSCND.

• A mathematical model for the flexible job-shop scheduling problem with sequencing flexibility and sequence-dependent setup times

Alejandro Vital-Soto*, Jessica Olivares-Aguila
Cape Breton University

Abstract: This research proposes an extension of the Flexible Job-Shop Scheduling problem. The extension allows arbitrary precedence relationships between the operations given by a directed acyclic graph. Additionally, it considers setup times that are dependent on the sequence of the jobs. Hence, the problem involves allocating operations to machines and sequencing them according to precedence relationships and dependent setup times. A mixed-integer linear programming model is formulated with the objective of makespan minimization. A numerical experiment is presented to show the applicability of it. The model allows the incorporation of real-world settings that have been studied independently.

• The perspectives of joint application of virtual reality and lean in end-of-life aircraft disassembly

Yinong Yang*, Samira Keivanpour
Polytechnique Montréal

Abstract: Research in the optimization of End-of-Life (EoL) aircraft treatment is challenging due to emergent needs. Integrating Lean concepts with Virtual Reality (VR) could be new efforts to improve EoL aircraft disassembly planning and operation. However, the application of Lean management and VR has not received much attention in the literature. This study proposes a novel framework (called "VR-Lean Smart Disassembly") and provides a SWOT analysis for its application in the EoL aircraft treatment context based on the best industry practices for aircraft decommissioning provided by the International Air Transport Association (IATA).

■ AD-II ThC 15:30- 17:00

Analytics Day - II

Chair/Président: Fredrik Odegaard,

• Business analytics and IoT

Gül Ege*, Mark Lewis, Donald L. (DJ) Penix, Jr., Michelle Hernandez*
SAS; Cornell University; Pinnacle Solutions, Inc.; UNC Department of Pediatrics

Abstract: IoT is the use of real-world data generated from connected devices to support processes or services that create valuable outcomes. IOT data is high dimensional and high frequency. It involves numeric sensor data as well as acoustic, image, and text. However, data without analytics has no value! The role of Analytics in IoT is to derive maximum value from the IOT data by providing real time actionable insight and measurable improved business performance. IOT has impact on every line of business from manufacturing, energy, retail, medicine, transportation, and agriculture. This presentation will cover use cases from our

experience in SAS and thru our customers/partners in different domains and highlight unique& innovative advanced analytics components that deliver business value from the edge to the cloud. Common themes and challenges will be highlighted across a variety of use cases.