IFORS
International Federation of Operational Research Societies

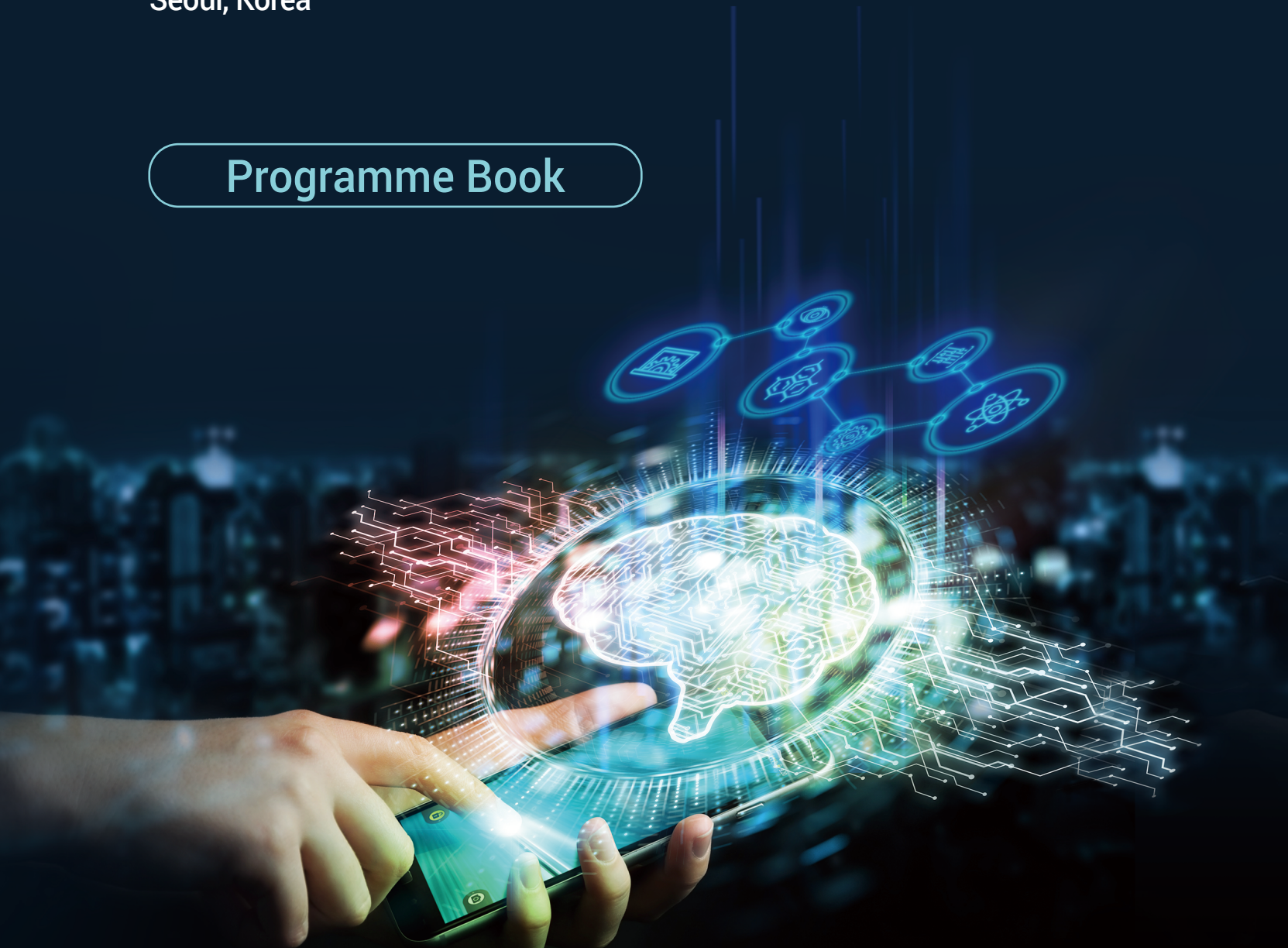
KORMS

The 22nd Conference of
the International Federation of Operational Research Societies

IFORS 2021 Virtual

August 23(Mon)~27(Fri), 2021
Seoul, Korea

Programme Book



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이 발표논문집은 2020년도 정부 재원(교육부)으로 한국연구재단의 지원을 받아 발간되었음.

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IFORS 2021 Virtual

Conference Handbook

PROGRAMME

PROGRAMME OVERVIEW

Time l Date	August 23 Mon	August 24 Tue	August 25 Wed	August 26 Thu	August 27 Fri
08:00-09:40 (100′)		**Plenary 1** (08:00-09:15) TA 01	Parallel Sessions WA 01-10	Parallel Sessions HA 01-10	Parallel Sessions FA 01-11
10:00-11:40 (100′)		Parallel Sessions TB 01-10	Parallel Sessions WB 01-10	Parallel Sessions HB 01-10	Parallel Sessions FB 01-10
12:00-13:40 (100′)		Parallel Sessions TC 01-07	Parallel Sessions WC 02-06	Parallel Sessions HC 02-06	Parallel Sessions FC 02-07
14:00-15:40 (100′)		Parallel Sessions TD 01-11	Parallel Sessions WD 01-11	Parallel Sessions HD 01-11	Parallel Sessions FD 01-11
16:00-17:40 (100′)		Parallel Sessions TE 01-11	Parallel Sessions WE 01-11	**Plenary 2** (16:30-17:45) HE 01	Parallel Sessions FE 01-11
18:00-19:40 (100′)		Parallel Sessions TF 01-11	Parallel Sessions WF 01-11	Parallel Sessions HF 01-10	**Plenary 3** (18:00-19:15) FF 01
20:00-21:40 (100′)	**Opening Session & Virtual Reception** (20:00-22:00) MA 01				**Closing Session** (20:00-21:00) FG 01
22:00-23:40 (100′)	IFORS AC Meeting 1 (21:30-24:00) MB 01 Invited	IFORS Representatives Meeting (21:30-23:00) TG 01 Invited	IFORS History and Beyond (22:00-23:00) WG 01	IFORS AC Meeting 2 (21:30-24:00) HG 01 Invited	

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TECHNICAL PROGRAMME

Monday, August 23

Track	20:00 - 22:00	21:30 - 24:00
Room 1	[MA-1] Opening session & Virtual Reception	[MB-1] IFORS AC Meeting 1

Tuesday, August 24

Track	08:00 - 9:15	10:00 - 11:40	12:00 - 13:40	14:00 - 15:40	16:00 - 17:40	18:00 - 19:40	21:30 - 23:00
Room 1	[TA-1] Plenary: Robin Keller	[TB-1] Keynote: Zelda Zabinsky	[TC-1] Behavioral Operations Management	[TD-1] Keynote: Regina Berretta	[TE-1] Inventories in Supply Chains	[TF-1] Sports schedules and tournaments	[TG-1] IFORS Representatives Meeting
Room 2		[TB-2] Supply Chains 3	[TC-2] Algorithms and theory for convex and nonconvex optimization	[TD-2] IFORS Prize for OR in Development 2020 - 1	[TE-2] IFORS Prize for OR in Development 2020 - 2	[TF-2] Automotive Production	
Room 3		[TB-3] Advances in robust optimization techniques	[TC-3] Financial mathematics and OR 1	[TD-3] Recent Progress in Semidefinite and Second Order Cone Programming	[TE-3] Logistics, Transportation and Traffic 4	[TF-3] Healthcare logistics	
Room 4		[TB-4] Radiation treatment planning optimization	[TC-4] Mathematical models of urban operations research	[TD-4] Timetabling	[TE-4] Assignment, location and routing in humanitarian logistics	[TF-4] Applications of OR 2	
Room 5		[TB-5] Optimization models for logistics	[TC-5] Pricing Strategies	[TD-5] Applications of DEA 2	[TE-5] Applications of DEA 5	[TF-5] Games and Applications 4	
Room 6		[TB-6] Combinatorial Optimization 1	[TC-6] E-commerce and urban logistics	[TD-6] Energy, Environment and Climate 2	[TE-6] Games and Applications 2	[TF-6] MCDA Methods 2	
Room 7		[TB-7] New topics in supply chain and revenue management	[TC-7] Production Management, Supply Chain Management and Location 2	[TD-7] Machine Learning, Data Mining and Analytics 2	[TE-7] OR in Health, Medicine and Life Sciences 1	[TF-7] Risk management and maintenance coordination	
Room 8		[TB-8] Machine Learning, Data Mining and Analytics 3		[TD-8] DSS applications	[TE-8] MCDA/MCDM DSS	[TF-8] Matheuristic Algorithms for Combinatorial Optimization Problems	
Room 9		[TB-9] Rail transport		[TD-9] Modeling and Solver Interfaces	[TE-9] Lot-sizing 2	[TF-9] Deep Learning 2	
Room 10		[TB-10] Machine Learning in Finance		[TD-10] Financial Reporting	[TE-10] Cutting and Packing	[TF-10] Knowledge Analytics	
Room 11				[TD-11] Advances in Optimization	[TE-11] Control Theory and System Dynamics	[TF-11] Risk management	

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TECHNICAL PROGRAMME

Wednesday, August 25

Track	08:00 - 9:40	10:00 - 11:40	12:00 - 13:40	14:00 - 15:40	16:00 - 17:40	18:00 - 19:40	22:00 - 23:00
Room 1	[WA-1] **Keynote:** Karen Smilowitz	[WB-1] **Keynote:** Wotao Yin		[WD-1] **Keynote:** Joseph Wu	[WE-1] **Keynote:** Martin Bichler	[WF-1] **Keynote:** Mihaela van der Schaar	[WG-1] IFORS History and Beyond
Room 2	[WA-2] Supply Chains 1	[WB-2] Agricultural Supply Chains	[WC-2] Convex Optimization and Applications	[WD-2] Sustainable Supply Chains	[WE-2] Game Theoretic Analysis of Supply Chains	[WF-2] Logistics, Transportation and Traffic 8	
Room 3	[WA-3] Logistics, Transportation and Traffic 5	[WB-3] Logistics, Transportation and Traffic 9	[WC-3] Stochastic models in finance	[WD-3] Logistics, Transportation and Traffic 1	[WE-3] Financial modelling	[WF-3] Healthcare delivery innovations	
Room 4	[WA-4] Prescriptive Models in Scheduling	[WB-4] Scheduling applications 2	[WC-4] Applied probability in queueing	[WD-4] Urban Operations Research II	[WE-4] Scheduling applications 1	[WF-4] Routing problems	
Room 5	[WA-5] Military OR 1	[WB-5] Stochastic simulation and its applications		[WD-5] Pricing and sourcing for supply chain risk management	[WE-5] OR, arts and creativity	[WF-5] Applications of metaheuristics and matheuristics	
Room 6	[WA-6] Games and Applications 3	[WB-6] Network design	[WC-6] Machine Learning, Data Mining and Analytics 4	[WD-6] Graphs and Networks 1	[WE-6] Supply chains for nanostores and warehouses	[WF-6] OR in Health, Medicine and Life Sciences 4	
Room 7	[WA-7] OR in Health, Medicine and Life Sciences 2	[WB-7] Energy, Environment and Climate 3		[WD-7] Computational and simulation methods in finance	[WE-7] OR in Health, Medicine and Life Sciences 3	[WF-7] Optimization in transportation and location	
Room 8	[WA-8] Meta-Analytics in Supply Chain and Logistics	[WB-8] Machine Learning, Data Mining and Analytics 1		[WD-8] Business Operation in the Electricity Sector	[WE-8] Data Science	[WF-8] Continuous Optimization 2	
Room 9	[WA-9] Decision Analysis and Decision Support Systems 1	[WB-9] Advances in Electricity System Modelling		[WD-9] Multiobjective Optimization 1	[WE-9] OR and ethics and societal complexity	[WF-9] Situational awareness for emergency management	
Room 10	[WA-10] IFORS - Sustainability Analytics and Modeling: Meet the Editor-in-Chief	[WB-10] Integrated Energy and Environmental Management		[WD-10] Supply Chains 2	[WE-10] Data mining and statistics	[WF-10] Mathematical models in macro- and microeconomics 1	
Room 11				[WD-11] Data Envelopment Analysis	[WE-11] Stochastic progamming methods and applications	[WF-11] Problem Structuring Methods, Behaviour and Society	

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TECHNICAL PROGRAMME

Thursday, August 26

Track	08:00 - 9:40	10:00 - 11:40	12:00 - 13:40	14:00 - 15:40	16:30 - 17:45	18:00 - 19:40	21:30 - 24:00
Room 1	[HA-1] **Keynote:** Erin Baker	[HB-1] Sports analytics		[HD-1] OR for development and developing countries	[HE-1] **Plenary:** Max Shen	[HF-1] **Keynote:** Prashant Yadav	[HG-1] IFORS AC Meeting 2
Room 2	[HA-2] Interior-Point Methods for Linear Programming	[HB-2] New models and algorithms for decision under uncertainty	[HC-2] Logistics, Transportation and Traffic 6	[HD-2] New Product Development in Supply Chains		[HF-2] Financial econometrics of cryptocurrency markets	
Room 3	[HA-3] Financial mathematics and OR 3	[HB-3] Behavioral finance	[HC-3] Advanced scheduling in theory and applications	[HD-3] Logistics, Transportation and Traffic 2		[HF-3] Project management and scheduling	
Room 4	[HA-4] Urban operations research I	[HB-4] Scheduling under Uncertainty	[HC-4] Stochastic optimization via simulation	[HD-4] Stochastic modeling and simulation in engineering, management and science		[HF-4] Applications of integer programming	
Room 5	[HA-5] Combinatorial Optimization 2	[HB-5] Applications of OR 1	[HC-5] Energy, Environment and Climate 4	[HD-5] Individual behavior and implications to operations management		[HF-5] Learning optimization of production systems	
Room 6	[HA-6] Metaheuristics 1	[HB-6] Applications of DEA 4	[HC-6] Quantitative methods in finance and risk management 1	[HD-6] Freight logistics		[HF-6] MCDA Methods 1	
Room 7	[HA-7] Extremal Problems on Graphs and Complex Networks	[HB-7] Graphs and Networks 3		[HD-7] Emerging applications in data science and optimization		[HF-7] Meta-Analytics in Innovative Applications of OR	
Room 8	[HA-8] Advanced statistical methods in finance and actuarial sciences	[HB-8] Metaheuristics 2		[HD-8] Developments in multistage stochastic programming		[HF-8] Decision Analysis and Decision Support Systems 2	
Room 9	[HA-9] Deep Learning 1	[HB-9] Optimization and Multi-agent Reinforcement Learning		[HD-9] Multiobjective Optimization 2		[HF-9] Production Management, Supply Chain Management and Location 1	
Room 10	[HA-10] Knowledge in Organizations	[HB-10] Multiobjective Optimization		[HD-10] Telecommunications		[HF-10] OR in Natural Resources 1	
Room 11				[HD-11] Ethics, fairness and governance			

PROGRAMME

TECHNICAL PROGRAMME

Friday, August 27

Track	08:00 - 9:40	10:00 - 11:40	12:00 - 13:40	14:00 - 15:40	16:00 - 17:40	18:00 - 19:15	20:00 - 21:00
Room 1	[FA-1] OR in Natural Resources 2	[FB-1] **Keynote:** Shmuel S. Oren		[FD-1] EJOR: Policy, Facts and Highlights	[FE-1] Cryptocurrency Pricing	[FF-1] **Plenary:** Maria Conceição Silva	[FG-1] Closing session
Room 2	[FA-2] Advances in Interior points methods	[FB-2] Continuous Optimization: Methods and softwares	[FC-2] Logistics, Transportation and Traffic 7	[FD-2] Inventory and Warehousing	[FE-2] Logistics, Transportation and Traffic 3		
Room 3	[FA-3] Data analytics and learning for health	[FB-3] Patient flow optimization	[FC-3] Logistics in maritime studies	[FD-3] Financial mathematics and OR 2	[FE-3] Games, strategies and optimization for health and life sciences		
Room 4	[FA-4] Applications in optimization under uncertainty	[FB-4] Time tabling and logistics in urban operations research	[FC-4] Applications of DEA 3	[FD-4] Applications of DEA 1	[FE-4] Humanitarian Logistics and Crisis Management		
Room 5	[FA-5] Revenue Management, Pricing, and Consumer Behaviours	[FB-5] Military OR 2	[FC-5] Graphs and Networks 4	[FD-5] Energy, Environment and Climate1	[FE-5] Games and Applications 1		
Room 6	[FA-6] MCDA Applications 2	[FB-6] Recent advances in social network and sharing economy	[FC-6] Simulation, statistical learning and applications	[FD-6] Logistics Systems Optimization	[FE-6] Maintenance scheduling and traffic capacity		
Room 7	[FA-7] Shared mobility and transport	[FB-7] Graphs and Networks 2	[FC-7] MCDA Applications 1	[FD-7] Decision theories	[FE-7] Data Science meets Optimization		
Room 8	[FA-8] Continuous Optimization 1	[FB-8] Quantitative methods in finance and risk management 2		[FD-8] MIP and LP software	[FE-8] Lot-sizing 1		
Room 9	[FA-9] Decision making in disaster management	[FB-9] Sequential learning in operations research		[FD-9] Performance Measurement and Valuation	[FE-9] Applications in Business Analytics		
Room 10	[FA-10] Mathematical models in macro- and microeconomics 2	[FB-10] OR in Natural Resources		[FD-10] OR, Human Behavior and Society	[FE-10] OR and Analytics Education		
Room 11	[FA-11] Simulation, Stochastic Programming and Modeling 2			[FD-11] OR analytics in human resource management and related challenges 1	[FE-11] Simulation, Stochastic Programming and Modeling 1		

IFORS 2021

Program

All times are Seoul time (KST / UTC + 9 hours)

August 18, 2021

TECHNICAL PROGRAM

Monday, 20:00-22:00

■ MA-01

Monday, 20:00-22:00 - Room 1

Opening session

Stream: IFORS Sessions
Invited session
Chair: *Bumsoo Kim*
Chair: *Bernard Fortz*

Monday, 21:30-24:00

■ MB-01

Monday, 21:30-24:00 - Room 1

IFORS AC Meeting 1

Stream: IFORS Sessions
Invited session

Tuesday, 8:00-9:15

■ TA-01

Tuesday, 8:00-9:15 - Room 1

Plenary: Robin Keller

Stream: Plenaries
Invited session
Chair: *M. Grazia Speranza*

1 - Honors & Awards: Fellows
M. Grazia Speranza

2 - Building insights by modeling stakeholders' multiple objectives
L. Robin Keller

Including multiple objectives in decision models can provide greater insights for decision makers. Examining the perspectives of multiple stakeholders builds understanding and can help to creatively design new alternative actions to resolve conflicts. Constructing a hierarchy of each stakeholder's objectives with respect to a decision situation can provide insights on areas of agreement and disagreement. Sometimes, one objectives hierarchy is suitable for a set of stakeholders, and differences in opinions can be characterized by differences in a stakeholder's tradeoff weights between the objectives. Examples include planning for protection against radioactive iodine releases in nuclear incidents and analysis for the founding of INFORMS. In other cases, a separate objectives hierarchy will be constructed for each stakeholder because their objectives are so different that construction of separate hierarchies better represents their divergent perspectives. Examples include a tuna fish supplier source selection decision, a prostate cancer treatment decision, and a building supply store facility location. Having modeled stakeholders' objectives and the performance of possible actions on their objectives, model results can show how much agreement there is among stakeholders on each possible action. Dynamic sensitivity analysis can be conducted using Excel sliders on the objectives' weights, to rapidly see how the preferred action may change with weight changes. Sometimes each stakeholder's model will be combined into one overall model to determine one overall value score for an alternative action, either by weighting each stakeholder equally, or applying different weights to different stakeholders. In spatial decisions involving socio-economic and environmental outcomes, such as household freshwater planning, each subregion can be seen as a stakeholder to the overall decision and could be given a weight in the overall value calculation.

Tuesday, 10:00-11:40

■ TB-01

Tuesday, 10:00-11:40 - Room 1

Keynote: Zelda Zabinsky

Stream: Keynotes
Invited session
Chair: *Illya Hicks*

1 - A Global Perspective on Optimization
Zelda B. Zabinsky

Optimization is a fundamental tool that has been used for many purposes, from strategic policy planning to last-mile distribution to optimal control of dynamical systems. There are also many algorithms to solve optimization problems. Typically, optimization algorithms are specialized for categories of formulations, such as real-valued decision variables versus discrete (integer-valued) variables, or deterministic versus probabilistic, or dynamic versus static. This restricts the scope of applications, since many realistic problems require mixtures of categories, and need flexible algorithms. We must recognize that there is a synergy between the formulation of the optimization model and the choice of algorithm. This talk takes a global perspective on optimization, and discusses commonalities and unifying concepts between algorithms and formulations. Several examples are used to illustrate the synergy between real-world problems, modeling, optimization theory and algorithms.

■ TB-02

Tuesday, 10:00-11:40 - Room 2

Supply Chains 3

Stream: Supply Chain Management
Invited session
Chair: *Seyed Mehdi Zahraei*

1 - Integrated location-transportation model for pharmaceutical distribution planning
Aura Jalal-Osorio, Reinaldo Morabito, Eli Angela Toso

Distribution planning involves strategic decisions, such as facility location, tactical decisions related to inventory management policies and distribution planning, and operational decisions related to inventory control and demand fulfillment. These decisions differ in terms of planning horizon, frequency, periodicity, and data aggregation level. Traditionally, they are made hierarchically, first the strategic decisions and then the tactical and operational ones without exchanging information between them. However, they are interrelated. Thus, a hierarchical approach can result in sub-optimal decisions. In this talk, we present a multiproduct, multiperiod, and multimodal mathematical model integrating network design and distribution planning decisions, such as product flow, transportation modes, type freight shipping, fleet sizing, and escorting services for the distribution of high-value medical items. The mathematical formulation takes into consideration realistic features such as value-added tax which rate varies among locations. Numerical results based on real-life data demonstrate the model's effectiveness to support compromised location and transportation decisions.

2 - Designing a multi-product supply chain to manage multiple oil companies supply chains that share storage facilities and pipelines
Rafael Carmona-Benitez

The objective of this study is to design a supply chain that minimizes the costs of distributing and storing different oil companies' gasolines through the same pipeline network and storage facilities. The problems for the companies sharing pipelines and storage facilities are the growth of costs (transport, transmix refining process, and inventory). The consecutively distribution of different gasolines through a pipeline increases costs because mid-grade gasoline is produced. This gasoline is transported to a refinery where a transmix refining process is applied to separate the gasolines, so transport and transmix refining process costs increase. Inventory costs increase because gasolines must be stored separately.

In this study, a supply chain based on gasoline standardization with postponement strategy is designed to minimize costs and solve the problem under study. The supply chain is sustainable, and it is designed based on 7 factors: value, volume, speed, visibility, volatility, variety and variability. To model the proposed supply chain, a multi-product pipeline inventory-transport problem with stochastic demand and variable lead time is designed. To solve this MINLP, an optimal solution methodology is developed in steps. The solvers Baron and CPLEX are applied using AMPL software.

The problem under study is based on the Mexican gasoline industry, Real data from this industry is used. The results validate the proposed supply chain of gasoline.

3 - A Tactical Planning Model for Supply Networks with Nested Ordering Policy, Production Smoothing and Freight Expediting
Seyed Mehdi Zahraei, *Chee Chong Teo*

In today's highly competitive business environment, supply chain managers have to make many planning decisions in the face of numerous interdependencies and trade-offs in the supply chain. To achieve the goal of an efficient supply chain, managers need to possess an integrated view of supply chain operations that encompasses the interactions among the planning parameters. In this paper we model a general network setting where the supply chain consists of production and inventory stages and operates with a nested periodic review base stock policy. In addition, we assume services from production and inventories are guaranteed by performing expediting actions in times of shortages. The model determines the expected expediting levels, safety stock levels, reorder intervals and production smoothness that minimize the expected total cost consisting of inventory holding cost, expediting cost, set-up cost and ordering cost. We illustrate the application of the model and its capability using numerical experiments.

■ TB-03

Tuesday, 10:00-11:40 - Room 3

Advances in robust optimization techniques

Stream: Continuous Optimization
Invited session
Chair: *Jianzhe Zhen*
Chair: *Viet Anh Nguyen*
Chair: *Jannis Kurtz*

1 - Natural disaster management: a two-stage distributionally robust approach
Mohamed El Tonbari, *Alejandro Toriello*, *George Nemhauser*, *Natashia Boland*

Natural disaster management is the task of minimizing the impact of disasters such as hurricanes or earthquakes via a pre-planning phase such as pre-allocating resources, and a response strategy after a disaster is declared to aid affected areas. Due to the high uncertainty underlying the impact and location of disasters, stochastic programming has been a popular method. Disaster management can be naturally modeled as a two-stage problem, where the first stage consists of a facility location problem modeling the allocation of resources such as medical and food supplies, and where the second stage (after observing a disaster) is a fixed-charge transportation problem modeling the routing of resources to affected areas. A major difficulty in disaster management is the lack of available data to estimate distributions and parameters of the underlying uncertainty, making methods such as the Sample Average Approximation potentially lead to poor out-of-sample performance. As such, we are interested in a two-stage distributionally robust model, where the worst-case expected value of the second stage cost is with respect to probability distributions in a Wasserstein ambiguity set. Due to the presence of binary variables in the second stage, most existing methods relying on duality can only be used as an approximation. As a result, we turn to global optimization techniques by leveraging the structure of two well-studied problems.

2 - Learning guarantees under distributional shifts: Wasserstein perturbation and conditional value-at-risk
Jaeho Lee

As opposed to standard empirical risk minimization (ERM), distributionally robust optimization aims to minimize the worst-case risk over a larger ambiguity set containing the original empirical distribution of the training data. In this work, we describe a minimax framework for statistical learning with two different types of ambiguity sets: Wasserstein balls and worst-case subpopulation. Under both scenarios, we prove generalization bounds that involve the hypothesis space complexity of the original ERM problem. For the former scenario, we additionally provide an illustrative example of transport-based domain adaptation problems where the Wasserstein distance between the source and target domain distributions can be reliably estimated from unlabeled samples. For the latter scenario, we provide extensions to other risk-sensitive measures of loss and discuss the connections to sample variance regularization.

3 - Data-Driven Robust Optimization using Unsupervised Deep Learning
Jannis Kurtz, *Marc Goerigk*

Robust optimization has been established as a leading methodology to approach decision problems under uncertainty. To derive a robust optimization model, a central ingredient is to identify a suitable model for uncertainty, which is called the uncertainty set, containing all scenarios against which we wish to protect. An ongoing challenge in the recent literature is to derive uncertainty sets from given historical data.

In this talk we use an unsupervised deep learning method to construct non-convex uncertainty sets from data, which have a more complex structure than the typically considered sets. We show that the trained neural networks can be integrated into a robust optimization model by formulating the adversarial problem as a convex quadratic mixed-integer program. This allows us to derive robust solutions through an iterative scenario generation process. We compare this approach to a current state-of-the-art approach, which derives uncertainty sets by kernel-based support vector clustering. We find that uncertainty sets derived by the unsupervised deep learning method can give a better description of data and lead to robust solutions that considerably outperform the comparison method both with respect to objective value and feasibility.

■ TB-04

Tuesday, 10:00-11:40 - Room 4

Radiation treatment planning optimization

Stream: OR in Health, Medicine and Life Sciences
Invited session
Chair: *Gino Lim*
Chair: *Peyman Kafaei*

1 - Multi-modality optimal radiation therapy
Minsun Kim, Roman Levin, Aleksandr Aravkin

We present a novel, radiotherapy planning paradigm using multiple radiation modalities to maximize the biological effect (BE) on the tumor while constraining BE to the normal tissue. This leads to non-convex, mixed integer programming and we design a two-step hierarchical optimization algorithm to efficiently solve the problem. We demonstrate our approach using a simple 2D phantom with two modalities. The numerical simulation results agree with the clinical intuition, validating our approach and potential to further clinical investigation.

2 - Imputing radiobiological parameters of the linear-quadratic dose-response model from a radiotherapy fractionation plan
Archis Ghate

The objective in cancer radiotherapy is to maximize tumor-kill while limiting toxic effects of radiation dose on nearby organs-at-risk. Given a fixed number of treatment sessions, planners thus face the problem of finding a dosing sequence that achieves this goal. This is called the fractionation problem, and has received steady attention over a long history in the clinical literature. Mathematical formulations of the resulting optimization problem utilize the linear-quadratic (LQ) framework to characterize radiation dose-response of tumors and OAR. This yields a nonconvex quadratically constrained quadratic program. The optimal dosing plan in this forward problem crucially depends on the parameters of the LQ model. Unfortunately, these parameters are difficult to estimate. The clinical literature is thus replete with debates about what parameter values will make specific dosing plans effective. In this talk, I will present an inverse optimization approach to solve this problem.

3 - An automated treatment planning strategy for highly noncoplanar radiotherapy arc trajectories
Pedro Carrasqueira, Humberto Rocha, Joana Matos Dias, Tiago Ventura

Radiotherapy is a technology-driven cancer treatment modality that nowadays allows the use of noncoplanar volumetric arc therapy (VMAT), one of the most recent photon treatment techniques, in clinical practice. In this work, an automated noncoplanar arc trajectory optimization framework designed in two modular phases is presented. First, a noncoplanar beam angle optimization algorithm is used to obtain a set of noncoplanar irradiation directions. Then, anchored in these directions, an optimization strategy is proposed to compute an optimal arc trajectory. Treatment plans obtained considering the optimized noncoplanar arc trajectories, for a pool of twelve difficult head-and-neck tumor cases, present a remarkable quality improvement when compared with treatment plans obtained considering coplanar equispaced beam directions, still commonly used in clinical practice. Furthermore, significant quality improvements were obtained for some of the cases when compared to coplanar VMAT treatment plans. Automated systems like the one proposed in this work will simplify the current treatment workflow, making better use of human resources and allowing for unbiased comparisons between different treatment techniques. As running the proposed automated framework will not waste any human resources, it can be assessed as being a valuable tool in clinical practice even if it only benefits specific patients.

4 - Simultaneous beam orientation and trajectory optimization for CyberKnife radiation therapy treatment planning
Peyman Kafaei, Marc-Andre Renaud, Louis-Martin Rousseau

Optimizing radiation therapy treatment planning has been studied extensively. However, there is a dearth of studies for the CyberKnife which delivers high precision dose towards the tumor. The lengthy treatment deliveries results in discomfort and inadvertent movements of the patient which can drastically reduce the quality of the treatment and endanger the patient. Observations reveal that the robotic arm movements between nodes (beams) around the patient takes more than 70% of the treatment time; therefore, selecting optimal set of beams such that the quality is almost maintained is highly beneficial. We reformulate the Beam Orientation Optimization problem as a Travelling Salesman Problem (TSP) with profits, which also finds the optimal trajectory of the robotic arm simultaneously. This model eliminates the need of predefined number of required beams given by an experienced physician, resulting in an automatic procedure. We explore different geometrical and radiobiological measures to assign prizes to individual beams. As a generalization of the TSP, this would be an NP-hard problem, so we resort to heuristics or approximations using Reinforcement Learning for large instances, as we are dealing within the domain of the radiation therapy. Following this phase, in order to find the value of the dose delivered from each selected beam direction, we use a mathematical model and solve it with column generation by exploiting the Karush-Kuhn-Tucker optimality conditions.

■ TB-05

Tuesday, 10:00-11:40 - Room 5

Optimization models for logistics

Stream: Discrete Optimization and Urban Operations Research
Invited session
Chair: *Chung-Lun Li*

1 - Train Timetabling with Stop-Skipping, Passenger Flow, and Platform Choice Considerations
Xiaoming Xu, Chung-Lun Li, Zhou Xu

We consider a train-timetabling model with stop-skipping decisions on a single, one-way rail track. Since stop-skipping has direct impact on passengers' journey time, we consider the passenger flow of each origin-destination pair. In addition, since stop-skipping will result in additional passenger transfers, our model considers the assignment of platform tracks (i.e., sidings) to trains at transfer stations, as well as the passengers' time and efforts required to walk between platforms when changing trains. Our model aims to simultaneously minimize the trains' operating costs and the passengers' satisfaction, where the passengers' satisfaction is measured by how many passengers' demand are satisfied, how long the passengers' journey times are, and how much walking the passengers need to do to transfer trains. We present a time-space network formulation, as well as a Lagrangian relaxation heuristic, for this train-timetabling problem.

2 - Incorporating holding costs in continuous service network design
Zhou Xu, Shengnan Shu, Roberto Baldacci

The continuous-time service network design (CTSNDP) problem aims to minimize the total operational cost by optimizing schedules of transportation services and routes of shipments for dispatching, which can occur at any time point along a continuous planning horizon. In order to be cost effective, shipments often wait to be consolidated, which incurs holding cost. Despite its importance, the holding cost has not been taken into account in the existing studies on the CTSNDP, since introducing it will significantly complicate the problem and make the solution development very challenging. To tackle this challenge, we develop a new dynamic discretization discovery algorithm, which can solve the CTSNDP with holding cost to exact optimum. The algorithm is based on a novel relaxation model and several new optimization techniques. Results from extensive computational experiments validate the efficiency and effectiveness of the new algorithm, as well as demonstrating the benefits that can be gained by taking into account holding costs in solving the CTSNDP.

3 - A Branch-and-Price Algorithm for Bunkering Tankers Dispatching Problem in Maritime Transportation
Feng Li

In this paper, we consider a routing and scheduling problem of bunkering tankers for a fuel supplier. In the problem, a number of ships (e.g., bulk ships, container ships, and tanker ships) arrive at different times and berth at anchorages waiting to be refueled. There are a given number of bunkering tankers of a supplier available to serve these ships. Every bunkering tanker can only serve one ship at a time but can serve multiple ships sequentially. The bunkering tanker needs to come back to be refueled when its fuel is used up. At most one bunkering tanker can be refueled one time at a single fueling dock. We help a fuel supplier to determine (i) which ships to be chosen to serve and (ii) routes and schedules of bunkering tankers such that the utilization of its bunkering fleet is maximized, subject to the limited time and number of bunkering tankers. We first formulate the problem as a mixed integer linear programming model (MILPM) and prove that the problem is strongly NP-hard. Then we develop a branch-and-price algorithm to solve the problem to optimality. Furthermore, we design an optimal algorithm for a special case of the problem. Finally, computational experiments based on real data demonstrate that our branch-and-price algorithm is significantly better than solving the MILPM directly using a commercial optimization solver, CPLEX 12.61, in terms of both of the computational time and the number of instances solved to optimality in a given time limit.

4 - A Binary Programming Formulation and Logic-based Cuts for Edge-based Districting without Predetermined Centers
Adolfo R. Escobedo, Zeyad Kassem

We introduce an edge-based districting optimization model with no predetermined centers to partition a road network into a given number of contiguous and balanced districts suited to logistics applications. The underlying dispersion measure aims to reduce the sum of node-to-edge distances, specifically from every edge to its assigned center, implicitly reducing the total distance traveled within each district. Since the optimization problem is computationally challenging, we derive logic-based cuts that enable a reduction of the solution space. The technique is tested on planar graphs with hundreds of nodes, leading to speed up in computational time up to 6x. Furthermore, we develop a bounding scheme that can provide the exact or approximate solution to the problem. From a practical perspective, the proposed model is inherently equipped to reduce fuel consumption and, hence, it could lead to reduced GHG emissions and other positive environmental impacts.

■ TB-06

Tuesday, 10:00-11:40 - Room 6

Combinatorial Optimization 1

Stream: Combinatorial Optimization
Invited session
Chair: *Junyoung Kim*

1 - Fully decomposed Lagrangean relaxations of RLT-1 models for some quadratic 0-1 problems with linear constraints
Jongwoo Park, Monique Guignard-Spielberg

The RLT method of Sherali and Adams, when applied to a 0-1 quadratic optimization problem (P) with linear constraints and n 0-1 variables, constructs a series of n continuous linear models RLT-k, for k=1, ..., n, whose sizes increase with k and whose optima provide tighter and tighter bounds on the integer optimum of (P). When k reaches n, the LP bound becomes equal to the IP optimum. Unfortunately, the problem sizes increase so rapidly that even computing bounds for small values of k may be challenging. We are proposing, for certain quadratic problem types, a way of producing stronger bounds than RLT-1 bounds in a fraction of the time it would take to compute standard RLT-2 bounds. We apply a specific decomposable Lagrangean relaxation to a specially constructed RLT1-type model. If the Lagrangean problem does not have the integrality property, and if it can be solved fast as a collection of small 0-1 problems, one may obtain 0-1 RLT-1 bounds of roughly the same quality as standard RLT-2 bounds, but much faster and with much smaller space requirements. This two-step procedure, RLT-1 formulation plus decomposed Lagrangean relaxation, will produce 0-1 linear Lagrangean subproblems with a dimension no larger than that of the original model. We present numerical results for the GQAP, the CDAP and the 0-1 Quadratic Knapsack Problem. Solving our relaxed RLT-1 model makes it feasible to compute RLT-2 quality bounds for instances much too large for computing them directly.

2 - The balanced maximally diverse grouping problem with attribute values
Arne Schulz

The balanced maximally diverse grouping problem with attribute values (BMDGPAV) is a variant of the well-known maximally diverse grouping problem (MDGP) which assigns items to groups such that the sum of absolute differences of all item pairs assigned to the same group is maximized. In the BMDGPAV absolute differences are absolute differences of the attribute values of the corresponding items. This is a realistic setting for example in the assignment of students to courses according to their academic achievements. Moreover, BMDGPAV searches for a best-balanced solution amongst all solutions with maximal sum of intra-group differences (i.e. optimal solutions of the corresponding MDGP instance). We present theoretical insights as well as solution approaches and a computational study for the BMDGPAV.

3 - Solving the unsplittable network flow problem using polar duality based cutting planes
Shuvabrata Chakraborty

This study addresses an optimal solution approach for the revenue-maximizing unsplittable network flow problem. The problem is defined on a network with given capacities on its edges and a set of commodities characterized by a source node, a destination node, demand quantity and a revenue. The objective is to find a subset of commodities to be routed simultaneously without exceeding the capacity constraints so that the total revenue collected is maximized. Most importantly, the flow of each commodity must use a single path. This problem finds frequent applications in telecommunication and transportation networks that have been highlighted in the extant literature. However, unlike the network flow or design problems which allow a commodity flow to split among several paths, the unsplittable versions have received relatively lesser attention from the management science community. In this study, a cutting plane mechanism based on polar duality is explored. The cuts generated correspond to facets of the underlying substructures identified and are valid inequalities for the original problem. The effectiveness of the approach to improve the LP relaxation and subsequent CPU time spent during the branch-and-bound process is demonstrated using extensive computational experiments.

4 - Rank-1 Chvátal-Gomory inequality for knapsack problem with generalized upper bound constraints
Junyoung Kim, Kyungsik Lee

In this talk, we consider Chvátal-Gomory (CG) inequalities associated with the knapsack problem with generalized upper bounds (GUBKP). We first characterize properties of non-dominated CG inequalities. Based on this result, we analyze the computational complexity of the corresponding separation problem and we show that it can be solved in pseudo-polynomial time even though the separation problem for general polyhedra is strongly NP-hard. An efficient heuristic is also devised based on the decomposition property of the separation problem. Computational tests on benchmark instances of 0-1 GUBKP and multi-dimensional multiple choice knapsack show that the CG inequalities generated by the proposed heuristic are more effective to tighten linear programming relxations than known valid inequalities.

■ TB-07

Tuesday, 10:00-11:40 - Room 7

New topics in supply chain and revenue management

Stream: Revenue Management and Pricing
Invited session
Chair: Zhaowei Hao

1 - Robust Capacity Planning with Product Substitution
Zhaowei Hao, Long He, Zhenyu Hu

In this paper, we develop a distributionally robust optimization model to determine the initial capacity planning decision considering product substitution. For the single-period model, the key challenge lies in how to characterize the extreme flows of a capacitated network. We propose an algorithm that can cut the capacitated network into a series of uncapacitated subnetworks whose extreme flows can be effectively characterized. The robust model can then be reformulated as a second-order cone program (SOCP). Although in general there can be an exponential number of constraints of the SOCP, we show it is polynomially solvable for some important cases. For the case where the unit upgrade revenue is equal to the selling price of the downward product, we find that the profit margin plays an important role in determining how the product substitution impacts the firm's initial ordering decision. For the multi-period model, we derive a tractable approximation formulation using the linear decision rule (LDR) techniques. We then develop a theoretical performance guarantee for the LDR by deriving an upper bound on the expected profit of the exact robust optimization model. Our extensive numerical studies show that the LDR is more capable to address temporal correlation and adverse distribution in the out-of-sample demand as compared to the dynamic programming (DP) approach. Computationally, LDR is shown to be much more efficient than DP.

2 - Opening the "Black Box": Why Providing Return Policies for Probabilistic Selling
Yuyang Zhao, Wang Fa, Hui Yang

Probabilistic selling, whereby the exact identity of a product remains unknown until after purchase. The existing literature on probabilistic selling primarily focuses on its attractiveness under the non-refundable condition. In this paper, we aim to study whether probabilistic selling integrated with return policies is still a lucrative marketing tool. This is an important new inquiry because of the prevalence of return policies in E-commerce platforms as well as heterogeneity in consumer preferences occurring in almost all markets. We develop a game-theoretic model to capture the fit uncertainty stemmed from online purchasing and the assignment uncertainty rooted in the stochastic assignment of probabilistic products. We characterize the seller's optimal pricing and integrated strategies of probabilistic selling and return policies. We find the attractiveness of the probabilistic selling strategy and its return policies depends on the degree of the fit uncertainty and the assignment uncertainty. Counterintuitively, we find that sellers should decrease rather than increase the customer hassle cost of returns. The higher prices of component products are used as an additional lever to suppress customers' return of the probabilistic products. We demonstrate the integrated strategies of probabilistic selling with return policies, as a general marketing tool, can be more valuable than a separate one. The integrated strategies can create a win-win situation.

3 - Using Competitive Pricing Data to Enhance Revenue Management and Pricing
Ravi Kumar, Wei Wang, Darius Walczak

Developing practical models for capturing competitive effects in revenue management and pricing systems has been a significant challenge for airlines and other industries. The prevalent mechanisms of accounting for competitive effects rely on changing the price structure and making manual adjustments to respond to dynamically evolving competitive scenarios. In this talk we present demand models to capture realistic competitive dynamics. We also develop a fast and scalable Bayesian machine learning based demand forecasting methodologies for such models with explicit competitive considerations and show the benefit of this approach over traditional models via simulations and real airline data set.

■ TB-08

Tuesday, 10:00-11:40 - Room 8

Machine Learning, Data Mining and Analytics 3

Stream: Machine Learning, Data Mining and Analytics (contributed)
Contributed session
Chair: Yuichi Takano

1 - Analysis of changes in the daily smartphone usage during the COVID-19 pandemic period
Yuxuan Yang, Maiko Shigeno

Since the World Health Organization announced the COVID-19 outbreak a pandemic in March 2020, curbing the spread of the virus has become an international priority, which has largely affected people's lifestyles. Due to the widespread usage of smartphones, the smartphone daily usage can indirectly show the changes in users' lifestyles. In this article, firstly, we define the smartphone daily usage feature data during a period as the cyclic time series. Then, we propose the method to measure the distance between the cyclic time series and calculate the distance matrix between users based on their changes in smartphone daily usage during the pandemic period. Lastly, we group the users based on the distance matrix between users by clustering. As a result, the different changes of daily usage and proportions of smartphone users in each group during the three periods of the pandemic period are shown. The difference in smartphone daily usage between the quarantine period and the non-quarantine period is extracted. This is expected to help us understand how people's lives have changed and evaluate people's living status during the quarantine period from the perspective of smartphone usage. In addition, we establish a model to predict the group information to find the factors that relate to the different changes in smartphone daily usage during the pandemic period.

2 - Auxiliary Information Based Disease Topic Mining for Hierarchical Clustering of Electronic Health Records
Wei Lu, Dinghao Xue

We investigate how auxiliary information can benefit content analysis and hierarchical clustering for topic mining in medication. Focused on electronic health records (EHRs), which are characterized by dynamic and sparse data matrices, we propose an auxiliary information based hierarchical Latent Dirichlet Allocation (ai-hLDA) model. Through incorporating patient relational meta-information, this algorithm takes advantage of natural hierarchical structure in medication and infers disease topics by jointly modeling clinical notes and ICD-9 billing codes. Experiments on the MIMIC-III database show that ai-hLDA achieves satisfactory performances in obtaining concise structural representation and accurate clustering.

3 - An estimation method of the presence and absence of humans indoor based on RSSI
Yuichi Takano, Takahiro Nishigaki, Takashi Onoda

From the viewpoint of energy saving in offices and hotels, the technology that manage the lighting and air conditioning facility by detecting the presence and absence of humans indoor has been paid attention. The presence and absence of humans indoor has been detected by the specific devices such as the human detecting sensor and cameras so far. Therefore, it was necessary to install the human detecting sensor anew for detecting the presence and absence of humans in the room where

hadn't installed the human detecting sensor. In this study, we propose a method of the detecting the presence and absence of humans indoor without using the specific devices. In the proposed method, we use only the received signal strength indicator (RSSI) which is measurable regardless of the kind of wireless devices. The RSSI changes due to the radio wave interference of multiple wireless devices and shielding and absorption by the human body. Due to the using just the change of RSSI, it isn't necessary to install anew the specific devices for the human detecting. The RSSI was measured in the case presence and absence of humans indoors by using multiple wireless devices in the experiment. We used the change of RSSI as training data, and we estimated the presence and absence of humans indoor by using support vector machine which is one of the methods of machine learning. It was confirmed it is possible to estimate the presence and absence of humans indoor 100% under a certain condition.

■ TB-09

Tuesday, 10:00-11:40 - Room 9

Rail transport

Stream: Innovative & Shared Mobility and Transportation
Invited session
Chair: Samir Biswas

1 - A Branch-and-Price Algorithm for Weekly Rolling Stock Planning in High-Speed Rail Networks
Jun Xia, Yuan Gao, Andrea D'Ariano, Lixing Yang

In high-speed rail networks, train units are scheduled to periodically meet all maintenance requirements while at the same time continuing to serve all scheduled passenger trips. Motivated by the trip demand variances on each days of every week, this paper studies a weekly rolling stock planning (W-RSP) problem that aims to optimize the rotation plan for the train units on each day of a week, so as to minimize their operating cost, including any (un)coupling costs and maintenance costs. We model the W-RSP on a newly developed rotation network by adopting particular nodes and arcs to address the (un)coupling operations of train units, and then propose an integer linear programming formulation for the problem. To solve this formulation, we develop a customized branch-and-price algorithm, which relies on a reduced linear programming relaxation for computing the lower bound, embeds a diving algorithm for computing the upper bound, and integrates advanced branching rules for effective explorations of the solution space. Computational results validate the effectiveness and efficiency of the proposed solution algorithm, which is able to solve large instances with more than 5000 trips to near-optimality.

2 - Implementation of a simulation model coupled to a lexicographic heuristic applied to the transportation optimization of multimodal logistical corridors
Matheus Mendonça, Rafael Medeiros, Pedro Duarte, André Rocha, Franklin Acevedo, Igor Caetano, Igor Fonseca, Gustavo Lacerda, Douglas Vieira

This work proposes a simulation model for terminals and ports of logistical corridors that is coupled to a lexicographic heuristic for the optimization of railway freight transportation. The terminals are modeled as nodes of the network that connect roadway to railway transport. Similarly, ports are nodes that connect railway to maritime transport. Both terminals and ports are instances capable of storing products and can be of two types: own and third-party. Due to practical applications, own nodes need to have their storage simulated, while third-party do not. This work implements a simulation algorithm for terminals and ports that takes as input the inbound and outbound demands of each node and simulates its storage (for own nodes) and queuing process while preserving each transportation modal's characteristics. Furthermore, the simulation algorithm interacts with a heuristic that aims to optimize the wagons distribution among all fluxes. A flux is a tuple that contains the origin, destination, product, client's minimum demand, and client's maximum demand. The optimization heuristic considers the objectives in the following order: (i) meet third-party fluxes' minimum demand, (ii) meet own fluxes' minimum demand, (iii) maximize the demand transportation of own fluxes, and (iv) maximize the demand transportation of third-party fluxes. The model was validated on the Brazilian Central-Southeastern corridor, and it proved to be a fast and reliable tool for operational planning.

3 - Implementation of a simulator and an interactive interface applied to optimize railway freight transportation
Letícia Resende, Fernando J. S. Magalhaes, Guilherme Fraga, Lucas Gomes, Pedro Elias Abreu, João Maia, Sara Ribeiro, Igor Fonseca, Rafael Medeiros, Matheus Mendonça, Gustavo Lacerda, Douglas Vieira

This work presents a system composed of a simulator, which works with shift time granularity and real data, and an interface that allows the viewing of the fleet's mapping in a graphical and integrated way of the railway freight transportation scheduling process. Also, the interface allows user interaction. We create an interactive interface to help the user simulate the network situation regarding the loading and unloading of wagons, thus being able to program, in a precise and efficient way, the dispatch of trains, according to the requested demand. However, the dispatch schedule of trains must take into account the limit of wagons that a train can send. Therefore, given the significant number of wagons, the simulator should compact this large volume of data into useful blocks so that the user can see the data more easily and in a more compact way in order to minimize the time spent making decisions. For this, the network is modeled with the nodes (loading and unloading stations), the decisions (train dispatch decisions given by the user), and the restrictions/trains (parameters that will dictate which wagons can be sent to where and how). Consequently, this work provides a better view of the fleet, monitoring of the execution indicators panel, ease of understanding the inputs and outputs of the daily schedule, and access by post-sales commercial. All this facilitates the response to customer information requests.

4 - Indian Railways: An Optimal Assignment of Railway Rakes in Suburban Services
Samir Biswas, Preetam Basu

Efficient utilization of railway rakes is an important objective for Railway Planners. The utilization efficiency can be increased by optimizing the number of rakes required on line to cover all designated services as per timetable. Moreover, this optimization provides flexibility to increase the frequency of maintenance of the rakes, to increase the number of passenger services in future or to make smooth backup arrangement during emergency situations if required. Consequently, it increases safety and reliability of the entire system. In this context, a service means a specific journey traversed by a particular rake from an originating station to the destination as per daily timetable followed in the suburban sections. Railway Planners have to assign a particular rake to multiple inter-linked services throughout a day considering different spatial, temporal and technical constraints. Currently, manual processes based on experience and heuristics have been followed in the Sealdah Division under Indian Railways to offer over 900 daily services to cater to the transportation need of Kolkata and its suburbs. However, in a manual heuristics-based method the optimality of the solution cannot be guaranteed. In this paper, we develop a MILP (Mixed Integer Linear Programming) model to derive an optimal assignment of rakes. Our results show significant improvements in utilization efficiency over the existing model followed in practice.

■ TB-10

Tuesday, 10:00-11:40 - Room 10

Machine Learning in Finance

Stream: Advanced Statistical Methods in Finance and Ac-

tuarial Sciences
Invited session
Chair: Qianhui Lai

1 - A Unified View on Diversified Portfolio of Time Series Momentum Strategies Using Multi-Task Learning
Joel Ong, Dorien Herremans

A diversified risk-adjusted time-series momentum (TSMOM) portfolio, is not only able to deliver substantial abnormal returns but also offer some degree of tail risk protection during extreme market events. The success of a TSMOM strategy relies not only on the quality of the momentum signal but also on the efficacy of the volatility estimator. Yet many of the TSMOM strategies which have been extensively studied have always considered them to be independent. Inspired by recent progress in Multi-Task Learning (MTL), we present a new approach, Multi-Task Risk-Adjusted Time Series Momentum (MTL-RATSMOM), that leverages the MTL architecture and consists of two task-specific output layers. The first task-specific output layer is directly trained by optimizing the Sharpe ratio of the signal and the other is trained by minimizing the estimation error between the ex-ante volatility and realized volatility of the assets. During inference, the ex-ante volatility estimates from one task-specific output layer are used to scale the portfolio positions recommended by the other task-specific output layer. Backtesting from January 2000 to April 2020 on a diversified portfolio of continuous futures contracts in bond, commodity, currency, and equity, we demonstrate that even after accounting for transaction costs up to 10 basis points, our approach continues to outperform existing TSMOM strategies. These findings provide important implications for implementation of MTL in finance.

2 - Reverse stress testing in financial networks
Eunji Kwon, Kyoung-Kuk Kim, Dohyun Ahn

We propose a novel method for reverse stress testing of financial networks, taking into account systemic risk contagion. In particular, we use the Eisenberg-Noe framework to model contagion effect and risk amplification inside a financial network. Likely scenarios are obtained by solving some mixed integer programming problems, and numerical examples are shown to illustrate how one can select plausible macroeconomic scenarios which may lead to adverse outcomes to a network. This work provides a systematic way of generating multiple shock scenarios to find hidden vulnerabilities in a financial system.

3 - Does COVID-19 Impact the Network of Volatility Spillovers between the SALT States and the South African Bond Market?
Nina Kajiji, Gordon Dash, Brittany Wilcox

Under the Africa Growth and Opportunity Act (AGOA), South Africa (SA), an emerging market economy, recorded substantial exports. However, the recent political agenda could lead to a weakened AGOA, thus undermining SA financial stability and possibly propagate financial contagion between SA and U.S. capital markets. The identification of any volatility spillover effects is made more convoluted by the persistence of the COVID-19 pandemic. This paper studies the network effect of volatility spillover transmission to the State and Local Tax (SALT) impacted municipal bond markets from the South African government bond market. Spillovers and financial contagion are attributed to the government bond market of SA, the trade of precious metals, and the sovereign effects of COVID-19. In our research study, we implicate over 3.8 million state-level municipal bond trades. We then examine COVID-19's shock to spillover transmission among impacted states using a supervised machine learning algorithm to map international volatility transmission into U.S. states. Preliminary results provide insights into SA volatility transmission's negative contribution into SALT states where the impact of the Tax Cuts and Jobs Act (TCJA) of 2017 was most felt. The states with moderate impact on personal income from TCJA exhibit a significant variation in spillover transmission and COVID-19 shock. Broadly, these states are geographically located in the south or mid-east part of the U.S.

4 - A data-driven deep learning approach for options market making
Qianhui Lai, Xuefeng Gao, Lingfei Li

We develop a data-driven approach for options market making. We first study the dynamics of option market order arrivals using data from CBOE for options on two stocks and find that both buy and sell orders exhibit strong self-excitation but cross-excitation is insignificant between them. We also show that the Hawkes process with a time-varying base intensity and a power kernel provides the best fit to the data of market buy and sell orders for stock options. To solve the optimal market making problem for a single option, we approximate the market making strategy at each decision epoch by a neural network and generate data for training the neural networks from dynamics of the stock price and the market order arrivals, for which realistic models can be used. We study feature selection for the neural networks and compare the optimal solutions from realistic and simple models. Our results suggest that using a realistic data-driven approach can bring substantial improvements. We also show how to solve the market making problem for option portfolios with Greek constraints using neural network approximation.

Tuesday, 12:00-13:40

■ TC-01

Tuesday, 12:00-13:40 - Room 1

Behaviorial Operations Management

Stream: Behavioral OR
Invited session
Chair: Yun Shin Lee

1 - Behavioral considerations in supply-chain inventory management
Jin Kyung Kwak

When retailers do not make optimal inventory decisions because they are humans, what can their suppliers do for their stock policies in order to reduce inventory costs? What are the factors that might affect these decisions? This study aims to search for the possible value of behavioral considerations in supply-chain inventory management.

2 - An Experiment Study on Learning of Strategic Customers
Seungbeom Kim

In industries with perishable goods dynamic pricing schemes are often used and many models have been proposed to maximize seller's revenues. We use laboratory experiments to gain insights into how customers make purchase decisions when they have the option of buying at a higher price or waiting for a lower price but incur the risk of the product being out of stock. We find that the quantal response model (QRM), a quasi-rational model, provides a more accurate description of customers' decisions. If decision making is consistent with our experimental findings, then pricing models that are based on the assumption that customers are rational expected utility maximizers can result in significant loss in profitability. We also study how customers learn in these types of settings.

3 - Are Two Better than One? Individual Bias and Group Dynamics in the Newsvendor Decisions
Yun Shin Lee, YoungSoo Park

In a practice of a Sales and Operations Planning (S&OP), newsvendor decisions are often made by two parties in a firm, Sales Department and Operations Department. We examine newsvendor decisions in a group setting in comparison to a setting where individuals make decisions. In the Individual Treatment, we ask subjects to make all of the decomposed order decisions - point forecasts, distribution forecasts, and service level decisions. In the Group Treatment, there are two players framed as a demand forecaster who is in charge of making point forecasts and distribution forecasts, and an operations manager who makes service level decisions. We find no benefit of separating the newsvendor tasks into two players; individual bias in demand forecasts and alignment in the order decisions are not improved, and bias in service level decision and order quantity even worsen in the Group Treatment. We further examine how individual bias and group dynamics change with different group structures. Depending on the group structure, individual biases in component decisions can become more severe and alignment in the order decision can be worse. This emphasizes an importance of integrating a S & OP process as one body process as dividing the task between two players brings no benefit.

■ TC-02

Tuesday, 12:00-13:40 - Room 2

Algorithms and theory for convex and nonconvex optimization

Stream: Continuous Optimization
Invited session
Chair: Bruno Lourenco

1 - Local convergence of primal-dual interior point methods for nonlinear semi-definite optimization using the family of Monteiro-Tsuchiya directions
Takayuki Okuno

Studies on algorithms for nonlinear semi-definite optimization problems, called NSDPs, have significantly advanced in the last 15 years. Yamashita et al. first proposed a primal-dual interior point method (PDIPM) for solving NSDPs using the family of Monteiro-Zhang (MZ) search directions which was originally proposed in the context of linear semi-definite optimization problems (LSDPs).

Since then, various kinds of PDIPMs for solving NSDPs have been proposed, but, as far as we know, all of them are based on the MZ family. In this paper, we present a PDIPM equipped with the family of Monteiro-Tsuchiya (MT) directions, which was also devised for solving LSDPs, and study its local convergence analysis.

Specifically, we establish superlinear convergence to a Karush-Kuhn-Tucker point of the NSDP in the presence of certain general assumptions on scaling matrices, which are utilized to produce MT directions, and standard regularity conditions.

2 - A new uncertainty model for positive-valued parameters with applications
Ellen Hidemi Fukuda, Tatsuya Tanaka, Nobuo Yamashita

In robust optimization, it is common to use boxes or ellipses to define the uncertainty sets. In this paper, we propose a new model of uncertainty set that considers only positive-valued parameters, which is appropriate for some specific optimization problems. This model uses a particular convex function that measures the variation of uncertain parameters from their nominal values. By using duality techniques, we derive a tractable equivalent form of the robust problem with our uncertainty model. Moreover, we show some properties for the robust optimization problems using this model. We finally present some numerical experiments, with two application problems. We observe that, differently from traditional uncertainty models, the proposed one can avoid infeasibility of the robust counterpart of such problems.

3 - Error bounds, facial residual functions and applications to the exponential cone
Scott Lindstrom, Bruno Lourenco, Ting Kei Pong

We construct a general framework for deriving error bounds for conic feasibility problems. In particular, our approach allows one to work with cones that fail to be amenable or even to have computable projections, two previously challenging barriers. For the purpose, we first show how error bounds may be constructed using objects called facial residual functions. Then, we develop several tools to compute facial residual functions even in the absence of closed form expressions for the projections onto the cones. We demonstrate the use and power of our results by computing tight error bounds for the exponential cone feasibility problem. Interestingly, we discover a natural example for which the tightest error bound is related to the Boltzmann-Shannon entropy. We were also able to produce an example of sets for which a Holderian error bound holds but the supremum of the set of admissible exponents is not itself an admissible exponent.

This is a joint work with Bruno F. Lourenco and Ting Kei Pong.

4 - Consistent error bounds and convergence rates
Bruno Lourenco

We discuss the notion of consistent error bound functions, which provides a framework for the study of error bounds for convex feasibility problems (CFPs), especially in settings where constraint qualifications may fail to hold. Our main result is that the convergence rates of several algorithms for CFPs can be obtained directly from the underlying error bound function. We also establish further links between the singularity degree and the convergence rates of a number of algorithms for conic feasibility problems. This is a joint work with Tianxiang Liu (RIKEN-AIP) and more information can be seen in our preprint arxiv:2010.16391

■ TC-03

Tuesday, 12:00-13:40 - Room 3

Financial mathematics and OR 1

Stream: Financial Mathematics and OR
Invited session
Chair: Norio Hibiki
Chair: *Katsunori Ano*

1 - Optimal execution strategies with generalized price impacts in a continuous-time setting
Makoto Shimoshimizu, Masaaki Fukasawa, Masamitsu Ohnishi

In this paper, we analyze a continuous-time analog of the optimal trade execution problem with generalized price impacts, which was recently discussed in Fukasawa, Ohnishi, and Shimoshimizu (2020) for a discrete-time setting. The market model considers transient price impacts of random trade execution volumes posed by small traders as well as a large trader. Our problem is formulated as a stochastic continuous control problem over a finite horizon of maximizing the expected utility from the final wealth of the large trader with Constant Absolute Risk Aversion (CARA) von Neumann-Morgenstern (vN-M) utility function. By examining the Hamilton-Jacobi-Bellman (HJB) equation, we characterize the optimal value function and optimal trade execution strategy, and conclude that the trade execution strategy is a time-dependent affine function of three state variables: the remained trade execution volume of the large trader and, so-called, the residual effects of past price impacts caused by both of the large trader and other noise–traders and the noise traders' aggregate volume of order itself. Further, the time-dependent coefficients could be derived from a solution of a system of Ordinary Differential Equations (ODEs) with terminal conditions, which is numerically tractable.

2 - Failure discrimination and variable selection problem by mixed integer semi-definite programming using maximal margin hyperplane
Katsuhiro Tanaka, Rei Yamamoto

Calculating credit risk for each corporate is one of major themes in financial risk management, and the logit model is a well-known model for its calculation. However, the logit model has an issue of multicollinearity. On the other hand, the support vector machine (SVM) does not have the issue. Also, some papers have reported that the discrimination accuracy of SVM is better than that of logit model, and the number of explanatory variables chose by SVM is smaller than that by logit model. Therefore, SVM is considered easy to use in practice.

We propose a new SVM that has two characteristics. First, we use a quadratic function with a positive semi-definite constraint to credit scores instead of a linear function. Second, we add the variables selection constraints to the SVM by using 0-1 integer variables. From these characteristics, our proposed model can be expected to be more practical, because this model can have high discrimination accuracy with smaller explanatory variables.

However, this model is formulated as a 0-1 mixed integer semi-definite programming problem and it can be difficulty solved within the practical amount of time. Therefore, we propose a heuristic algorithm that decomposes the original problem into three partial problems. And we show that our proposed algorithm can heavily reduce the calculation cost without decreasing the discrimination accuracy by the computational experiments with actual market data in the Japanese market.

3 - Asset Allocation with Forward-Looking Distribution
Takuya Kiriu, Norio Hibiki

In asset allocation, selecting an approach to estimate return distribution has a significant impact on investment performance. To predict future returns, a forward-looking approach that reflects the market's outlook is desired rather than a backward-looking approach. Previous studies show the effectiveness of the forward-looking approach for timing the stock market. In practice, it is common to consider asset allocations that include bonds and stocks. However, a forward-looking approach for bonds has not been developed or investigated. In this study, we develop a forward-looking method to estimate bond return distribution from current market prices. Then, we construct a forward-looking asset allocation model for a Japanese investor under a practical setting that includes both bonds and stocks. From the out-of-sample performance comparison with non-forward-looking approaches, we obtain the following results. First, the forward-looking approach performs better than the non-forward-looking approaches. This result holds under multiple evaluation metrics, objective functions, and implementation methods. Second, the timing ability contributes to the better performance of the forward-looking approach. Third, the use of implied distribution risk adjusted by the forward-looking approach is beneficial for bonds as well as stocks. The findings presented in this study imply the importance of the forward-looking approach in asset allocation.

4 - Investment Timing and Capacity Decisions with Time-to-Build in a Duopoly Market
Haejun Jeon

In this study, we investigate optimal investment timing and capacity decisions in the presence of time-to-build and competition. Due to uncertain time-to-build, a leader, who invests first, may have its product enter the market after a follower's. We show that a dominated firm with the longer time-to-build can become a leader by making the investment earlier than a dominant firm with shorter investment lags. The leader's capacity choice increases with the dominated firm's time-to-build, even if the dominated entity is the leader. This finding is consistent with the observation in the electric vehicles market in which a relatively new firm with little experience of mass production makes aggressive investment early on, while the biggest carmakers capable of mass production are timing their investment. With a welfare-maximizing policy, however, the dominant firm with the shorter time-to-build always becomes the leader. There is a significant loss of social welfare with the dominated firm being the leader, and the loss increases with the asymmetry of time-to-build.

■ TC-04

Tuesday, 12:00-13:40 - Room 4

Mathematical models of urban operations research

Stream: Discrete Optimization and Urban Operations Research
Invited session
Chair: Yudai Honma

1 - Equality of the Indexes to Evaluate Buildings for Public Facilities with Distance Decay of the Utilization Ratio in Short-term Optimal Sequential Building Removal Process
Tohru Yoshikawa

In Japan, the reorganization of regional public facilities including removal of the existing public building stock is a pressing issue. Thus, the goal of the study is to develop indexes of the evaluation of the existing public building stock in terms of location for planning of the reorganization. The most popular index is the average of the nearest distance from each resident to the facilities. However, for the facilities to which the probability of visiting by the residents decreases according to the distance, its social implications is not clear. Thus, this study compares the following three indexes to evaluate the existing public building stock as the potential space for regional public facilities to which the probability of visiting by the residents decreases according to the distance: the average of the probability of visits; the average of the consumer surplus; the average of the nearest distance. This paper applies the three indexes to the evaluation of seven elementary school buildings in Tama New Town in the suburbs of Tokyo. The visitors choose the nearest facility and the probability of the visit follows a logit model. It is assumed that one building of these schools with the lowest index will be removed and, in the other buildings, community facilities will be installed. The removal process continues until the number of the buildings equals to one, and thus it is a short-term optimal process. The equality of the facility location by the three indexes is compared.

2 - Optimal Location of MLIT Roadside Stations to Improve Robustness in Disaster Prevention Scenario
Yudai Honma, Shinichiro Kai, Ryota Horiguchi, Kazushi Sano, Takashi Oguchi

In Japan, there are plenty of "Roadside Stations," which are government-designated rest areas along roads and highways. Their basic concepts are proposed by the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) and are regarded as one of the most successful examples of government-oriented business models. Recently, MLIT is considering using the stations for disaster prevention as well. Therefore, in this study, we discuss the optimal location of MLIT roadside stations to improve robustness in disaster prevention scenarios. Especially, we focus on not only the nearest station but also the "second" nearest stations from each demand, and optimize their locations with multiple criteria. Our analysis is calculated with very detailed GIS data: we consider 47,340 meshes and 45,868 flows in total. All distances are also calculated based on the detailed actual road networks, consisting of 245,709 nodes and 358,702 links. We believe this research is at the forefront of locational analysis, both in terms of the mathematical model and the amount of data.

3 - A Study on 3D Element Arrangement to Realize Photographic Composition
Kyoichiro Hirata, Daisuke Hasegawa, Hiroko Watanabe, Yudai Honma

In this study, we focused on object placement in urban landscape photography and showed the movable regions of objects that satisfy a specific composition. Urban landscape photographs are not random shots of the urban landscape, but the composition and other photographic techniques are used intentionally. Therefore, it is necessary to consider the photographic techniques used when considering urban landscape photography. In this study, we explore the possibility of movable object placement in characteristic urban landscapes. The method is based on mathematical modeling to analyze object placement and composition. We place a fixed object, a movable object, and a camera in a three-dimensional space, and illustrate the possible three-dimensional regions of the movable object such that the fixed object and the movable object create a specific composition on the two-dimensional map when the camera is moved. The fixed objects are mountains, horizon lines and roads, and the movable objects are people's faces. First, as a basic analysis, we consider the case where there is only one movable object. Next, we consider the case where there are multiple movable objects and consider the areas that can be reflected simultaneously. The results of this study will help us to understand how to create attractive vistas in building design and urban planning.

4 - DEA Analysis to Categorize Japanese Shopping Districts in Terms of Economic Efficiency
Kawaguchi Yuya, Daisuke Hasegawa, Hiroko Watanabe, Yudai Honma

This study will analyze the economic efficiency of shopping districts throughout Japan and present the characteristics of shopping districts. Shopping districts have played an essential function in supporting the daily purchasing of local residents. However, in recent years, shopping districts have been expected to serve not only as a commercial function but also as a community function. In fact, in this corona disaster, the importance of shopping districts is attracting renewed attention for their ability to enhance ties with the local community, which is restricted to face-to-face social activities. In order to develop a shopping district, it is essential to gain enough income. In this study, we examine the economic efficiency of shopping districts, and categorize shopping districts to describe their characteristics based on Data Envelopment Analysis. First, we evaluate the DEA efficiency of shopping districts in Japan. We use the number of businesses, the number of workers, and the sales floor area as variables of DEA, and evaluate their efficiencies. Next, we categorize the shopping districts to illustrate the characteristics of each shopping district. Finally, we will show a target district that acquires the maximum score in terms of DEA efficiency, which can be regarded as a future goal for each district.

■ TC-05

Tuesday, 12:00-13:40 - Room 5

Pricing Strategies

Stream: Revenue Management and Pricing
Invited session

Chair: *Feng Tao*
Chair: *Manlu Chen*

1 - Price and effort decisions of two competing retailers in omni-channel retailing
YanHong Xie

Showrooming and webrooming are common in omni-channel retailing. The former refers to the case where consumers check a product in an offline store but buy it from the online, and the latter refers to the case where consumers learn product information from an online store but buy it from the offline. In this paper, we considered an online retailer and an offline retailer, who ordered from the same supplier. Both retailers exerted effort to increase demand and these effort may benefit both offline retailer and online retailer, namely, showrooming and webrooming occurred. Therefore, we established a model to study the optimal effort level of these two competing retailers. From the research we found that: first, it is not always beneficial for a retailer, no matter whether she is online or offline, to exert more effort. Second, the retailer with higher market share may earned lower profits. Finally, we analyzed the effect of the showrooming and webrooming on the retailer's profit. Intuitively, showrooming will benefit online retailer and webrooming will benefit offline retailer, which indicates that the retailer with larger transfer profits will have higher profits. However, when showrooming is larger than webrooming, the profit of online retailer may be less than that of offline retailer. Likewise, when webrooming is larger than showrooming, the profit of offline retailer may be less than that of online retailer.

2 - Selection of contracts for perishable product supply chain under a two-price policy
Chang Xu, Tijun Fan

In perishable product supply chain, a two-price policy is ubiquitous usually due to the increase price sensitivity of customers. In this paper, we discuss the selection of contracts for perishable product supply chain with a two-price policy. Firstly, we formulate the profit model, optimize the prices in two-time phases, compare and analyze the prices of fresh produce in two-time phases under the two contracts. Next, we investigate the trend of price and profit under the impact of decay rate and price markdown time. Finally, we analyze the contract selection and preference of the supplier and the retailer. The results show that the optimal prices show the opposite trend in two parameters under two

contracts. It is always better off for the supplier to choose the revenue-sharing contract. In addition, the perishable product supply chain can achieve a win-win situation when 1) the price sensitivity increase in second time phases is large 2) market size is large; 3) the price sensitivity increase and the market size are small, the price markdown time is early or late.

3 - Uniform vs. retailer-specific pricing: how a strategic supplier responds to the dominant retailers' markup pricing strategy
Yao Yu Wang

This study investigates the pricing strategy choice game in a supply chain with one supplier and two retailers. The retailers move first to choose either a fixed-dollar-markup or a percentage-markup. The supplier also has two pricing strategies, namely, the retailer-specific wholesale pricing (RSWP) and the uniform wholesale pricing strategy (UWP). Our results show that as long as the retailers choose the same markup scheme, RSWP scheme results in higher profit for the retailers, but lower profits for the supplier and the channel. However, when the two retailers choose different markup scheme, the impacts of the two wholesale pricing schemes on supply chain members depend on the markup format the retailer chooses and the level of competition. Moreover, we show that under the UWP strategy, the retailer who adopts the fixed-dollar-markup policy will obtain higher profit in compared with the one who adopts the percentage-markup variant, which is another point that has not been well recognized in the literature. At last, this paper demonstrates that the equilibrium pricing strategy for the whole supply chain is [UPP]-strategy, i.e., the retailers will always choose the percentage markup variant and the supplier always chooses the uniform pricing scheme no matter what the level of competition is. Furthermore, our results show that the supplier gets better while the retailers get worse as the level of competition increases at this equilibrium.

4 - Food Delivery Service And Restaurant: Friend Or Foe?
Manlu Chen, Ming Hu, Jianfu Wang

With emerging food delivery services, customers can hire delivery workers to pick up food on their behalf. To investigate the long-term impact of food delivery services on the restaurant industry, we model a restaurant serving food to customers as a stylized single-server queue with two streams of customers. One stream consists of tech-savvy customers who have access to a food delivery service platform. The other stream consists of traditional customers who are not tech-savvy enough to use a food delivery service and only walk in by themselves. We study a Stackelberg game, in which the restaurant first sets the price of the food, the same for online and offline customers; the food delivery platform then sets the delivery fee; and, last, rational customers decide whether to walk in, balk, or use a food delivery service if they have access to one.

■ TC-06

Tuesday, 12:00-13:40 - Room 6

E-commerce and urban logistics

Stream: Logistics in new economies
Invited session
Chair: *Shu Zhang*
Chair: *Chung-Cheng Lu*

1 - Dynamic inventory relocation for a one-way electric car sharing system with uncertain demand
Rui Liu, Shu Zhang, Ping Chen

In this study, we investigate an inventory relocation operation of a car-sharing system with electric vehicles (EV). We consider a one-way car sharing system in which users can pick-up and return vehicles at different stations. We consider uncertain pickup and return demands from and to a station and assume that there are several personnel working to relocate vehicles between stations. The charging levels of returned vehicles are uncertain and customers will not pick up a vehicle with low battery. Upon arrival at a station, an EV relocation person needs to decide which vehicle to relocate and which station to move the vehicle. We formulate the problem as a Markov decision process and adopt an approximate value iteration (AVI) approach to solve our problem. We develop state space aggregation schemes and use dynamic lookup tables to improve the computational efficiency in the AVI. We demonstrate the effectiveness of our solution approach via preliminary experiments.

2 - Optimal Scheduling of Unmanned Aerial Vehicles for Meal Delivery Services
Chung-Cheng Lu, Yi-Cheng Lan, Yu-Shyun Chien

This study applies time-space network modeling techniques to solve the scheduling problem of multi unmanned aerial vehicles (UAV) for meal delivery services. The model takes into account the battery capacity constraint of UAVs and aims to minimize the total distribution cost. The proposed model is classified as a multi-depot vehicle scheduling problem, which is characterized as NP-hard. In order to efficiently solve large problem instances, the study develops a math-heuristic, network decomposition by drones, which integrates Gurobi solver to solve the decomposed sub-problems. The model and the algorithm are examined and evaluated using the test instances generated based on Solomon's VRPTW benchmark instances. The heuristic is able to obtain good quality solutions in a reasonable amount of time. The differences between the objective values of the heuristic solutions and those of the lower bounds produced by Gurobi are less than 5% for all the test instances. The results show that the proposed model and the heuristic can be applied to solve the problem instances with practical sizes. The finding of this study can provide a reference on scheduling UAVs to operators who plan to use drones for meal delivery services.

3 - Generating Delivery Plan in Real Time for Vehicle Routing Problem with Dynamic Orders before Cut-off time
Xiaoying Gou

Nowadays, many E-commerce platforms set deadlines for receiving orders and promise to complete accepted orders within a certain time. These platforms often face the considerable pressure of generating delivery plans quickly after customers' order confirmation. The problem in this situation can be modelled as classical Vehicle Routing Problem (VRP). When the problem size becomes larger, the performance of traditional heuristic algorithm is not good enough compared with optimal solutions. Here, we propose a framework in order to get an instant distribution plan at cut-off time. By this framework, the calculation is started in advance. With the help of historical data and forecast for future orders, multiple VRP scenarios including plenty of common customers have been generated. For these scenarios, firstly, we came up with a genetic algorithm that can simultaneously solve towards multiple VRP scenarios. Based on which, we further present a framework that could update scenarios with newly confirmed information and correspondingly the solutions can be further improved and progressively head to the direction of the most likely happened scenario. Immediately the deadline for placing orders arrives, a delivery plan come out. We also extend this framework to accommodate not only Vehicle Routing Problem (VRP) but also Capacitated Vehicle Routing Problem with Time Windows(CVRPW).

■ TC-07

Tuesday, 12:00-13:40 - Room 7

Production Management, Supply Chain Management and Location 2

Stream: Production Management, Supply Chain Management and Location (contributed)
Contributed session
Chair: *Yongkyu Cho*

1 - Hub Interdiction Under Stochastic Demand and Congestion: Models and Solution Methods
Sneha Bhatt, Ankur Sinha, Sachin Jayaswal

The advantages of hub-and-spoke networks are well documented in the literature. However, they have their drawbacks too: any disruption at a hub has a cascading adverse effect on the remaining network, thus making them especially susceptible to terror attacks. One such adverse effect of a hub disruption is the congestion caused at other hubs due to diversion of the affected traffic through them. In this paper, we study the hub interdiction (intentional disruption caused by an attacker) problem under the case of possible congestion. Specifically, the network operator (defender) in our hub interdiction problem would like to avoid heavy congestion at the hubs, besides keeping the flow costs low, while diverting the affected traffic through the remaining surviving hubs. The contribution of the paper is twofold: firstly, we use a bi-level (max-min) framework to model the hub-interdiction problem and use two alternate ways to model congestion, leading to a max-min problem with non-linearity in the objective function. Secondly, we propose two solution approaches and present their computational performance. The first approach is a unique inner approximation of the non-linear objective function that is improved iteratively. We compare this with a second-order conic programming-based approach that can be solved directly using commercial solvers. Our computational study demonstrates the superiority of the inner-approximation approach.

2 - An energy-efficient operation of computing resources in cloud data centers: join-the-minimum-power job routing and minimizing earliness speed scaling
Yongkyu Cho

As the need for mission-critical mobile applications increases in the present Industry 4.0 such as smart manufacturing or self-driving cars, strictly guaranteeing some desired level of service becomes more important. This service level is mainly determined by computation time in cloud data centers (or server farms) as well as the speed of communications network. However, the uncertainty and burstiness present in user data traffic are imposing most data centers over-provision their computing resources to keep a robustly stable service level, which waste vast electric energy.

In this research study, we suggest to utilize real time information to optimize the energy efficiency in data centers. In particular, we propose an adaptive operation in data centers: routing an incoming job to the server of the highest instantaneous electricity consumption and scaling the servers' speeds such that minimizing the earliness of job completion while guaranteeing a service level agreement (SLA). Simulation experiments under a virtual data center given synthetic user data traffic (generally distributed and time-varying) showed the effectiveness of the proposed operation. As a result, we notice the price of real time information in terms of energy efficiency.

Tuesday, 14:00-15:40

■ TD-01

Tuesday, 14:00-15:40 - Room 1

Keynote: Regina Berretta

Stream: Keynotes
Keynote session
Chair: *Dong Gu Choi*

1 - Inventory Management of Agri-fresh Products
Regina Berretta

The food production in Australia is responsible for $117 billion per year and it is increasing by a yearly rate of 2.1%. The problem of determining optimal production plans within an industry that handles perishable products presents several challenges. Food waste and loss is one of them. In Australia, around 13 per cent of the food production is wasted. Another challenge is inventory management, since perishable products have variable lifetime depending on the conditions in which they are stored. In addition, the minimisation of all the costs involved, subject to several constraints is a highly complex computational problem.

In order to achieve an optimal plan, sophisticated mathematical models are essential. This talk will describe optimisation mathematical models for inventory management for agri-fresh products when different types of warehouses are available, with the aim to reduce cost, including those costs associated with waste. The talk will also present computational methodologies to provide solutions.

■ TD-02

Tuesday, 14:00-15:40 - Room 2

IFORS Prize for OR in Development 2020 - 1

Stream: IFORS Prize for OR in Development Finalists
Award Competition session
Chair: *Mario Guajardo*

1 - JalTantra: Impacting the practice of rural water network design in India
Nikhil Hooda, Om Damani, Ashutosh Mahajan

JalTantra has changed the practice of rural piped water network design in and beyond the state of Maharashtra, India. Existing tools for water network design look at only pipe diameter optimization and are either difficult to use because of hardware requirements and licensing costs or have limited capabilities developed in the 1990s. Real world networks however also contain components such as tanks, pumps and valves whose parameters require a careful selection. JalTantra takes a deterministic and optimal approach to the overall design and is developed as a free to use web application. The problem is modeled as a Mixed-Integer Linear Program. The simultaneous consideration of pipes, tanks, pumps and valves results in a complex model for network sizes of practical importance. The time taken to optimize an example 150 node network was 40 minutes and a 200 node network could not be solved within 24 hours. Several reformulations were introduced to produce a much tighter model, resulting in the two networks taking just 5 and 70 seconds respectively. Developed in partnership with water supply engineers, JalTantra is an example of how the university can help government departments in carrying out their developmental duties. JalTantra has been successfully deployed by government engineers for designing rural water networks and due to its minimum cost design, saves the government 100s of millions of Indian Rupees each year. It is now part of the training curriculum of these engineers.

2 - School Choice in Chile
Ignacio Rios, José Correa, Rafael Epstein, Juan Escobar, Bastián Bahamondes, Carlos Bonet, Natalie Epstein, Nicolás Aramayo, Martin Castillo, Andres Cristi, Boris Epstein, Felipe Subiabre

Centralized school admission mechanisms are an attractive way of improving social welfare and fairness in large educational systems. In this paper, we report the design and implementation of the newly established school choice system in Chile, where over 274,000 students applied to more than 6,400 schools. The Chilean system presents unprecedented design challenges that make it unique. First, it is a simultaneous nationwide system, making it one of the largest school choice problems worldwide. Second, the system is used at all school grade levels, from pre-K to 12th grade. One of our primary goals is to favor the assignment of siblings to the same school. By adapting the standard notions of stability, we show that a stable assignment may not exist. Hence, we propose a heuristic approach that elicits preferences and breaks ties between students in the same priority group at the family level. In terms of implementation, we adapt the Deferred Acceptance algorithm as in other systems around the world.

3 - A light-touch tool for optimal vaccine distribution in Mozambique
Larissa P.G. Petroianu, Zelda B. Zabinsky, Mariam Zameer, Yi Chu, Mamiza Muteia, Mauricio Resende, Aida Coelho, Jiarui Wei, Turam Purty, Abel Draiva, Alvaro Lopes

Planning vaccine distribution in rural and urban poor communities is challenging, due in part to inadequate vehicles, limited cold storage, road availability, and weather conditions. The University of Washington and VillageReach jointly developed and tested a user-friendly, Excel spreadsheet-based optimization tool for routing and scheduling to efficiently distribute vaccines and other medical commodities to health centers across Mozambique. We will describe the tool and the process used to define the problem and obtain feedback from users during the development. The distribution and routing tool, named Route Optimization Tool (RoOT), uses an indexing algorithm to optimize the routes under constrained resources. Numerical results are presented using three realistic datasets. RoOT can be used in routine or emergency situations, and may be easily adapted to include other products, regions, or logistic problems.

■ TD-03

Tuesday, 14:00-15:40 - Room 3

Recent Progress in Semidefinite and Second Order Cone Programming

Stream: Continuous Optimization
Invited session
Chair: Makoto Yamashita
Chair: *Sunyoung Kim*

1 - Exact semidefinite relaxations for QCQPs with forest-structured matrices and its applications
Godai Azuma, Mituhiro Fukuda, Sunyoung Kim, Makoto Yamashita

We study exact semidefinite relaxations of nonconvex quadratically constrained quadratic programs (QCQPs). Investigating exact conditions of semidefinite relaxations, which implies that a solution of the original QCQP can be recovered, is important to identify what type of QCQP can be handled in polynomial-time. One of recent works has constructed a polynomial-time checkable method for diagonal QCQPs in which all matrices are diagonal. In this talk, extending the result to more general QCQPs, we propose exactness conditions for the semidefinite relaxation of forest-structured QCQPs by utilizing a lower bound for the rank of tree-structured matrices. Furthermore, some results related to the exactness of the semidefinite relaxation are discussed, which include specialized conditions which can be obtained by applying the proposed conditions to some classes of QCQPs.

2 - An efficient approach with aggregate sparsity based on second order cone programming relaxations for quadratic constrained quadratic programming problems
Makoto Yamashita, Heejune Sheen

Semidefinite programming (SDP) relaxation is known to give a tight approximation for many quadratic constrained quadratic programming (QCQP) problems. In general, however, solving SDP problems is a demanding task. To solve SDP faster, Fukuda et al. (2001) proposed a chordal sparsity method to exploit the aggregate sparsity in SDP. Another approach to obtain an approximate solution is to employ second-order cone programming (SOCP) relaxation.

In this paper, we address an exploitation of the aggregate sparsity in the framework of SOCP relaxation for QCQP problems. The numerical performance of the chordal sparsity method for SDP depends on the aggregate sparsity, thus the chordal sparsity method does not always improve the performance for solving SDP. We show that, in SOCP relaxation, we can lower the number of second-order cones by the aggregate sparsity, and this leads to a reduction in the computation time. Furthermore, our approach does not require the completion step of the chordal sparsity method. We also discuss that our approach has a max-determinant property in a similar way to the chordal sparsity method.

The numerical results indicate that the use of the aggregate sparsity pattern enhances the numerical performance of SOCP relaxation.

■ TD-04

Tuesday, 14:00-15:40 - Room 4

Timetabling

Stream: Scheduling, Timetabling and Project Management
Invited session
Chair: *Pieter Smet*
Chair: Martin Gutjahr

1 - Scheduling volunteer interviews using integer programming
Christian Braathen

Numerous organizations arrange events requiring a large number of volunteers. Examples are festivals, conferences, and sport events. Hiring volunteers involve several challenges, such as scheduling interviews to recruit them and allocating them to their most preferred tasks. Likewise, to conduct the interviews the organizations require to allocate staff and valuable time of the interviewers. In this talk, I will present an integer programming model that automatically creates an interviewer- and interviewee-friendly schedule. The model has been successfully applied to a festival and a sports event, replacing the previous semi-manual procedure used by the involved organizations.

2 - Models and algorithms for large-scale personnel rostering problems
Chao Li, Pieter Smet, Patrick De Causmaecker

We analyze large-scale personnel rostering problems which arise when constructing long-term schedules for large organizations. Typical rostering constraints are considered, including complex restrictions on consecutive assignments. Commonly used integer programming models consist of millions of decision variables and constraints and often cannot be solved directly. Efficient models and algorithms are discussed in this work based on insights derived from polynomially solvable subproblems in personnel rostering.

3 - On the complexity of the crew assignment problem at Air France
Nour ElHouda Tellache, Frédéric Meunier

The crew scheduling problem is one of the most important problems in the airline planning because the total crew cost is considered, next to fuel cost, the largest single cost of the airlines. For large fleets, this problem is decomposed into a crew pairing problem and a crew assignment problem. We focus on the following crew assignment problem that has been encountered at Air France. The input consists in a set of activities with fixed starting and ending times to be assigned to a set of crews such that each activity can be covered by one crew. We seek an assignment of all the activities to a minimum number of crews in a Horizon (H) of one month. Each crew should have a rest period of 13 days that contains 7 consecutive days called rest block. We first show that the problem of assigning activities to one crew member so that his working time is maximized, while satisfying the rest period and rest block constraints, is polynomial. However, when H is not fixed, the problem becomes as NP-hard as the subset sum problem. The general problem of assigning all the activities to a minimum number of crews can be solved in polynomial time when the starting and ending times are expressed in full days, but again when H is not fixed, the problem becomes as hard as the 2-partition problem.

4 - Task selection with complex personnel restrictions in a timetabling environment
Martin Gutjahr, Sophie Parragh, Fabien Tricoire

The paper considers a complex real-world scheduling problem proposed by a company, in which tasks are to be picked and assigned to a set of differently skilled employees. Employees are able to perform multiple tasks in parallel. All tasks belong to specific task families. Assignments are limited regarding the overlap of tasks of different families. Furthermore, there can be precedence relations between tasks. Some tasks are classified as mandatory and have to be assigned. Each employee requires the construction of shifts inside given availability periods. In addition, legal break and rest requirements as well as possible break splitting with preparation time have to be considered. We maximize the weighted sum of the number of assigned tasks while minimizing penalties. Each task is weighted by its priority. Assignments of tasks to underskilled employees incur a penalty. A large neighbourhood search algorithm has been developed to tackle the described problem and tailored to company needs. The algorithm includes repair and destroy operators that consider opportunity cost. It has since been used in practice. For a more general variant of the problem, we propose a mixed integer programming formulation that is solved using CPLEX. All approaches are tested and compared on a set of test instances derived from real world data. Alternative objectives derived from company goals are considered and tested using the proposed LNS implementation.

■ TD-05

Tuesday, 14:00-15:40 - Room 5

Applications of DEA 2

Stream: Data Envelopment Analysis and Performance Measurement
Invited session
Chair: *Petra Zýková*

1 - The evolution of performance over time of European countries' education systems in the light of Europe 2020 strategy
Audrone Jakaitiene, Ana Camanho, Flávia Barbosa, , Dovilė Stumbrienė

The assessment of progress of education systems over time is at the top of the agenda of governments and educational authorities worldwide. The European Commission monitors the performance of education systems in Member States according to the strategic framework "Education and Training 2020"(ET2020). However, studies dedicated to the assessment of performance of education systems at country level based on panel data are very scarce. The framework used to evaluate European education systems is based on the construction of a composite indicator adopting a benefit-of-the-doubt approach. The evaluation of performance change over time is done using a global Malmquist index using a non-convex metafrontier approach. We assessed the performance of education systems in 29 European countries analysing the ET2020 indicators for the period 2006-2018. We observed the convergence of European countries for half of indicators. Bulgaria, Hungary and Romania have the largest scope for improvement. The results obtained can help monitoring convergence in terms of the educational achievements amongst European countries. Acknowledgments. The research is funded by the European Social Fund according to the activity 'Improvement of researchers' qualification by implementing world-class R&D projects' of Measure No. 09.3.3-LMT-K-712. The project DOTSUT-39 (09.3.3-LMT-K-712-01-0018) / LSS-250000-57.

2 - Investment Efficiency Analysis of European Education and Health Sectors
Edo Omic, Etleva Gjonca

In recent years policymakers throughout Europe have been determined to enact strategies and investment plans that will strengthen their respective public social sectors. To help guide future investments, this paper aims to examine two of those sectors, education and health, and how efficient past investment levels have been in achieving desired social outcomes. We use panel data sets and employ Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) models to study the investment efficiency change in the education systems of 33 Europe countries (plus 10 advanced, non-European countries) from 2012 and 2015, and in the health systems of 34 European countries from 2011 to 2016. To capture optimal outcomes for each sector, we utilise a country's average PISA score for the education sector and the number of avoidable deaths for the health system; our primary input variables of interest are public expenditure on education per student (for education analysis) and health expenditure as a percentage of GDP (for the health analysis). We find that in the education system, the efficiency of investments between 2012 and 2015, on average, did not substantially improve in both DEA and SFA models. Meanwhile, in the healthcare system, we find that investment efficiencies between 2011 and 2016, on average, have been improving in both the DEA (Malmquist index) and SFA models. The paper also examines a number of environmental inputs as well as country-specific control variables.

3 - Using Metafrontier Methods to Estimate the Effects of Instruction Time on School Efficiency
Chris O'Donnell, Giovanna D'Inverno

We assume that high-school managers can choose both the number of classes that are delivered each week and the duration of those classes. We are interested in whether academic performance and employability are affected by the total amount of instruction time and the manner of its delivery. We use a stochastic metafrontier model to analyse data from more than 7900 schools across 52 countries. We find that, if done properly, delivering many short classes each week can be more effective than delivering a few long classes.

4 - Dynamic convex DEA models
Petra Zýková

This paper focuses on dynamic efficiency analyses based on Data Envelopment Analysis (DEA) models. This paper contributes to the DEA broad theory and proposes a new dynamic convex DEA model and its super-efficiency modification. The new dynamic DEA model with time series computes the unit's overall efficiency with the impact of all units' inputs and outputs in all periods. We introduce DEA models with quadratic objective function and nonlinear constraints that differ in every unit's time weights every year. The proposed model has a convex vector of the time weights. The model divides the set of units into two subsets: efficient and inefficient units. The inefficient units can be easily rank according to the efficiency scores. The efficient units have identical efficiency score equal to one and cannot be

raked. Therefore the super-efficiency model is proposed. The super-efficiency model computes the super-efficiency scores greater than one for the efficient units, and the efficient unit can be ranked according to this super-efficiency score. The proposed models are compared with already known models invented by Park and Park (2009).

■ TD-06

Tuesday, 14:00-15:40 - Room 6

Energy, Environment and Climate 2

Stream: Energy, Environment and Climate (contributed)
Contributed session
Chair: *Chiara D'Alpaos*

1 - CO2 Concentrations and the Earth's surface radiation budget: An Analysis Using Data Science
Kevin Forbes

The Earth's surface radiation budget refers to the difference between the absorbed solar radiation and the net infrared radiation that passes through the atmosphere between space and Earth's surface. According to the IPCC, "The radiation budget of the Earth is a central element of the climate system.. . . Anthropogenic influence on climate occurs primarily through perturbations of the components of the Earth radiation budget." Unfortunately, there are no analyses on the linkage between CO2 concentrations and energy budget listed in the various IPCC reports. This paper represents an attempt to address this gap in the research using hourly data from the Barrow (BRW) Atmospheric Observatory in northern Alaska.

The analysis begins by noting that the net incoming irradiance quantity at BRW was largely positive from 1996 to 2016. This indicates that less energy over this period left the Earth's surface at Barrow than arrived at the Earth's surface. A time-series model to explain the net irradiance levels was formulated. The model was estimated using hourly data for the period May 1993 through 31 Dec 2015. There are 146,170 observations in the sample. The results are consistent with the hypothesis that increases in CO2 concentration levels have adverse consequences for net energy levels leaving the Earth's surface. Consistent with causality, the out-of-sample predictions are more accurate if the estimated effects of CO2 are included in the prediction equation.

2 - Multitask learning for data-driven wind farm management and condition-based maintenance
Angela Meyer

While wind power is undergoing a strong growth globally, the profit margins of wind farm operators are shrinking in competitive electricity markets. The condition-based maintenance of wind turbines offers a cut in O&M expenses by reducing on-site inspections and unplanned maintenance work. Modern turbines comprise comprehensive sensing technology to enable 24x7 remote condition monitoring. Analyzing this sensor data facilitates the automated detection of incipient faults and asset underperformance. This study introduces multitask machine learning models to enable the monitoring of wind turbine operation and anomaly detection and to support condition-based maintenance decisions by facilitating an early informed planning of inspection and repair. We introduce multi-target machine learning regressions to provide a more efficient and accurate approach for the simultaneous monitoring of wind turbine subsystems. We demonstrate that early faults in the power train can be detected based on component temperatures logged in the turbines' supervisory control and data acquisition systems. We analyze the detection accuracy and detection delays based on multiple machine learning models of the normal turbine operation. Our results demonstrate that multi-target normal operation models can substantially reduce the lifecycle management cost of automated condition monitoring and thus support condition-based maintenance strategies of wind farm owners and operators.

3 - The value of investments in Solar Home Systems in a Peer-To-Peer trading scenario
Chiara D'Alpaos, Francesca Andreolli, Peter Kort

Due to the deployment of distributed renewable energy sources (e.g., solar), the introduction of communication technologies and the digitalization of the power system (e.g., smart meters, control devices), electricity consumers are switching from passive to active in managing their own energy consumption, production and storage. In a consumer-centric electricity market, Peer-to-Peer (P2P) trading allows consumers and prosumers to directly trade energy among each other without any intermediation by traditional energy suppliers. In this paper we investigate the decision of households to invest in a domestic PV plant coupled with battery storage, namely a solar home system (SHS), and to participate in a local energy community (EC), where energy quotas can be exchanged among EC members via P2P trading. Thanks to storage and P2P, households can strategically decide their optimal course of action and their otipmal energy production/consumption patterns and can actively offer services that other EC partcipants bid for. In detail, we examine whether P2P trading can increase the value of investing in an SHS and affect the decision on both optimal investment timing and size. Following the real option approach, we develop a stochastic optimization model. Our results show that ceteris paribus, thanks to P2P trading opportunities, households accelerate investments and invest in larger plants compared to scenarios where P2P trading in not permitted.

■ TD-07

Tuesday, 14:00-15:40 - Room 7

Machine Learning, Data Mining and Analytics 2

Stream: Machine Learning, Data Mining and Analytics (contributed)
Contributed session
Chair: *Małgorzata Wrzosek*

1 - Experimental evaluation of the performance of some features selection algorithms on different machine learning methods
Thibault Agondja, François Delbot, Jean-François Pradat-peyre

Amyotrophic Lateral Sclerosis, more commonly known as Charcot's disease, is a neurodegenerative disorder for which there is currently no cure. The median life expectancy at the onset of symptoms varies between 3 and 5 years. Establishing a reliable prognosis is a major challenge since it conditions the patient's management and quality of life.

The classification of patients, allows individuals to be grouped according to their needs and thus to adapt the patient's treatment in a more relevant way. The recent availability of ALS patient data for research allowed the study of different prognostic and classification models. Some machine learning methods have been successfully used to highlight the correlations present in the data which allows to better understand the progression of the disease.

Usually, data scientists apply a feature selection algorithm and then apply different machine learning methods. Then they keep the method that has the best predictive quality.

There are many algorithms to perform a feature selection. Sometimes the choices made are arbitrary. Thus, it is possible that one algorithm produces a selection of features favoring one machine learning method, while another algorithm would have produced another selection of features favoring another machine learning method. In this work, we conduct an experiment to determine which features selection method would be the most adapted given a learning method.

2 - Determining the best set of Molecular Descriptors for a Toxicity Classification Problem
Badri Toppur, Jaims Kj

A dataset of molecules used in the Pharmaceuticals industry, was shared during a hackathon, by a government health agency, for COVID-19 related drug discovery. The molecules were provided in Simple Molecular Input Line Entry (SMILE) format. It is decoded using the chemo-informatics development kit written in the Java and R programming languages (rcdk). The output to be predicted is the cardiotoxicity of the molecule, as a blocker or non-blocker. The strings representing the molecular structure, are parsed by the rcdk functions, to provide structure-activity descriptors, that are conjectured, to be good predictors for biological activity. These descriptors constitute the input to the Logistic Regression algorithm. This paper reports the results of the data science project to determine the best subset of molecular descriptors, from the large set that is available.

3 - Integrating Predictive and Prescriptive Analytics to Make Better Business Decisions
Francis Miranda

Most companies use either predictive or prescriptive analytics, but not both. This paper will discuss the main reasons why there is a disconnect. It will also give examples how predictive and prescriptive analytics can be combined to make better business decisions.

Examples will be given for several industry cases including retail sales forecasting, telco churn prediction, employee attrition, credit scoring, handling covid-19 and retail measurement.

4 - Application of data mining methods in identification of the skills indicators of people active in the labor market
Małgorzata Wrzosek

The impact of rapid technological progress on the labor market, observed since the 1980s, intensified especially at the beginning of the 21st century. Technology and skills, which were previously substitutes, have become complementary factors of production since the 20th century. Therefore, technological progress has resulted in an increase in demand for high skills of employees. Research and analyzes of the processes taking place in this market for several years indicate a significant increase in the demand for highly skilled employees. The skills heterogeneity is indicated as an important factor influencing the level of unemployment and employment, as well as the main cause of growing pay inequalities. However, the empirical analysis of these relationships is challenging due to difficulties with determining a measurable indicator of employee skills. The analyzes conducted so far indicate that the level of education does not fulfill this role. Research indicates that it is the field of education rather than its level that indicates skills for which there is high demand. Nevertheless, this element is not enough to define the employee's skills. The paper presents the results of the analysis aimed at identifying the factors characterizing the level of skills. The research was carried out using data mining techniques, with particular emphasis on cluster analysis.

■ TD-08

Tuesday, 14:00-15:40 - Room 8

DSS applications

Stream: Decision Support Systems
Invited session
Chair: *Shaofeng Liu*

1 - A fuzzy system selector for the container stacking problem under uncertain conditions
Jana Ries, Leonardo Maretto, Rosa G. González-Ramírez, Maurizio Faccio

The Container Stacking Problem is known to be one of the key decisions to be made in container port management. Port terminals are increasingly under pressure to ensure optimal use of existing resources. At the same time, port operations are managed under highly uncertain conditions, resulting in disruptive events within and beyond the port. The work adapts this argument of moving from 'one size fits all' algorithm to a selecting strategy that chooses the best fitting algorithm for the problem. A decision support system (DSS) for real-time container allocation is proposed, that selects the most suitable container allocation strategy for an incoming container. A rule-based selector in combination with Fuzzy Logic has been implemented and computational results are presented for a real-work case. Uncertain conditions are simulated by means of disruptive events. Performance is discussed for a set of relevant KPIs, including rehandles and congestion within the yard.

2 - A multi-perspective knowledge mobilisation framework to support collaborative decision making in agri-food value chains
Shaofeng Liu, Huilan Chen, Guoqing Zhao

Knowledge sharing for decision support has received great attention. However, majority of existing work has focused on knowledge sharing to support decision making within the same organisation or community where people have a shared sense of identity, values and some common practice, that is, knowledge process and learning is within relatively homogeneous groups. There is inadequate research to address the issue of cross-boundary decision making, hence it is important to explore approaches to knowledge mobilisation spanning across knowledge boundaries in order to support the value chain decisions. Knowledge boundaries can erect significant barriers to collaborative decision making especially in the value chain context where there are a great number of players from different domains, with varied level of knowledge, having different and possibly conflicting interests - participating in knowledge and decision activities. This paper will explore how such knowledge boundaries can be identified and how knowledge gaps among different value chain players can be closed by using appropriate boundary-crossing mechanisms. A multi-perspective knowledge mobilisation framework is proposed, based on empirical evidence from an EU Horizon 2020 project, RUC-APS, which investigates key issues of agri-food value chain across Europe and South America in seven countries. RUC-APS stands for Risk and Uncertain Conditions in Agriculture Production Systems.

3 - Studying the generation of decision alternatives in the urban planning domain
Linda Migliorati, Valentina Ferretti

Generating alternatives for decision problems/opportunities is a fundamental step of the decision process and indeed the driver of one of the six requirements for decision quality, i.e. the one about considering creative but feasible alternatives. However, this step has received less attention, both in theory and in practice (Colorni and Tsoukiàs, 2020). Research has shown that the range of alternatives people identify for a given decision is often too narrow and that decision makers often anchor their thinking to an idea they are familiar with. Indeed, the first alternatives that come to mind are the obvious ones, those that have been used before in similar situations and those that are readily available. The paper aims to compare with a systematic approach the effectiveness of two different techniques that seem to be promising in supporting the alternatives' generation. In particular, the research tested and compared the traditional SWOT analysis and the more innovative Value Focused Thinking approach (Keeney, 1992) through the analysis of 52 building regeneration projects developed during a workshop with master students. The results of the analysis confirm that a dedicated and focused effort within a methodological support allows the decision maker to identify more and better alternatives from which to choose. Additionally, the results suggest that Value Focused Thinking is performing better than SWOT with reference to the mitigation of narrow framing and anchoring bias.

■ TD-09

Tuesday, 14:00-15:40 - Room 9

Modeling and Solver Interfaces

Stream: Mathematical Optimization Software
Invited session
Chair: Stefan Mann

1 - AMPL solver interfaces with callbacks

Filipe Brandão, Robert Fourer

Using a high-level algebraic representation that describes optimization models in the same ways that people think about them, AMPL helps successfully implementing large-scale optimization projects. AMPL does not incorporate solvers, but rather provides interfaces to all of the best products of competing solver developers. In this talk, we will present new solver interfaces for several MIP solvers which allow users to implement solver callbacks. We will focus on the Python interface for Gurobi, but similar interfaces with callbacks are available for other solvers and programming languages.

2 - Deploying models with GAMS MIRO

Stefan Mann, Franz Nelissen

During this presentation we will introduce GAMS MIRO, a web interface for GAMS models. GAMS MIRO has tight connections to the GAMS modeling system, allowing users to manipulate data, manage scenarios, evaluate the results graphically, and much more from within the web browser, by adding very few annotations to the model.

The users specify which input and output datasets they want to visualize, and the result is a fully functional GUI that can be launched directly from GAMS Studio or via a shortcut on the Desktop.

GAMS MIRO also facilitates the generation, organization, and sensitivity analysis of multiple scenarios of an optimization model. A server version will support additional features: managing multiple optimization models for concurrent users with access management, load balancing, batch configuration, and much more.

3 - Efficient presolving methods for solving maximal covering and partial set covering location problems

Wei-Kun Chen, Liang Chen, Shengjie Chen, Yu-Hong Dai

The maximal covering location problem (MCLP) and the partial set covering location problem (PSCLP) are two fundamental problems in facility location and have a widespread applications in practice. The MCLP determines a subset of facilities to open that maximizes the demand of covered customers subject to a budget constraint on the cost of the open facilities; and the PSCLP aims to minimize the cost of the open facilities while requiring that a certain amount of customer demand is covered. Both problems can be modeled as mixed integer programming (MIP) formulations. However, because of the intrinsic NP-hardness nature, it is a great challenge to solve them to optimality by standard MIP solvers, especially for large-scale cases. In this paper, by exploiting the special problem structures of the two problems, we propose five customized presolving methods for enhancing the capability of employing standard MIP solvers in solving the two problems. The proposed presolving methods are designed to reduce the sizes of the problem formulation and the branch-and-bound search tree. By extensive numerical experiments, the proposed presolving methods are demonstrated to be effective in accelerating the solution process of solving the MCLP and PSCLP. Moreover, they enable us to solve problems with billions of customers, which is at least one order of magnitude larger than those that can be tackled by previous approaches.

4 - How linear programming became practical

Robert Fourer

Although a recognizable simplex approach to linear programming was being studied by Dantzig and others by 1947, the initially proposed algorithms were (and have remained) computationally impractical. Drawing on a series of obscure RAND technical reports, this talk tells the story of how the "revised" simplex method subsequently emerged to make today's powerful solvers possible. The presentation concludes by considering how the earlier, impractical simplex algorithms have come to be adopted by almost all textbooks, while computationally practical versions remain known mainly to experts.

■ TD-10

Tuesday, 14:00-15:40 - Room 10

Financial Reporting

Stream: Operational Research in Financial and Management Accounting
Invited session
Chair: Sascha H. Moells

1 - Comparative research in corporate governance and accounting: a methodological note

Vladlena Prysyazhna, Sascha H. Moells

In this work we address the selection bias due to observables as an important methodological issue that is highly relevant for comparative corporate governance research as well as (financial) accounting. The methodological problem under investigation arises because companies from different countries are being compared which systematically differ with regard to their firm-specific characteristics. While we consider the propensity score matching (PSM) as an appropriate technique to handle this problem, such a treatment is ignored by many scholars working in the aforementioned fields. Except for single papers, most authors fail to address the problem of selection due to observables in their empirical studies or only refer to it in a not very concincing fashion as typically the applied matching techniques or the covariates used to estimate propensity scores are neither justified (and only mentioned) nor economically motivated. PSM, however, cannot be automatically applied in the context of comparative corporate governance and accounting research without further adjustments resulting in an extensive discussion in each single case. We claim that by carefully justifying the formulated propensity score model and applied matching technique and by carefully assessing the matching quality interesting insights can be provided and new directions of future investigation could be proposed.

2 - Forecasting methods in accounting to improve financial reporting quality

Lukas Benjamin Heidbrink

Companies are required to forecast under IFRS and are facing a rising number of prognostic elements in their annual statements (e.g. forecasting cash flows to legitimate the going concern assumption, impairment tests under IAS 36 and valuation of financial instruments under IFRS 9). Hence, methods for the preparation of forward-looking information become more important in order to prevent biased forecasting and earnings management. I provide an overview of crucial forecasts in accounting, identify interdependencies and compare different forecasting methods to reveal earnings management implications. I focus on quantitative forecasting methods and evaluate the influence of discretionary disclosures. Taking measures of earnings management into consideration reveals significant improvements of accounting-based forecasts. I suggest installing an integrated forecasting system that explicitly considers the dependencies of time series in order to get consistent forecasts for different forecasting problems in accounting. Moreover, reporting on methods and parameters used for forecasting is needed for auditing purposes. As a result, this will ensure a fair presentation and an improvement of the quality of financial statements.

3 - Deferred taxes in context of corporate management by accounting-based value added figures

Carolin Famulla

Deferred taxes are defined as futural tax payments respectively refunds according to IAS 12, existing because of temporary differences between the accounting and tax balance sheet. With regard to the external reporting and in sense of the temporary-concept the purpose of deferred taxes is to represent the correct corporate assets. In context of the value-oriented management based on accounting key figures there is the question how to treat deferred taxes. For this investigation the Economic Value Added (EVA) is used. The external accounting provides the basic parameters of the EVA. For the internal management it is necessary to modify the external accounting data. The choice of the conversions rests on the decisioner and reveals discretion to influence the figures. For the conversions of deferred taxes, there exist two approaches. First, there is the possibility to consider only the actual incurred taxes, so that deferred taxes are disregarded. Second, they are taking into account as well in the profit as capital size of the EVA. The presented approach shows the relevance of deferred taxes for the corporate management based on accounting-oriented figures by example of the EVA.

■ TD-11

Tuesday, 14:00-15:40 - Room 11

Advances in Optimization

Stream: Data Science meets Optimization
Invited session
Chair: *Adam Górski*

1 - Use of soft computing for solving combinatorial optimization problems

Arindam Roy, *Ilkyeong Moon*

Abstract Soft computing (SC) is a widely used technique in the present research of optimization. Nowadays SC is used to design complex real-world problems. Evolutionary computing techniques are a part of SC, and genetic algorithm (GA), ant colony optimization (ACO), and particle swarm optimization (PSO) are most popular evolutionary approaches for designing and solving complex optimization problems. GAs are robust adaptive optimization techniques based on a biological paradigm. Similarly, ACO and PSO are the biologically inspired SC techniques used to solve complex decision-making problems. The hybridization of these methods is much effective for solving complex combinatorial optimization problems. There is a lot of scope for developing different GA operators and also the hybridization of GA, ACO, and PSO for the optimum solutions of NP-hard problems. In this study, we present real-life examples in which soft computing is well utilized. We developed new operators in GA and show the effectiveness of the operators using numerical experiments.

Acknowledgments This research is supported by the BP Program of the NRF, Korea funded by the Ministry of Science, ICT, and Future Planning [Grant No. NRF-2020H1D3A2A01085443].

2 - Sparse simultaneous component analysis using alternating maximization and adaptive lasso penalty

Rosember Guerra-Urzola, *Juan Vera*, *Katrijn Van Deun*, *Klaas Sijtsma*

Data integration is currently one of the main challenges in data analysis. Often information from different sources is collected and joined as one -for instance, psychological questionnaire data and genetic risk scores. Thus, more and more data consist of multiples data blocks that share the same observations. Simultaneous component analysis (SCA) has been traditionally used for integrative analysis of such kind of data. SCA allows for identifying the same component for all sources. However, basing the analysis on all variables makes the interpretation difficult, especially in high-dimensional settings. Therefore, looking for a sparse structure is natural; it identifies the common and distinctive source of variation across all data blocks. This paper tackles the sparse SCA problem. We present two algorithms. The first solves the cardinality-constraint formulation by alternating maximization over the spere and Mix Binary Linear Optimization. The second one is an extension of the GPower method for sparse-PCA and solves the adaptive lasso penalty formulation. We use simulation to assess these formulations regarding the optimal value, sparse structure recovery rate, and computational time. These methodologies allow finding high-quality feasible solutions in seconds for large dimensions.

3 - Bayesian multiobjective ranking and selection

Sebastian Rojas Gonzalez, *Juergen Branke*, *Inneke Van Nieuwenhuyse*

In multiobjective optimization, several conflicting objectives are optimized simultaneously. The goal is to find or approximate a set of Pareto-optimal solutions that reveal the essential trade-offs between the objectives, where optimality means that no objective can be improved without deteriorating the quality of any other objective. We consider a setting where the objectives have to be observed through stochastic simulation. Current multiobjective algorithms focus predominantly on deterministic problems; the few literature for stochastic problems normally assumes homoschedastic noise, and approximates the Pareto-optimal combinations simply using the sample means. This may lead to two possible errors: solutions that are actually Pareto-optimal can be wrongly considered dominated, or solutions that are truly dominated are wrongly considered Pareto-optimal. We aim to improve this identification by developing a novel Bayesian multiobjective ranking and selection algorithm for problems with heteroscedastic noise. We propose a sequential sampling technique that uses a combination of stochastic kriging metamodels and hypervolume estimates to decide how to allocate samples. Experiments show that the proposed method only requires a small fraction of samples compared to the standard allocation method, with the exploitation of the correlation structure being the dominant contributor to the improvement.

Tuesday, 16:00-17:40

■ TE-01

Tuesday, 16:00-17:40 - Room 1

Inventories in Supply Chains

Stream: Supply Chain Management
Invited session
Chair: Dušan Hrabec

1 - A new data-driven approach for multi-period inventory management
Felix Schmidt, Richard Pibernik

Multi-period inventory problems have been studied extensively during the last decades. A common assumption is that the decision maker knows the distribution of uncertain demand. In practice, however, the underlying demand distribution is difficult to estimate: demand is often non-stationary, correlated across time and different products, and may depend on external factors (e.g., weather, holidays). Several studies have shown that estimating a (stationary) demand distribution and subsequently solving a stochastic optimization problem may lead to inferior results. Recently, Ban and Rudin (2019) have shown how "optimal" ordering quantities in a single-period setting can be derived using machine learning techniques that take historical demand and auxiliary data as input to directly prescribe inventory decisions. In this presentation, we show how such "data-driven" approaches can be applied to the more challenging multi-period inventory problem (fixed setup costs, ordering decisions interrelated, dependent demand). We develop an approach based on "weighted sample average approximation" as proposed by Bertsimas and Kallus (2019) and demonstrate how it can be tailored to a multi-period inventory problem with many items and demand that may depend on various external factors. We discuss the challenges that arise when applying prescriptive analytics to multi-period settings and illustrate first findings based on a real-world application in the pharmaceutical industry.

2 - The Effect of Inventory Sharing and Postponement Strategies on Prepositioned Stocks
Lamia Gulnur Kasap, Burcu Balcik

Humanitarian organizations (HOs) pre-position their relief items in regional humanitarian warehouses to respond to disasters that occur in different countries. However, pre-positioning (PP), although required to reduce the demand uncertainty, is an expensive disaster preparedness strategy. Maximizing the benefits from the significant PP investments and making PP more efficient are important concerns for HOs. In this study, we evaluate the effects of postponement and stock sharing practices on the post-disaster demand fulfillment performance, which is measured by fill rate (FR) and response speed (RS) metrics. Motivated by our collaboration with the practitioners, we design a model in which the final labeling process of relief items for each HO is postponed. In this way, the HOs that do not respond to the affected country can efficiently share the unused stocks with the HO that does respond. To determine the amount of stock shared among HOs, the sharing policies (SP) reviewed in the literature are handled in three ways in the proposed model: uncontrolled, proportional, and equal. To cope with the difficulties of modeling some aspects of the SPs, we use Monte Carlo simulation technique. Specifically, we develop a simulation model that includes an inventory allocation model and evaluate the three SPs under different postponement proportions on FR and RS metrics. We use scenario data on disasters in the Caribbean region to analyze the impact of the proposed inventory system.

3 - A stochastic multi-item inventory system with full backlogging under limited warehouse capacity
Joaquin Sicilia-Rodriguez, Luis A. San-José-Nieto, David Alcaide Lopez de Pablo, Beatriz Abdul-Jalbar

This work presents a multi-item inventory system with a known inventory cycle under stochastic demands. We suppose that shortages are allowed and they are completely backordered. Moreover, we consider that demands are independent random variables, and they follow power patterns throughout the inventory cycle. We develop a mathematical model to determine the optimal inventory policy that maximizes the expected profit per unit time. Next, we present an efficient algorithm to obtain the initial inventory levels and the optimal reorder points when the warehouse has a limited capacity. This work extends several inventory systems analyzed by other authors, in particular, the newsboy problem with a single linear resource constraint. Finally, we present various numerical examples to illustrate the applicability of the theoretical results developed in this work.

4 - The value of integrated planning for production and inventory routing problems: A systematic review and meta-analysis
Dušan Hrabec, Lars Magnus Hvattum, Arild Hoff

This paper presents a comparison of sequential and integrated planning for the production routing problem, in which production, inventory, and routing decisions must be made. The aim is to estimate the expected value of treating the problems as a whole, rather than making decisions sequentially. In particular, the following research questions are posed: What is the expected cost reduction when combining production, inventory, and routing in a single modeling framework, compared to solving the problems individually in a sequence? Under which circumstances is it most beneficial to tackle an integrated problem? The goal is to establish whether the solutions obtained by the integration are clearly better than approximate solutions obtained by a more simplified process, and if so, under which circumstances this difference is the most pronounced. To answer these research questions, a systematic review is performed, followed by a meta-analysis. The systematic review provided a set of 20 relevant articles that were analyzed in depth. Computational results from 15 articles were obtained and included in a meta-analyis. The meta-analysis provides a general conclusion on the expected cost savings provided by integration, corresponding to 11.08 % (with a 95% confidence interval [6.58, 15.58]). Finally, individual results obtained via sensitivity analyses in the collected articles are summarized, enabling insights into how paticular parameters influence potential savings by integration.

■ TE-02

Tuesday, 16:00-17:40 - Room 2

IFORS Prize for OR in Development 2020 - 2

Stream: IFORS Prize for OR in Development Finalists
Award Competition session
Chair: Mario Guajardo

1 - Decision support for locating optimal tower sites for early-warning wildfire detection systems in South Africa
Andries Heyns, Warren du Plessis, Kevin Curtin, Michael Kosch, Gavin Hough

Early wildfire detection can effectively be achieved by systems of specialised tower-mounted cameras. Historically, the locations at which a system's towers are placed have been planned by foresters and locals with intimate knowledge of the terrain rather than by computational optimisation tools. When entering vast new territories, however, such knowledge and expertise may not be available to system planners. With the aim of maximising system visibility of smoke above a prescribed region, the process of selecting multiple tower sites from a large number of potential site locations is a complex combinatorial optimisation problem. We present a site-selection optimisation framework which may be used in such instances. Novel geographical and spatial analysis tools are implemented together with a genetic algorithm and a

weighted-sum integer-linear programming approach to determine superior candidate tower-site layout alternatives. Guided by feedback from experts from the South African-developed ForestWatch wildfire detection system, the framework has matured into a fully-functioning decision support tool. This was recently demonstrated when the framework was implemented in the site-selection process of a four-tower camera-based wildfire detection system in South Africa's Southern Cape - a mere 60 km away from the location of arguably the most devastating wildfire in South Africa's history, which occurred in 2017.

2 - Optimal Investment Strategies to Minimize Flood Impact on Road Infrastructure Systems in Vietnam, GCRF-OSIRIS

Maria Paola Scaparra, Trung Hieu Tran, Siao-Leu Phouratsamay, Thinh Dang, Phùng Chính, Hiep Nguyen, Graham Adutt, Dang Phuong, Chinh Ngo, Pham Chung

Development challenges such as urban flooding in Southeast Asia are typically addressed with approaches drawing on environmental science, cost-benefit analysis and local political expediency. The GCRF-OSIRIS Project, funded by the Global Challenge Research Fund through the British Academy, introduced a novel approach to identify cost-efficient measures to mitigate the impacts of urban flooding by integrating OR with transport economics, climatology, hydrology and social science. In close partnership with Vietnamese academic and government agencies, the project created a scenario-based, multi-period, bi-objective Mixed Integer Linear Programming model to minimize infrastructure damage and traffic congestion in central districts of Hanoi. A GRASP metaheuristic was developed to solve large-scale instances of the problem and the overall approach was embedded into a Decision Support System to enable planners and policy makers to use the optimisation tool. Using a set of drainage mitigation measures provided by Vietnamese stakeholders and flood maps generated by researchers at the Vietnam Institute of Meteorology, Hydrology and Climate Change, the optimisation tool was applied to generate a 20-year plan of investments. More than half of the total reduction in congestion and damage was found to be achievable with less than 25% of available budgets. The project has catalysed interest in Vietnam and in neighbouring countries to develop capacity in OR to address development challenges.

3 - Eco-friendly mobile application for the Household Waste Collection and Transportation Problem: Case of the City of Sousse

Haifa Jammeli, Masri Hatem, Fouad Ben Abdelaziz, Mejdi Argoubi

This paper's aim is to develop a model for the household waste collection and transportation problem in the city of Sousse, one of the largest cities in Tunisia. Several vehicles with a finite capacity are located at the depot. The vehicles must collect the waste accumulated in all bins. The waste is then delivered to a transfer center, before vehicles return to the depot. The proposed model determines the routes of the vehicles and the number of bins to be assigned to each potential location, while minimizing the collection costs and the environmental impact. The problem can be considered as a bi-objective optimization problem, as cost minimization will be ensured by the optimal assignment of the determined minimum number of bins. We also consider the stochastic aspect of population size, which is supposed to follow a normal distribution. Our model is then a stochastic bi-objective programming model. A solution is obtained with reasonable computational effort using a hierarchical approach consisting of two stages as "cluster-first route-second". In the first stage, a set of n locations of bins is assigned into k disjoint clusters using the K-means clustering algorithm. In the second stage, a certainty equivalent program to the bi-objective stochastic program is proposed, based on a chance-constrained, recourse and a goal programming approach. The model is tested and implemented using real data from the municipality of Sousse. The study shows that our model leads to lower environmental impact and an almost 38% reduction in the economic costs.

■ TE-03

Tuesday, 16:00-17:40 - Room 3

Logistics, Transportation and Traffic 4

Stream: Logistics, Transportation and Traffic (contributed)
Contributed session
Chair: Johann Hartleb

1 - Green logistics and transportation: Estimating a fuel consumption formula based on driver behaviour

Zhuowu Zhang, Emrah Demir, Robert Mason

It is well known that road freight transport is one the main contributors of carbon emissions, which in turn is contributing to climate change. Since, in the very near future, the potential efficiency improvements from new vehicle and engine technologies aspects are limited, many researchers have focused on factors which impact on reducing fuel consumption and consequently reducing CO2e emissions, as a short-term solution. Yet, driver related factors are often left in the basket, or at least not be studied in a comprehensive way. Therefore, this paper aims to gain a better understanding of the relation between driver behaviour (professional logistics drivers) and fuel consumption. By quantifying the characteristics of driver behaviour from telematics, a data set of over 4,000 driving records in the freight logistics sector, the relationships between driver behaviour variables (11 parameters) and fuel consumption are analyzed. The results of this research show that driver behaviour does influence fuel consumption, yet, only some of the driving characteristics have significant impacts on fuel consumption. The research firstly develops a fuel consumption model based on driver behaviour which fill the research gap. In addition to this, the results provide some useful implications and guidance for eco-driving programs and other methods that target changing professional driver behaviour.

2 - A sequence-dependent traveling salesman problem in outbound logistics

Hyung Joo Cha, Taesu Cheong, Joonyup Eun

We address the sequence-dependent traveling salesman problem (SDTSP) which is a generalization of the well-known traveling salesman problem (TSP). The SDTSP arises in outbound logistic applications, such as a Hazardous Materials (HAZMAT) shipping problem. Safety issues emerge during the HAZMAT delivery and the magnitude of an accident is dependent on the load of the HAZMAT vehicle and the route it moves along. This type of routing problem is categorized as a sequence-dependent TSP that requires dynamic decisions of the next area to visit. Dynamic nature of this problem requires heavy computation which makes it very hard to reach its optimality. In this sense, we develop a heuristic search algorithm that utilizes the lower and upper bounds of the solutions to reduce the search space efficiently. A computational study is given to show the efficiency of the computational cost compared to a conventional approach.

3 - Integrated planning in public transport: robust and cost-efficient vehicle and crew scheduling with controlled trip shifting

Bastian Amberg, Boris Amberg

This work combines integrated vehicle and crew scheduling in public bus transport with simultaneous trip shifting. During integrated scheduling the mutual dependencies between vehicle and driver schedules are taken into account to compute resource schedules that are both cost-efficient and robust against small disruptions during operations. In addition, the possibility to shift trips within small defined time windows, i.e. slightly modifying the underlying timetable without changing trip durations, is used for both increasing cost-efficiency and robustness. However, shifting of particular trips may have an unwanted impact on the original timetable structure. For example, headways between consecutive trips of a line may be changed, or the quality of some passenger connections may be lost. To avoid this, the proposed approach further aims at minimizing changes to the original timetable structure when shifting trips.

We propose a column generation based solution approach to solve the integrated scheduling problem with controlled trip shifting. Robust and

cost-efficient vehicle itineraries and driver duties are generated in the column generation pricing problems. The pricing problems are modelled as resource constrained shortest paths problems and solved by dynamic programming using a labelling algorithm. We evaluate the solution approach on real-world datasets and examine the impacts of shifting trips on costs, robustness, and alteration of the original timetable structure.

4 - Modeling and solving line planning with integrated mode choice
Johann Hartleb, Marie Schmidt, Dennis Huisman, Markus Friedrich

We present a mixed integer linear program (MILP) for line planning with integrated mode and route choice. In contrast to existing approaches, the mode and route decisions are modeled according to the passengers' preferences while commercial solvers can be applied to solve the corresponding MILP. The model aims at finding line plans that maximize the profit for the public transport operator while estimating the corresponding passenger demand with choice models. Both components of profit, revenue and cost, are influenced by the line plan. Hence, the resulting line plans are not only profitable for operators but also attractive to passengers. By suitable preprocessing of the passengers' utilities, we are able to apply any choice model for mode choices using linear constraints. We provide and test means to improve the computational performance. In experiments on the Intercity network of the Randstad, a metropolitan area in the Netherlands, we show the benefits of our model compared to a standard line planning model with fixed passenger demand. Furthermore, we demonstrate with the help of our model the possibilities and limitations for operators when reacting on changes in demand in an optimal way. The results suggest that operators should regularly update their line plan in response to changes in travel demand and estimate the passenger demand during optimization.

■ TE-04

Tuesday, 16:00-17:40 - Room 4

Assignment, location and routing in humanitarian logistics

Stream: OR in Health, Medicine and Life Sciences
Invited session
Chair: *Sibel Salman*
Chair: *Carlos Rojas*

1 - Drone routing for post-disaster damage assessment
Birce Adsanver, Elvin Coban, Burcu Balcik

In this study, we consider routing Unmanned Aerial Vehicles (UAVs) for post-disaster assessment. Disasters are events that seriously disrupt the functioning of society and are often unpredictable. Therefore, the management of disaster response and rescue operations is difficult. Decisions, such as where and when resources should be sent, should be rapidly evaluated after the disaster. Although widespread use of UAVs in disaster situations is a current issue in the humanitarian sector, few studies have developed methods to support decision-makers and practitioners for effective use of UAVs in disaster assessment. We propose a mixed-integer linear programming model to route UAVs for post-disaster assessment. Computational results will be presented based on an earthquake setting.

2 - A Multi-Period Capacitated Mobile Facility Location Problem for Mobile Demands: Relief Aid Provision Planning for En Route Refugees
Amirreza Pashapour, Sibel Salman

Nonprofit humanitarian organizations aim to fulfill the requirements of en route refugee groups who are on their journey to cross borders due to social life issues. Therefore, some mobile facilities are required to provide refugee groups with packages of services. We study the problem of deciding the number, routes, service providing locations and periods of such mobile facilities. In each period, refugee groups move from one node to an adjacent one in their predetermined path. For the continuum of service, the people of each refugee group should be served at least once in a predetermined number of consecutive periods. Each mobile facility has a determined capacity and at each period can provide service only for some refugees with respect to its capacity. So, we aim to minimize the total cost of the mobile facilities that comprises of the fixed setup costs, daily operational costs and travel costs, while ensuring the service continuum requirement. We call this problem the multi period capacitated mobile facility location problem with mobile demand (MCMFLP-MD). We formulate a mixed integer linear programming (MILP) model for this problem and show that it is indeed an NP-Hard problem. We also develop an accelerated Bender's decomposition algorithm as an exact solution method. The required data is extracted from the 2020-2021 Honduras Migration Crisis.

3 - A robust optimization model for relief distribution network under uncertainty
Gyu M. Lee, Moddarssir Khan Nayeem

Humanitarian logistics has recently gained significant attention due to the increasing frequency of natural and human-made disasters. An efficient relief distribution strategy is required to avoid significant suffering in disaster-stricken areas. Most governments pre-located the relief goods at the pre-determined warehouses against possible disasters. Upon the disasters, those goods must be shipped to the relief distribution centers (RDCs) to be further distributed to the residents in impacted areas. Secondary disasters can strike the areas impacted by the first disaster. The needs of additional RDCs must be determined as well in response to the secondary disasters. A robust optimization model is proposed to hedge against uncertainties in RDCs' capacity and relief demand. Its objective is to minimize transportation cost, additional RDC cost, and unmet demand. A numerical analysis is given to demonstrate the effectiveness of the proposed model.

4 - Location, Allocation, Routing models for humanitarian relief considering accessibility limitations
Carlos Rojas, José David Meisel Donoso, Wilson Adarme

Like the coordination of transport operations, decisions on the location of facilities and the allocation of demand nodes are a challenge for the humanitarian supply chain. In disaster situations, especially in the immediate response phase, it is necessary to distribute emergency aid to the population in the affected areas. However, some disaster events such as landslides, earthquakes, storms or floods can generate transitory road disruptions causing accessibility limitations and therefore difficulties in humanitarian operations. Therefore, this paper presents an adaptation of the location, allocation, and routing problem to a humanitarian aid context considering accessibility constraints. This work proposes the application of analytic hierarchy process for the identification of safe zones and a mixed integer linear programming model that contributes to optimize the location decisions of temporary distribution points based on the identified potential safe zones and the distribution of humanitarian aid considering the response times to the affected population and the transitory interruptions of the roads. The main contribution of the work is the proposal of mathematical modeling of the situation in which, given the accessibility limitations generated by a sudden natural catastrophe, it affects the response times or attention to the affected population. Finally, an example of application and analysis of the results is presented.

■ TE-05

Tuesday, 16:00-17:40 - Room 5

Applications of DEA 5

Stream: Data Envelopment Analysis and Performance

Measurement
Invited session
Chair: *Jing Fu*

1 - Waste management evaluation accounting for Sustainable Development Goals: A DEA-TOPSIS approach
Giovanna D'Inverno, Laura Carosi, Giulia Romano

In the 2030 United Nation Agenda, solid waste management is directly related to 12 out of 17 Sustainable Development Goals. Looking at the specific targets, municipalities are supposed to reduce their environmental footprint by improving waste management: prevention, reduction and recycling are the priority. The waste management performance evaluation must consider the municipal efforts towards both the service provision and the accomplishment of the sustainable development targets. An innovative efficiency model is proposed by integrating two different tools, a frontier estimation technique and a multicriteria decision making approach. As for the latter, an environmental indicator is constructed by means of the TOPSIS technique, taking into account dimensions strictly linked to the Sustainable Development Goals. As for the former, municipalities' performance is investigated by suggesting a novel Data Envelopment Analysis model where both volume and ratio outputs are considered and weight restrictions are fixed. The presence of weight restrictions emphasizes the extent of the municipality's willingness to accomplish the environmental targets from the input side. A robust conditional analysis is also provided to investigate the influence of contextual variables on the municipal waste management performance while accounting for atypical observations. The empirical use of the proposed model is shown by assessing the waste management performance of 232 Tuscan municipalities.

2 - A fairer assessment of DMUs in a generalised two-stage DEA structure
Marios Dominikos Kremantzis, Patrick Beullens, Jonathan Klein

Single-stage and basic serial two-stage systems within Data Envelopment Analysis (DEA), have used various methods to attain fairness in the evaluation outcomes. Little work, however, has been done addressing this challenge in a generalised two-stage structure with additional inputs in the second stage and part of intermediate measures as final outputs. In this paper, we argue that fairness is improved by increasing measures related to the discriminatory power and the weight scheme. We also provide a mechanism that gives prominence to a more contemporary concept of fairness about diversity and inclusion of minority opinions. The latter aspect has, to our knowledge, not yet received explicit attention in the methodological development of DEA. To this end, we propose a novel combination of an additive self-efficiency aggregation model, a minimax secondary goal model, and the CRiteria Importance Through Inter-criteria Correlation (CRITIC) method, to achieve the aforesaid aspects of fairness and thus a better degree of cooperation between stages of a DMU and among DMUs. The minimax model, in particular, seeks for peer evaluation whereby each peer aims to evaluate the worst of the other players in the best possible light. Finally, the application of the CRITIC method to DEA, which is by itself novel, alternatively addresses the aggregation problem within the cross-efficiency concept. A numerical experiment illustrates the applicability of the proposed models.

3 - A novel productivity index for the Value-Based DEA approach
Maria Gouveia, Carla Margarida Saraiva Oliveira Henriques, Luis C. Dias

This paper proposes a novel productivity index based on Value-Based Data Envelopment Analysis. This methodology combines Data Envelopment Analysis and Multi-Criteria Decision Analysis converting the original performance data for each criterion into value functions that translate the decision makers' preferences. Furthermore, it also suggests a robustness assessment for the productivity indicator developed. The usefulness of proposed approach, which is inspired on the Luenberger Productivity Indicator, is illustrated through an example with real world data. Specifically, we address the assessment of relative eco-efficiency changes of the production and consumption chains of the electricity sector of 28 countries European Union. This allows understanding the extent to which eco-efficiency gains were the result of pure efficiency (movements toward the frontier) or technology improvements (frontier shifts). Overall, our findings highlight the advantage of using value functions in the context of productivity analysis, suggesting the existence of distinct productivity gains if the decision makers' preferences are addressed through nonlinear value functions.

4 - Meta-frontier DEA Analysis to Hometown Tax Efficiency in Koga
Jing Fu

In this research, meta-frontier DEA is utilized in the analysis of hometown tax efficiency in Koga. Hometown tax is a unique system in Japan that allows residents to make donations to any municipality based on their own preferences, and donors in turn receive tax saving and reciprocal gifts as benefits. The initial purpose of the hometown tax was to rectify local tax revenue disparities and promote revitalization. Mainly owing to the marketing strategy on reciprocal gifts to donors, hometown tax has increased dramatically in recent years. However, some municipalities started to include high-end gifts that are not their local products to appeal donations. As a result, a large portion of the tax receipts went into expenses for the gifts and future marketing. In June of 2019, Japanese government strictly regulated the reciprocal gifts to be local products with less than 30% of the donation amount and quite a few municipalities have to renew their lineup of the gifts. We will conduct meta-frontier DEA analysis from the perspectives of municipality, portal website, enterprise as well as product and propose strategies to Municipality K for gift lineup adjustment.

■ TE-06

Tuesday, 16:00-17:40 - Room 6

Games and Applications 2

Stream: Dynamics and Games
Invited session
Chair: *Hyojin Joo*

1 - Control properties of some parametric games from an algebraic variety point of view
Denis Fedyanin

It is known that Nash equilibria can be found as a solution of the system of the best answers, i.e. varieties [1]. If the best response functions are given algebraically, then the corresponding algebraic variety is obtained. This interpretation allows one to prove the existence of equilibrium using fixed point theorems. In this work, we will be interested in parametric equilibria and, accordingly, a variety of a particular form. The task will be to find a parameter for which the maximum of the function given at the variety's points is maximum [2]. A game is considered in which the players' best response is the polynomials of the sum of the actions of other players of given nonzero degrees. It is shown that if the number of Nash equilibria is finite, then their number does not exceed the maximum degree among the polynomials of the best responses, if there are no additional restrictions on the actions of the players. We have investigated the influence of the coefficients of the polynomial best responses on equilibria.

2 - Strategic partnership formation in networks
Qiongyuan Cao, Joosung Lee

In this paper, we study the role of strategic partnership formation in the decentralized bilateral bargaining game. In particular, our model allows players to strategically choose their bargaining partners and those who reach an agreement will leave the game without replacement. Allowing players to choose their bargaining partner, we find a maximum matching in a Markov perfect equilibrium. It is noticeable that current studies of bilateral bargaining in non-stationary networks

focus on pairwise random meetings, which restricts players' bargaining partners. Hence, multiple equilibria may coexist, and the Markov perfect equilibrium fails to yield a maximum matching in some networks. Compared with them, our finding indicates that players will form a link included in a maximum matching and lead to efficiency no matter what the underlying network is.

3 - On savings on the makespan and on the total costs under positional effects: a natural extension of sequencing games
Alejandro Saavedra-Nieves, Maria Gloria Fiestras-Janeiro, Manuel Alfredo Mosquera-Rodríguez

Sequencing problems describe situations where several jobs have to be processed on a set of machines. This class of problems are formally characterized by an initial order for the jobs and a family of cost functions by their processing. In this sense, different factors, as the starting time or the position in the queue of a job, naturally affect its real processing time.

Cooperation in sequencing problems was widely treated in literature with the aim of minimizing the processing total costs. In this sense, the usual idea of savings in sequencing can be naturally extended to any other setting in which the measured magnitude is not constant over all orders. Under positional effects, other classical measures of orders, as the makespan, may be considered since that, in this setting, savings also come from repairing positions of jobs. However, two common issues have to be still addressed: identify the optimal sequence for the jobs, and distribute the associated savings of the measure of interest with respect to the initial order among the agents using cooperative game theory.

In this work, we analyse sequencing problems with learning and deterioration positional effects of the machine. Specifically, we obtain some results on the optimal order for the makespan and for the total costs and analyse the cooperation through the saving games associated to these situations.

4 - A principal-agent model of partnership
Hyojin Joo, Sayantan Ghosal, Wee Meng Yeo

In this model, Department Work and Pensions (Principal) in the United Kingdom provides menus of Universal Credit contracts to recipients (Agent) and then they apply for it to receive benefits. Department Work and Pensions does not know about the recipients' properties whether they genuinely need Universal Credit or not and wants to avoid mimicking each other, so it uses the assessment period for four weeks after submitting it by the recipients and could try to use food banks as an instrument of differentiating the recipients. Department Work and Pensions could observe whether the recipients are going to food banks or not because if their situation is urgent, they would go to food banks for survival. The existing problem is that it does not differentiate between the people who genuinely need help and the people who do not genuinely need help. Therefore, a lot more the latter access the food bank even though they do not need to go to the food bank if they are different payment scheme. The point of this model is to examine the delay that Department Work and Pensions has to do in the payment and therefore people are having to rely on the food bank.

■ TE-07

Tuesday, 16:00-17:40 - Room 7

OR in Health, Medicine and Life Sciences 1

Stream: OR in Health, Medicine and Life Sciences (contributed)
Contributed session
Chair: Francisco Martos-Barrachina

1 - The Impact of Vertical Integration on Physician Behavior and Healthcare Delivery: Evidence from Gastroenterology Practices
Lina Song

The U.S. healthcare system is undergoing a period of substantial change, with hospitals purchasing many physician practices ("vertical integration"). In theory, integration could improve quality by promoting care coordination, but could also worsen it by impacting the care delivery patterns. The evidence quantifying these effects is limited, because of the lack of understanding of how physicians' behaviors alter in response to the changes in financial incentive structures after integration. We study the impact of vertical integration by examining Medicare patients treated by gastroenterologists, a specialty with a recent increase in integration. Using a causal model and national panel data of 2.6 million patient visits across 5,488 physicians between 2008-2015, we examine changes in quality and spending. We find that integration resulted in increased spending and worse quality of care. In particular, physicians reduce recommended care processes (e.g., anesthesia with deep sedation) after they integrate, which results in a substantial increase in patients' post-procedure complications. This is because the financial incentive structure of the integrated practices discourages them from allocating expensive resources to relatively unprofitable procedures. Our results suggest that policymakers should carefully align the financial incentives of the integrated providers to prevent the unintended consequences on the quality that may result from the current integration trends.

2 - Blood inventory management: ordering policies for hospital blood banks under uncertainty
Maria Meneses, Inês Marques, Ana Paula Barbosa-Póvoa

The blood supply chain faces several challenges, such as stochastic demand and supply, the relation between the various stages of the chain, and the intrinsic nature of the product. Blood is a perishable, scarce, and (in most cases) voluntarily supplied product used to perform vital transfusions in patients which increases the pressure of managing its supply chain as efficiently and effectively as possible. For these reasons, it is crucial to have optimized inventory management that allows the availability of the right type of blood product, in the right place, at the right time, and in the right amount while avoiding wastage, especially in hospital blood banks that are the direct link to patients. This work aims to address these challenges with a new two-stage stochastic programming model for defining optimal ordering policies for blood products, considering demand uncertainty. This model minimizes wastage, shortages, and total costs related to blood inventory management, including ABO-substitutions. The model supports hospitals' tactical-operational decisions of when and how much blood products to order. A case study of a Portuguese hospital is used to validate and show the applicability of the model. By comparing several ordering policies, we show that it is possible to contemplate the decision maker's goals whilst obtaining substantial reductions in terms of wastage and costs. These results allow the definition of an important set of managerial insights.

3 - Extended operating room hours: towards an analysis framework
Mariana Oliveira, Valérie Bélanger, Angel Ruiz, Daniel Santos, Inês Marques

Providing timely surgical care to those in need is an important goal to operating room managers. In a context where a mismatch between demand and supply exists (e.g. resuming elective surgeries after the COVID-19 pandemic), long backlogs of patients may increasingly hinder access to care. Frequently, to maximize the number of surgeries performed in due time, hospitals need to rely on different strategies to increase surgical capacity. Particularly, extended operating room hours may be used to increase productivity and throughput. They include after operating room hours (for instance, evenings and weekends) and slots that were planned but cancelled due to different disruptions. Thus, it involves complex implications such as voluntary work outside personnel's regular working time or incentives. Extended hours are often required to guarantee timely access to surgery and to avoid penalties to the hospital. Motivated by a public Portuguese case study, this work

proposes a definition for extended operating room hours and guidelines for its implementation, which should serve as a framework for researchers, managers and policymakers to assess the sustainability of extended hours in specific contexts.

4 - Designing SHARP n-day menus using OR techniques
Francisco Martos-Barrachina, Laura Delgado Antequera, Monica Hernandez, Rafael Caballero

Looking into diet as a combinatorial problem, linear programming is the most used tool to get solutions. However, the dependence on the objective function is high and the results are frequently given in amounts of raw foods of daily intake. This last point actually limits the applicability of the studies and the ability to affect our lifestyle, there is a 'feasibility gap'. In fact, these studies merely make the succinct yet necessary point that a better, more sustainable, more affordable and equally nutritious diet is possible. Therefore, in the scientific analysis of the human diet, there is a consequential step to take, the construction of real menus that take into account both the recommended amounts of raw food and all the additional requirements often found as constraints in the linear programming approach. Besides, the SHARP framework support the idea that is necessary to have more sustainable, healthier, affordable, reliable and palatable diets. In this work, we have developed and implemented an algorithm, based on metaheuristic strategies, that departs from an original level of consumption (reference diet) and produces n-day menus, in order to fill the aforementioned feasibility gap. We try to ensure, additionally, that palatability is the center of our optimal diet, giving the solution that is as close as possible to that reference diet while complying with the SHARP principles. We have applied this algorithm to the current Spanish diet, and analyze the results.

■ TE-08

Tuesday, 16:00-17:40 - Room 8

MCDA/MCDM DSS

Stream: Decision Support Systems
Invited session
Chair: K.Nadia Papamichail

1 - A comparative study to evaluate the robustness of two prominent MCDA methods (for the MCDA Applications: ff23a7d2 session)
Saeideh Babashahi, Paul Hansen, Ronald Peeters, Trudy Sullivan

Very few studies attempt to measure the capability of MCDAs to generate robust results. Multiple MCDA methods might suit a particular decision problem, but they could potentially produce conflicting results. Validity and reliability of the results generated by MCDA methods are two key factors that influence the quality of the decisions within a priority-setting framework. In this study, using two real-world decision cases, a holdout choice task was undertaken to examine the extent to which the ranking results yielded by two widely-used MCDA methods (and software) - i.e. AHP (Expert Choice) and PAPRIKA (1000minds) - were consistent with participants' true preferences. In addition, four sub-samples of 25 people were asked to complete the surveys twice, two weeks apart, in order to check the test-retest reliability of the results. Our findings demonstrate that PAPRIKA is more likely to support the robustness of results and the legitimacy of decisions by producing reliable results over time. Moreover, PAPRIKA showed higher validity to predict participants' true preferences based on two real-world decision case studies. Potentially, the framework employed in this study could guide MCDA practitioners to integrate a series of robustness checks into their priority-setting process to ensure the legitimacy and robustness of the decisions made.

2 - Explanation-based Decision Analysis
K.Nadia Papamichail, Theodor Stewart, George Demetriou, Jim Q. Smith

The explainability and interpretability of decision models are essential requirements for the acceptance and adoption of Decision Analysis (DA) tools. The ability to explain and interpret DA functionalities and outputs facilitates the understanding of the underlying processes of problem structuring and decision modelling and increases confidence in the DA results. This paper presents a framework for explanatory DA. We have developed a typology of explanations that add transparency into the justification of preferences, explain outputs and guide the development of decision models in task-dependent scenarios. The applicability of the framework is demonstrated in two settings: probabilistic graphical models and Multi-Criteria Decision Analysis (MCDA) tools using Natural Language Generation techniques.

3 - Large-scale group decision making approach to manage the opinions and relationships between experts and its application in supplier selection
Guangxu Li, Yongming Song, Yanhong Li

As the number of participants involves in decisions increases, the complexity of decision-making process is getting higher. The social networks entered people's daily life and the opinions of experts will be influenced by each other in the decision-making process. How to manage the opinions and relationships between experts to promote the consensus is an important issue. Therefore, this paper proposed a large-scale group decision making approach based on bounded confidence and social network to manage the information between experts. Firstly, fast unfolding algorithm is used to reduce the dimension of large-scale and the weights of experts can be obtained by social network analysis. Secondly, consensus reaching process is built based on Manhattan distance, and the feedback mechanisms should be developed to adjust the opinions of experts based on bounded confidence and social network when some experts do not reach the consensus. Finally, a numerical example about supplier selection is applied to show the feasibility of the proposed approach and the result illustrates that the consensus speed is faster when used the proposed to manage the information.

■ TE-09

Tuesday, 16:00-17:40 - Room 9

Lot-sizing 2

Stream: Lot Sizing, Lot Scheduling and Production Planning
Invited session
Chair: Viktor Bindewald

1 - The collaborative capacitated multi-level lot sizing problem
Margaretha Gansterer, Patrick Födermayr, Richard Hartl

Increasing customer demands for individualized products pushes companies towards agile and modularized production processes. Digitalization enables them to safely connect to other companies in order to build up collaboration networks and to overcome inefficiencies by sharing resources among each other. We introduce the collaborative capacitated multi-level lot sizing problem with transshipments and set up carry-over. In this setting, we consider components that can only be produced by one specific agent as well as components, that can be provided by more than one producer. Since capacities are limited, agents might have to share resources and cover required demands jointly. In this case, finished components are transshipped between agents. As an agent can be in charge of producing more than one component, we include the concept of set up carry-over into our modeling. We address a centralized planning approach, where the objective is to find a globally optimized lot sizing plan for all participating agents. Thus, we cover

both horizontal and vertical collaboration. The problem is formulated mathematically. We propose a solution approach based on a fix-and optimize procedure with interrelatedness. This solution approach is applied to an extensive set of test instances. For small instances, the optimal solution can be found in short amount of computational time. For larger instances, we show that the proposed solution method improves non-collaborative costs considerably.

2 - A flexible modeling framework for decision making under uncertainty exemplified by a variant of the lot sizing problem
Viktor Bindewald, Fabian Dunke, Stefan Nickel

We consider multi-stage optimization problems with uncertain future data. Several methodologies are available for this problem class, such as online optimization, multi-stage stochastic programming and multi-stage robust optimization. However, these methodologies all differ in nuances such as end of planning horizon, required data or objective function character. In practice, information about the future is only accessible for a rather narrow time window and not for the entire decision horizon. Typically, new information is revealed gradually and information concerning later periods is based on forecasts. Hence, the multi-stage problem dissolves into a series of highly coupled snapshot problems that contain uncertain parameters. In this talk we present a new modeling framework for multi-stage problems that incorporates all three methodologies mentioned above on the snapshot problem level, thus providing the decision maker with a rich toolbox from different fields. Our framework is highly customizable: it allows to switch between methodologies in reaction to changing risk attitudes and covers problems that are event-driven (e.g., scheduling) or time-driven (e.g., lot sizing). Furthermore, our framework allows to study the impact of different algorithms, amount of available information and applied methodology on the solution quality. The talk is concluded by discussing experimental results regarding these questions for a lot sizing problem with uncertain demand information.

■ TE-10

Tuesday, 16:00-17:40 - Room 10

Cutting and Packing

Stream: Cutting and Packing
Invited session
Chair: Iván Giménez-Palacios

1 - A branch-and-price algorithm for two-stage Cutting Stock Problem of steel tube
Ying Meng, Lixin Tang

Taking the practical production process of steel tubes as background, a two-stage cutting stock problem of steel tube is investigated. Given a set of the customer orders with different length requirements, and a set of raw tubes with fixed length, the problem is to determine how to cut the raw tubes into intermediate tubes, and then how to cut the intermediate tubes into final steel tubes required by customer. For the two-stage cutting stock problem of steel tube, a branch-and-price algorithm is proposed to obtain the optimal cutting plan. On the basis of the problem structure, a set covering model is reformulated. Then, column generation algorithm is adopted to get the linear relax solution. Finally, the column generation algorithm is embedded into the branch-and-bound framework to obtain the optimal integer solution. Computational experiments are carried out to test the performance of the proposed algorithms. The results show that the proposed branch-and-price algorithm outperforms the general integer programming solver CPLEX and can obtain optimal solution in a reasonable time.

2 - An efficient formulation for the Three-Dimensional Bin Packing Problem in e-commerce
Pirmin Fontaine, Stefan Minner

E-Commerce with its large number of shipped parcels is one of the contributors to emissions and congestion inside and outside of cities. One option to enhance efficiency is to improve the utilization of the vehicles. While trucks are typically well packed, there is still potential to reduce the empty space in parcels through efficient packaging. We propose an efficient formulation and valid inequalities for the three-dimensional bin packing problem in e-commerce. The objective is to minimize the unused space in the selected parcels (bins) when packing rectangular boxes (ordered items) without overlapping into one or several parcels. The complexity of the bin packing application in e-commerce has two reasons: 1) typically, all items are different resulting in a heterogeneous item set, 2) compared to most packing problems, the number of available package options is significantly larger than the number of items. In the numerical study, we evaluate the performance of our model against existing formulations. We show run time improvements of 40 percent on average compared to the literature and can solve more and larger instances to optimality. Further, we find that forcing orders to be shipped in one parcel increases the unused space by 10 percent on average. About half of the parcels could be packed more efficiently in two packages. However, the benefits of allowing orders to be shipped in more than two parcels are negligible.

3 - Packing disks in a container using Voronoi Diagrams and important applications
Deok-Soo Kim, Joonghyun Ryu, Hyunwoo Kim, Mokwon Lee, Josef Kallrath, Jong Kim

Disk packing problem (DPP) is to find an arrangement of disks within a container without any overlap. Disk shape can be circular or elliptical and container shape can be circular, elliptical, or polygonal. DPP is known to be NP-hard and is frequently formulated as a non-linear program which has non-convex constraints. There are many heuristic studies to solve DPP which usually requires an enormous computation time to get a reasonable solution for a data set of moderate size. Here we introduce an algorithm VOROPACK, together with its implementation, to quickly find a good solution for many disks, e.g. 10,000 disks, using a single CPU. The algorithm uses a computational geometric construct called Voronoi diagram. A Voronoi diagram is a tessellation of a space where input particles exist. Given the Voronoi diagram of disks within a container, we can efficiently locate the interstitial regions among disks. VOROPACK exploits this useful property of the Voronoi diagram to find a good feasible solution of DPP. We believe that the VOROPACK idea can also be used for other packing and cutting problems. An important output type from VOROPACK is the maximal disk packing which is a sequence of the maximum disks that can be placed within a polygonal container. We surprisingly confirm that the maximal disk packing is an excellent representation of polygonal shapes and can be used to accelerate the deep learning algorithm for geometric problems.

4 - The Complete Shipment constraint in Container Loading Problem
Iván Giménez-Palacios, Maria Teresa Alonso Martínez, Ramon Alvarez-Valdes, Francisco Parreño

Efficient logistic planning has an impact on transport companies, which can make greater profits, and on the environment, by reducing pollution. One of the most common problems is Container Loading Problem, which involves loading boxes into containers or trucks so that empty space is minimized. In practical situations, besides the basic geometric constraints, there some other physical and logistic constraints to be considered, and some of them have hardly been studied. This is the case of Complete Shipment. This restriction models a real situation in which orders for the same client are formed by several boxes, and therefore when we are going to load them in the container, either we load them all or we do not load any of them. In this work, we study with four different heuristic strategies the effect of the Complete Shipment constraint on the Container Loading Problem. Our computational results show that when using an appropriate strategy, the impact of these constraints is quite small.

■ TE-11

Tuesday, 16:00-17:40 - Room 11

Control Theory and System Dynamics

Stream: Continuous Optimization
Invited session
Chair: *Jim Duggan*

1 - Food loss problem and retailer's commitment strategies in the presence of strategic customers

Yasushi Masuda, Taishi Kawahara, Hideaki Takagi

Consider a retailer of food products. It is well documented in literature that the presence of strategic customers diminishes the effectiveness of the responsive pricing. If the retailer adopts the responsive pricing strategy, the strategic customers may hold off purchasing at the regular price and wait for the discount price, which hampers the profitability of the retailer. To discourage such customers' strategic behavior, two retailer's strategies are known: quantity commitment and price commitment. We explore how the choice of retailer's strategy influences the retailer's profit and the amount of food loss. To this end, we build a game theoretic model with two periods, the regular sale and the discount sale periods, where the retailer sets the order quantity at the beginning of the regular sale period and the reduced price for the discount sale period in case of an overage. The customers strategically choose when to buy or not to buy at all. The customers' valuation of the product is heterogeneous and is discounted when they wait for a discount sale. This study helps us to understand the effect of retailer's profit maximizing behavior on the reduction of the food loss/waste. In particular, we find that the retailer's profit maximizing choice of the (non-)commitment strategy is largely consistent with the reduction of food loss.

2 - Dynamic programming and linear programming for odds problem

Sachika Kurokawa, Tomomi Matsui

This presentation discusses odds problem, which is proposed by F. T. Bruss in 2000, and its variants. A recurrence relation called DP (Dynamic Programming) equation solves most of the finite optimal stopping problems, which include odds problem and its variants, and finds optimal stopping rules. In 2013, Buchbinder, Jain, and Singh proposed a new linear programming technique for finding an optimal stopping rule of the classical secretary problem, a particular case of the odds problem. The proposed linear programming problem, which maximizes the probability of win, differs from DP equation known for long periods of time. This presentation shows that the linear programming proposed by Buchbinder, Jain, and Singh is a modification of the dual problem of the classical DP equation. We also propose linear programming formulations which find optimal stopping rules of the odds problem and its variants.

3 - A fast Bernstein global optimization procedure for nonlinear MPC

Bhagyesh Patil

In recent years, nonlinear model predictive control (NMPC) has shown considerable success in the control of a nonlinear systems due to its ability to deal directly with nonlinear models. However, the inclusion of a nonlinear model in the NMPC framework potentially results in a highly nonlinear (usually 'nonconvex') optimization problem. Under such circumstances, it is necessary to answer following two important questions: (i) Can the nonlinear optimization procedure be completed until a convergence criterion is satisfied to guarantee the optimality of the solution obtained? (ii) Can (i) be achieved within the prescribed sampling time? This paper attempts to address (i) as well as (ii) using the Bernstein global optimization algorithms. More specific, this paper first studies the classical Newton root finding method. Then after, an extension of classical Newton method is introduced by utilizing the geometrical properties associated with the Bernstein polynomial form. This extended Newton method accelerates the convergence of the Bernstein global optimization algorithm by discarding those regions of the solution search space which do not contain any solution. The significance of the extended Newton method is realized in MATLAB nonlinear MPC simulations to demonstrate tracking of multiple setpoint changes in the reactor temperature of a continuous stirred-tank reactor (CSTR) system. The paper concludes with new research directions for fast nonlinear MPC scheme.

4 - Exploring the Impact of School Reopenings using a System Dynamics Model of the Next Generation Matrix

Jim Duggan

A key challenge in infectious disease modelling of COVID-19 is to assess the impact of easing restrictions such as reopening schools. Survey data - such as the POLYMOD study, contains information on inter-cohort contacts, including estimates of the ratio of contacts that are attributable to school interactions, for school going ages. While system dynamics models often focus on population-level dynamics, there is considerable benefit from disaggregating models into age cohorts, and infer key dynamics based on (1) survey-based contacts and (2) calibrating the model to available incidence data, in order to estimate disease transmission parameters for each cohort. A model of the next generation matrix, which represents the number of secondary infectious persons generated by an infectious person in each model cohort, can be used as a structure to support policy exploration. With this model, aligned to systematic review data on key biological parameters, estimates of the population R0 value can be calculated outside of the simulation model, using repeated draws of possible contact patterns aligned with the model parameters in order to create a distribution of outcomes for an increase in the population R0 value due to school reopening. Based on a calibrated model, this paper demonstrates the utility of this approach, and highlights its potential for use in the context of policy analysis.

Tuesday, 18:00-19:40

■ TF-01

Tuesday, 18:00-19:40 - Room 1

Sports schedules and tournaments

Stream: OR in Sports
Invited session
Chair: Michael Trick

1 - Flexible home away pattern sets
Frits Spieksma, Roel Lambers, Dries Goossens

Schedules for round-robin tournaments are often generated using a first-break, then-schedule approach. Then, so-called Home Away Patterns (HAPs) are specified for the teams, and the remaining challenge is to find a round for each match that is compatible with both team's patterns. When using such an approach, it matters how many rounds are available for each match: the more rounds are available for a match, the more options exist to accommodate particular constraints. This leads to the notion of flexibility of a HAPset, and we introduce three measures assessing this flexibility, called the width, the fixed part, and the spread. We investigate properties of these measures for specific HAP-sets; in particular, we are interested in HAPsets where each HAP has at most one break (a break refers to the occurrence of consecutive symbols that are identical) - such a HAPset is called single-break. In the context of single round-robin tournaments, we prove that so-called single-break HAPsets have width 1. Further, we show how a well-known HAPset, the so-called Canonical Pattern Set (CPS), behaves on the three measures. Finally, by solving integer programs, we give explicit values for all possible single-break HAP-sets with at most 16 teams.

2 - A constraint programming approach to the sports scheduling problem
Chung-Hsieh Tsai

The purpose of this paper is to create a single round robin tournament schedule for18 teams that satisfies venues availability and various timing restrictions. To this end, a constraint programming approach is employed as the methodology to solve the problem. The proposed schedule is reasonably fair to each team, thus games between team and team are assigned at three venues on specific time with evenly spaced throughout the season. By introducing a tri-consecutive game model, the schedule for individual teams is concentrated which is a valuable property when real sports leagues are considered. Results imply that after several virtual teams are added to the scheduling process to meet all the requirements, the constraint programming approach achieves feasible solution efficiently for the sports scheduling problem.

3 - Evaluation of double-bracket tournament format using winner prediction capability and match quality criteria
Simon Anthony Lorenzo

Esports is an emerging area of sports which involves digital games played on different platforms. Tournaments of games such as Dota 2 and Fortnite in 2019 reached prize pools of over 30M USD. Most of the tournaments in esports are held in a different tournament format than conventional sports. Big esports tournaments such as CS:GO Majors, The International, and the Tekken World Tour make use of a format similar to the double-elimination bracket. This format commonly used in esports (two-bracketed format) separates the teams into halves: an upper bracket (double elimination) and a lower bracket (single elimination). Any loss in the upper bracket sends the losing team to the lower bracket, and any loss in the lower bracket leads to elimination. The study compares this two-bracketed format to more common tournament formats: round robin, randomly-assigned single elimination and seeded single elimination. Two criteria were used to asses each of these formats: winner prediction capability (probability of the best team winning) and match quality (how competitive each match is). Each setup was simulated 1,000 times in RStudio. The results of the simulations tell us that out of the four formats tested, the two-bracketed tournament format produced the highest match quality, as well as the highest tournament predictability. This means that for both the participants (winner prediction capability) and the spectators (match quality), the two-bracket format is the best to implement.

■ TF-02

Tuesday, 18:00-19:40 - Room 2

Automotive Production

Stream: Supply Chain Management
Invited session
Chair: Gülser Köksal

1 - Analyzing a shared buffer in automotive manufacturing - a simulation study
Mareike Mueller, Heinrich Kuhn

We examine the impact of a shared buffer for bodies in white and painted car bodies on the stability level of flexible automotive production systems. The problem is motivated by the necessity of car producers to transform their existing plants to a stabilized production in order to deal with the increasing complexity in the production process. Core of the stabilized production is an unaltered assembly line sequence, which is the baseline of the entire production process. A frequently used concept to attain sequence stability is allocating large facultative buffers between the production steps. These storage systems require a noticeable invest and obstruct the limited floor space. A flexible centralized buffer has a balancing effect on the stock level of unpainted as well as painted car bodies. It decouples the production process with a smaller buffer size, consequently occupying less floor space and reducing investment cost. To quantify the balancing impact of a centralized buffer on the stability level of the production process, all the functions need to be considered. We propose a discrete event-based simulation model to determine the optimal size of the buffer. To verify the performance of this method, an empirical study with data of an OEM is conducted. The transparency and fields of action provided by this simulation study reduce the uncertainties in the planning activities and contribute to the successful transformation process.

2 - Designing JIT/JIS supermarkets supplying assembly lines in automotive production plants
Heinrich Kuhn, Marcel Lehmann

The current trend towards an increased number of models and variants in the automotive industry leads to a rising logistical effort to supply the mixed model assembly lines on a daily basis. Therefore, so called supermarkets are installed to feed the assembly areas by using different JIT applications. Parts and subassemblies have to be assigned to these areas located inside and outside of the manufacturing plant. We propose a MIP model minimizing the costs supplying the assembly lines while considering the limited space of the storing and picking system, the mutual dependencies between products and the internal supply and transportation system. A real case study at a German premium car manufacturer demonstrates the applicability of the MIP model and the solution approach suggested.

3 - Multivariate quality loss function cost parameter estimation
Gülser Köksal, Levent Erişkin, Leman Esra Dolgun

In this study, we consider estimating the cost matrix parameters of the multivariate quality loss function which is commonly used in product and process design parameter optimization. Multivariate quality loss functions consider multiple responses simultaneously for determining the optimal levels of design parameters that yield a high-quality performance. They are also used in quality improvement decision making and statistical tolerancing. To that end, we propose an interactive and evolutionary method for estimating the cost matrix parameters of the

multivariate quality loss functions. We present the applicability of the method on a real-life example based on the honing operation of the automotive industry. Additionally, we conduct a computational experiment to show that the problem converges to the underlying loss function after a few iterations even when the information provided by the decision-maker contains certain degrees of errors. The convergence is also shown for different variance-covariance structures.

4 - The Assembly Line Feeding Problem: An extended formulation with multiple line feeding policies and a case study
Reinhard Baller, Steffen Hage, Pirmin Fontaine, Stefan Spinler

The number of parts per assembly lines increases due to an increasing number of car models as well as a decreasing model cycle time. Therefore, more part numbers have to be supplied to the assembly line, which results in a shortage of space at the line. To achieve feasible solutions and to lower costs the number of applied line feeding polices rises. This increases the effort involved in assigning part numbers to line feeding policies. To address this problem, we extend mixed-integer programming formulations from the literature by considering nine different line feeding policies, different line feeding policies per part families, variable walking distances not only at the assembly line but also in the supermarket and flexible line side spacing. The mathematical model was applied in a case study at a large German automotive company. In this case study total costs are reduced by 3.36% compared to manual planning, whereas models from the literature have been able to reduce total costs by only 0.49%. A reduction of 7.54% of total costs is possible by further allowing flexible line side spacing. When - as an alternative scenario - a rounding of operators without flexible line side spacing is applied, the number of needed operators is reduced by 6.88% compared to manual planning.

■ TF-03

Tuesday, 18:00-19:40 - Room 3

Healthcare logistics

Stream: OR in Health, Medicine and Life Sciences
Invited session
Chair: Helena Ramalhinho Lourenco

1 - Vehicle routing model for emergency medical services with partial outsourcing
Nikki Rathore, Pramod Kumar Jain, Manoranjan Parida

The efficiency of Emergency Medical Services (EMS) relies on the response time which depends upon availability and location of vehicle and real time traffic information. In India, no centralized EMS is available (unlike 911 in USA). Semi-government bodies and NGO's provide EMS operations. The growing demand for EMS stresses on capacity improvement. By outsourcing of resources, future demands can be handled without increasing the internal capacity of EMS providers. A sustainable vehicle routing and scheduling model is developed by integrating all the available EMS resources as well as alternative non-ambulatory vehicles such as police cars, taxi, etc. Nonlinear integer programming model has been used in the study. Additionally, the model allows rerouting of vehicles carrying non-critical patients to serve another patient and dispatch a vehicle to the nearest hospital instead of designated hospital to stabilize the critically injured patient. Real-time traffic information obtained from Google Maps Distance Matrix API is used to predict the travel time and avoid congested routes. The proposed framework also monitors in real time the location and status of vehicles, hospital's available capacity, availability of doctors, etc. to avoid unexpected delays. The model is tested on data gathered from GVK Emergency Medical Research Institute of Dehradun district in Uttarakhand, India and successfully reduces response time by 62% and 13.8% in urban and rural area respectively.

2 - The impact of synchronization in home health and social care services
Helena Ramalhinho Lourenco, Jesica de Armas, Marcelus Lima

Home Health Care (HHC) is defined as medical and paramedical services delivered to patients at home. A patient in a hospital has a high cost for the community, so the main benefit of the HCC service is the significant decrease in the hospitalization rate, as well as, the improvement on the quality of patient recovery. The current trend is to send medical personal to visit patients in their home in order to reduce costs for the community and increase quality of life of the patients. Home Social Care (HSC) refers to provide social work, personal care, protection or social support services to a population in need or at risk, or adults with needs arising from illness, disability, old age or poverty with the objective to meet their specific needs. The providers of these services are a set of different professionals, that need to be coordinate by a central, usually, public organization. Frequently, a large set of the population needs both HHC and HSC services. Therefore, the closer integration of the HHC and HSC is a policy goal for many government institutions. This integration has had a limited implementation due several reasons as cultural, ways of working, regimes and logistics complexity. In this work, we propose optimization models to optimize to solve the Integrated Home Care (IHC) and evaluate the cost and quality service impact of introducing synchronization in the full system. The work is done taken into account the reality at the city of Barcelona, Spain.

3 - A hybrid simulation framework to evaluate the patient access to public health in Brazil
Vivianne Horsti dos Santos, Kathy Kotiadis, Maria Paola Scaparra

Healthcare has been one of the domains which have benefited from the exponential growth of academic literature on Hybrid Simulation (HS). HS is defined as the approach which combines two or more simulation methods, and System Dynamics (SD), Discrete Event Simulation (DES) and Agent-Based Simulation (ABS) are the three most frequent mixed methods. HS publications frequently focus on System Dynamics (SD) and Discrete Event Simulation (DES) hybrid models. Hybrid Discrete Event Simulation and Agent-Based Simulation (ABS) models, especially studies with stakeholder involvement over the simulation life cycle, are still unexplored in literature. The involvement of stakeholders shown to be useful in stand-alone simulation studies. In those cases, stakeholder involvement throughout the simulation life-cycle increases the participant commitment and enhances the quality of the outcomes. Additionally, those simulation studies are keener to implement their findings. Therefore, this research aims to propose a DES-ABS hybrid model framework, with active stakeholder participation, applied to public health in Brazil for evaluating the use of telehealth in delivering primary care. This framework is based on the PartiSim methodology (Tako and Kotiadis 2015) and consists of six main stages: study initiation, finding out about the problem, defining conceptual model, model coding, experimentation, and implementation. For all stages, stakeholders participate actively in the development of the DES-

4 - Modelling behaviour for health planning
Steffen Bayer

Patient and provider behavior is a major determinant of how healthcare services are provided in practice. This presentation examines the use of hybrid modelling to take patient and provider behavior into account in health planning.

■ TF-04

Tuesday, 18:00-19:40 - Room 4

Applications of OR 2

Stream: Applications of OR (contributed)
Contributed session
Chair: Bernd Heidergott

1 - Is Q1 qualification of journals adequate measure of excellence: evidence from JCR Operations Research & Management Science
Veljko Jeremic, Nikola Zornić, Sandro Radovanović, Mladen Stamenković

Journal Impact factor (JIF) has been perceived as the benchmark of quality for journals. Concerning the differences in citation patterns, journals are classified in particular Journal Citation Report (JCR) and rank in a specific category. Accordingly, journals are being classified in one of the Q1-Q4 class, with the Q1 being designated for the most prestigious journals. Being classified as the Q1 is of particular importance since the ARWU Subject Rankings have included solely Q1 journals as the measure of publication output for ranked universities. However, one of the questions arising is whether journals classified as Q1 should be considered equal. This is an especially triggering issue since the citation distribution of articles within journals is skewed, meaning that the JIF of specific journals can be high (even classified as Q1) while heavily relying on the high citation score of a small number of articles. As a possible remedy to the issue, we propose implementing the resampling without replacement approach when calculating JIF. We selected Q1 journals in JCR 2019 report for Operations Research & Management Science and obtained the citation score of each article published in selected journals in 2018 and 2017 (ones included in the JCR 2019 report). Using the approach mentioned above, in 1000 iterations, we calculated the JIF and respected rank of each observed Q1 journals. Results present considerable differences among Q1 journals.

2 - Research of influencing factors on employment of university students using network analysis
Kim HyoJung

Youth employment rate in South Korea is being treated as the serious social problem with the highest level since the foreign-exchange crisis. It was announced that youth unemployment rate even in OECD countries reaches two times of entire employment rate as the poor employment status of young people was common place in case of the developed countries as well. This research carried out the filtering and searching the factors that influence on the employment actually using RapidMiner that is one of network analyses targeting the university graduates. This research was carried out targeting 170 university graduates of K university and 55 of various variables related with the employment were measured. As its results, data of 167 people was used for actual analysis and 16 variables were used in this analysis as the ones that influenced on the employment actually. As the results of research, whether they are employed or not was distinguished by whether they completed the long-term internship as root node was long-term internship (15 grades). And it influenced on the employment positively when they experienced internship in South Korea and foreign countries and interviewed with their professors frequently.

3 - Preference Relation Lattices: Using Asymmetric Relations to Represent Uncertain Assessments
Christian Carling

Most techniques for assessing and ordering uncertain propositions, e.g. for risk analyses or intelligence estimates, rely on either of two methods 1) direct ranking on a linear scale, and 2) indirect ranking, through pairwise comparison followed by linearisation. This is useful when uncertainties are bounded and utility functions can be clearly defined. However, in situations with large uncertainties and potentially catastrophic outcomes, there are two dangers with this approach: overconfidence and a singular focus on the leading event. This is more due to cognitive effects than inherent in the method but other representations may improve the situation. A simple scheme to represent subjective assessments as asymmetric preference relations is presented here. Preferences that cannot immediately be decided are incomparable, expressing the uncertainty. Cycles and intransitive subsets are used to measure overconfidence. This work explores a number of techniques to analyse and aggregate individual assessments. Various distance and dispersion measures are studied and the aggregation schemes are explored through the inclusion lattice of asymmetric relations. The objective is to find simple ways to summarise and communicate results to analysts and decision makers. The method is tested using data collected from groups of analysts, having varying levels of analytical maturity. Although based on a limited sample, there is clear evidence of inconsistency and overconfidence.

4 - Minimal invasive decomposition of social networks into evenly sized groups
Bernd Heidergott

We consider the problem of splitting a social group into evenly sized groups. This problem is motivated by the Covid19 pandemic where departments, sports clubs, or school classes had to be split into groups in order to allow for social distance. In this talk, we propose a new algorithm for splitting a social network in such a way that the "social pain" (measured in terms of loss in connectivity of the ensuing groups) of the split is minimized. Next to a basic splitting algorithm, we present an extension taking agent-specific attributes into account. The algorithms are tested on various data sets.

■ TF-05

Tuesday, 18:00-19:40 - Room 5

Games and Applications 4

Stream: Dynamics and Games
Invited session
Chair: *Andrzej Ameljanczyk*

1 - Sensitivity analysis for the hospitals-residents with consistent couples matching model
Nitsan Perach, Shoshana Anily

The hospitals-residents with consistent couples (HRCC) model is a generalization of the original Gale-Shapley hospitals-residents (HR) stable matching model, in which the residents set consists of singles and couples. The joint preference-list of any couple over pairs of hospitals is consistent with the preference-list of each of its partners. A feasible stable assignment has the property that the residents of each couple are assigned to a pair of hospitals in their joint preference-list or they are both unassigned. In this paper we study the implications on the existence and on the form of a feasible stable assignment by the following variations of a given HRCC instance: (i)forming or breaking couples; (ii) new arrivals or departures of residents; and (iii) increments or reductions of the number of open positions in hospitals. In particular, for the case that new residents arrive, we propose an algorithm that generates a feasible stable assignment, if such one exists, by starting from a feasible stable assignment over the set of residents before the new arrivals. Similarly, if some residents depart, we use a feasible stable assignment that existed before the departure, in order to provide an alternative stopping condition while searching for a feasible stable assignment after the departures.

2 - On Hedonic Coalition Formation with Social Concern Graph
Erika Momo, Shao-Chin Sung

Hedonic coalition formation game or simply hedonic games, is a game model with coalition structures as its outcome, and players' preferences are assumed to be purely hedonic, i.e., each player's preference depends only on the composition of her coalition. There are several graph-based models such as fractional hedonic games and social distance games, which are subclasses of hedonic games. Recently, an extended class of hedonic games called hedonic games with social contexts is proposed. Such a model is graph-based as well, and each player is concerned not only with composition of her coalition, but also with the status of her friends no matter each of them is a member of her coalition or not. In this study, this model is slightly generalized by introducing a parameter called social concern, which is not necessarily positive, and hence, each player may concerned with the status of

other players which are not necessarily friends. In terms of stable intervals for social concern, we analytically and numerically studied the existence of Nash stable coalition structures.

■ TF-06

Tuesday, 18:00-19:40 - Room 6

MCDA Methods 2

Stream: Multiple Criteria Decision Aiding
Invited session
Chair: *Rhitankar Saha Roy*

1 - FAHP MCDA Model for implementation of SSCM during VUCA conditions
Rhitankar Saha Roy, Karim Ahmed

The COVID-19 pandemic and BREXIT has highlighted the effects VUCA conditions can have on supply chains. During VUCA times, supply chains struggle to maintain and implement sustainability in their production lines especially for swift decision making for business growth, which are hinged on a set of selected KPIs. Theoretical models do identify KPIs applicable to a particular industry but, these models do not give the supply chain industries the independence to set their own criteria or guide their decision making. Decision making processes for procurement or business area growth can be time consuming and is further complicated due to the multiple criteria that arise during VUCA conditions. To find a solution, this paper discusses an interactive mathematical Decision Support System using modified FAHP based calculations to aid in organizational decision making. This model gives the user/organization the autonomous independence to set own criteria rather than being based on a list of pre-defined theoretical KPIs to choose from. The output is in the form of suggesting the most sustainable options a supply chain organization can implement based on the analysis of data input by the organization during VUCA times. Case studies have been applied to the MCDA model to compare results with actual decisions made. This model correctly ranked the best options as well as indicated that it can replace the multiple meetings organizations usually conduct during the decision-making processes.

2 - Integrating socio-demographic profiles into multi-actor multi-criteria analysis: A case study on university COVID-19 policy evaluation
He Huang, Cathy Macharis

The Multi-Actor Multi-Criteria Analysis (MAMCA) is a methodology which is developed to support decision-makers to handle complex decision-making processes that involve multiple stakeholder groups who usually hold different interests, points of view and objectives. MAMCA can reflect the differences from diverse stakeholder groups on their priorities and preferences. Meanwhile, a reliable and transparent way of eliciting weight and visualizing opinions of stakeholders within one stakeholder group can be interesting, certainly when there is quite some heterogeneity within the group like the citizens. The stakeholders need to be beware of their specific inputs within the group which have been taken into account. Hence, a weight deviation chart was developed in MAMCA to visualize the difference between the weight allocations from respondents within one stakeholder group. We think it is valuable to extend the comparison in one group from different socio-demographic aspects. As we want to extend the MAMCA to a mass-participation context, we explore in this paper the possibilities to cluster the differences within a stakeholder group based on their weighting and socio-demographic data. Detailed weight deviations, i.e., the priorities of stakeholders from different profiles will be explored. This paper compares different possibilities to cluster the points of view within one stakeholder group: we are comparing different methods and identify which one would be the most appropriate.

3 - Interval group judgments in AHP based on geometric standard deviation
Petra Grošelj, Gregor Dolinar

Group decision making is an important issue in multicriteria decision making. The synergy of collaboration can improve and enrich the decision making process. One of the goals of group decision making process is to reach a good decision that is acceptable to all parties. In the analytic hierarchy process (AHP), the most widely used group method is the weighted geometric mean method (WGMM). One of the main problems of WGMM is that the group results are represented with the scalar-valued judgments, which can hardly reflect the diversity of opinions, so interval values can better represent the group judgments. We present a new approach to derive interval-valued group judgments from individual scalar-valued judgments based on the geometric mean and geometric standard deviation. The method incorporates the power factor λ to adjust for interval width. While wider group interval judgments may be more acceptable to decision makers, they may also be less accurate and introduce uncertainty into the final decision. Acceptable inconsistency of individual judgments is a well-known requirement from scalar-valued AHP. The aim of this research is to define acceptable inconsistency of interval-valued judgments, which provides acceptable inconsistency of group interval judgments when all individual scalar-valued judgments are acceptably inconsistent. We present a new model for deriving weights based on the logarithmic least squares approach and incorporating the power factor λ.

■ TF-07

Tuesday, 18:00-19:40 - Room 7

Risk management and maintenance coordination

Stream: Graphs and Networks
Invited session
Chair: *Mami Matsumoto*

1 - Optimal railway track maintenance and management strategy in consideration of train derailment accident risk
Masashi Miwa, Tatsuo Oyama

It is imperative for us to keep railway track irregularities at a satisfactory level thorough appropriate maintenance work with due consideration of both tamping cost and risk of occurrence of a train derailment accident. Therefore, we developed an optimal decision making model for setting upper bound for the irregularities and track inspection period in accordance with the magnitude of the risk. Firstly, we analyzed the past derailment accident data occurred in Japan to build a model for estimating the number of casualties when the accident occurs. From the results of the analyses, we developed a derailment risk estimation model in consideration of the magnitude of the accident, which includes the number of casualties, the loss of railway equipment, and the cost regarding suspension time. After the estimation, we can obtain the total cost of the accident. Using the model, we can investigate an optimal track maintenance policy in consideration of the risk. Next, by applying the risk estimation model, we also developed an optimal track maintenance scheduling model for the tamping operation to minimize the track irregularities and mitigate the accident risk. The model enables us to decide which unit section should be selected and when we should carry out tamping taking various conditions into consideration. Finally, by applying the models to the actual railway data, we confirmed that our models were effective enough to optimize yearly tamping schedule.

2 - Transportation infrastructure protection against sea level rise: multimodal simulation of SF Bay Area
Jiayun Sun, Samer Madanat, Aaron Chow, Alain Tcheukam

Transportation infrastructure resilience is an important component of a region's ability to recover itself from natural disasters. While sea level rise (SLR) is becoming inevitable with climate change, we do not yet understand how relevant protection strategies will affect the transportation system. In the present study, we develop a framework where a range of coastal protection strategies are undertaken in the case of one meter of SLR (expected by the year 2100). The methodology incorporates high-resolution hydrodynamic simulations with the Coastal Storm Modeling System (CoSMoS) and the Multi-Agent Transport Simulation (MATSim) to quantify the potential impact of SLR and protection strategies on the transportation system. The improved spatial resolution reveals transportation phenomena that were not identified in previous studies. A case study of the San Francisco Bay Area is presented to demonstrate the effectiveness of the methodology. The Bay Area has an extensive transportation system along the coastline which is prone to inundation. Modeling results show that coastal protection of one area will affect the transportation system (sometimes negatively) in areas beyond its vicinity. By quantifying the impacts on commuters' mobility in different Transportation Analysis Zones, the methodology can be used to propose effective and inclusive strategies against SLR for the whole region.

3 - Optimal multi-scale inspection and maintenance policies in roadway asset management systems
Jinwoo Lee

This paper presents an optimization framework for multi-scale decisions in roadway asset management systems, such as inspection scheduling and maintenance and reconstruction (M&R) planning. The multi-scale model involves three different levels of decisions in terms of spatio-temporal heterogeneity. At the system level, a limited budget will be allocated over a whole roadway network to perform inspection and M&R activities along a given period. The entire roadway system can be divided into several groups, where multiple pavement segments included in each group share the same inspection frequency. At the group level, the objective is to find the optimal inspection frequency for each group. Here, a segment is defined as the unit pavement section to carry out an M&R activity. The optimal decision of the segment-level problem is to find the best M&R policies for each pavement segment based on its condition state that can be known by periodic inspection. To overcome the nature of exponential complexity, we propose an efficient method that enables us to solve real-world problems in polynomial complexity while guaranteeing close-to-optimality. The proposed method converts the original multi-scale problem to the tri-level Stackelberg model and solves it by using Lagrangian Relaxation, Convex Optimization, and Approximate Dynamic Programming. We demonstrate the proposed decision-making framework through a numerical case study in Korea and draw practical implications from the findings.

4 - Applying a ballast tamping and rail grinding combined operation technique to implement an optimal railway track maintenance schedule.
Mami Matsumoto, Masashi Miwa, Tatsuo Oyama, Kenta Yasaka

We have been working on making optimal railway track maintenance schedules by applying mathematical programing modeling techniques. Our maintenance schedules have been practically used in several railway companies in Japan. In order to implement an optimal railway track maintenance schedule obtained from our optimization model more efficiently and more desirably we propose a ballast tamping and rail grinding combined operation technique (combined maintenance), which uses ballast tamping and rail grinding machines. Recently, even though maintenance cycles could be extended and the total cost of maintenance could be reduced by efficiently combining these two machines, they are operated independently. It is because scheduling combined operations is complex and there is no validated model to quantitatively estimate the effect of the combined maintenance. The purpose of this research was to build a model for estimating the effect and duration of the combined maintenance, and to develop a scheduling system to facilitate the preparation of ballast tamping and rail grinding schedules while considering the effect of combined maintenance. Investigations were also carried out to establish how long this type of maintenance lasts, and determine the optimum ratio of combined maintenance to total railway track length. Furthermore, we verified the estimation model by using actual data, and proved that the model had enough prediction accuracy.

■ TF-08

Tuesday, 18:00-19:40 - Room 8

Matheuristic Algorithms for Combinatorial Optimization Problems

Stream: Meta-Analytics: A Marriage of Metaheuristics and Analytics
Invited session
Chair: Nelson Maculan

1 - About the bandwidth reduction on sparse matrices
Nelson Maculan, Michael Souza, Rogério Tostas, Webe João Mansur

Given the great importance of solving large linear equation systems, which can reach a billion equations, associated with engineering problems, where sparse matrices appear, it is important to swap columns and rows to minimize the bandwidth. This problem is NP-hard. We make a brief introduction to the exact and heuristic methods associated with this problem, and we present a metaheuristic algorithm to find better solutions and compare them with traditional methods. co-authors: Rogério Tostas 1, Michael Souza 2, Webe Mansour 1, 1-Federal University of Rio de Janeiro, 2-Federal University of Ceara.

2 - Solution approaches and managerial insights for truck and drone systems in last mile logistics
Claudio Sterle, Maurizio Boccia, Adriano Masone, Antonio Sforza

Last mile logistics (LML) is one of the most important and expensive part of the freight distribution process in a supply chain. LML role is not going to change in the future since we are observing an always increasing shift away from physical stores to digital shopping. In this context, the integration of new distribution technologies in the delivery systems, specifically drones, has been investigated by several companies to reduce the LML costs. The most promising delivery system, in terms of emissions and completion time reduction, consists of a truck and a drone operating in tandem for the parcel delivery to the customers. These new drone-based delivery systems have led to the definition of new and complex decision and optimization problems for which operations research methodologies represent a valuable support tool. In this context, several contributions have appeared in the last years providing ILP and MILP formulations for these kinds of problems. Nevertheless, these formulations suffer from dimensional drawbacks which make their solution impracticable even on small instances. In this work, we discuss exact and heuristic approaches for specific variants of the problem, and we provide a computational study on literature instances aimed at determining features characterizing good/optimal solutions. These features can be used both to decompose or reduce the size of the addressed problems and to derive managerial insights on this kind of distribution system.

3 - Multi-wave tabu search for the boolean quadratic programming problem with generalized upper bound constraints
Zhen Shang, Jin-Kao Hao, Songzheng Zhao, Yang Wang

The boolean quadratic programming problem with generalized upper bound constraints (BQP-GUB) is an NP-hard problem with many practical applications. In this study, we propose an effective multi-wave tabu search algorithm for solving BQP-GUB. The algorithm performs a sequence of search waves, where each wave alternates between the vertical and horizontal phases and the transition between two adjacent waves depends on a hybrid perturbation phase. The vertical phase employs tabu search to reach a critical solution and the horizontal phase follows to reverse previously performed moves and perform an equal

number of moves by referring to the search information gathered from the latest search process. The hybrid perturbation phase adaptively chooses a directed perturbation, a frequency-based perturbation or a recency-based perturbation to achieve search diversification. Experimental results on 78 standard instances indicate that the proposed algorithm is able to improve the lower bounds for 6 instances and match the best solutions in the literature for most instances within competitive time.

■ TF-09

Tuesday, 18:00-19:40 - Room 9

Deep Learning 2

Stream: Deep Learning
Invited session
Chair: *Toru Amagai*

1 - Pruning Deep Neural Networks with Second-Order Cone Programming
Buse Cisil Otar, Abdullah Nazhat Abdullah, Sureyya Ozogur-Akyuz

The field of machine learning achieved a great deal of progress due to the use Deep Neural Networks (DNNs) in the past several years. However, measuring the performance of DNNs requires significant amount of computation and memory. Pruning techniques in deep neural networks have been used to reduce the complexity of neural network architectures through compression. Hence, we propose a new optimization model to prune the ensemble of various diverse solutions that includes different depths and layers of Deep Neural Networks by using second-order cone programming (SOCP) where accuracy and diversity trade-off is optimized. The CIFAR10 data set is used to obtain metrics of performance which gives promising results.

2 - Pruning ensemble of deep networks using convex- concave optimization
Muhammad Ammar Ali, Pinar Karadayi Atas, Abdullah Nazhat Abdullah, Sureyya Ozogur-Akyuz

Multiple classifiers improve the result of a given problem. Generating multiple Deep neural networks for a specific task might be computationally expensive and ineffective as some classifiers might not contribute as much to the shared output. In order to remove these low contributing deep networks, we prune ensemble of deep networks by optimizing accuracy and diversity trade of with an optimization approach called disciplined convex concave programming (DCCP). An ensemble of 300 Deep Neural Networks is tested on the CIFAR-10 dataset and results show an increase in accuracy while maintaining a level of relative entropy.

3 - A risk detection framework of Chinese high-tech corporates using wide & deep learning model involving business-related text
Fang Da

High-tech corporates have been recognized as a major source of earnings in the world especially in China. High-tech corporates develop business activities based on continuous research and development and the transformation of technological achievements. A high degree of information asymmetry has led to the problem of difficult financing, high interest rates, and complicated audit procedures for high-tech corporates. However, little works focus on a suitable indicators and efficient automated framework based on high-tech corporates' peculiarities to improve risk detection accuracy. The objective of our work is to propose a new framework using wide & deep learning model using business-related text to detect risk based on substantive characteristics of high-tech corporates. Firstly, we collect one-hand data of 1800 Chinese high-tech corporates consisting of basic information, financial information, business-related text information and status (risky or no risk). And then we perform an experiment and verify the effectiveness by comparing the performance of the basic classifiers using complementary business-related text and traditional financial data. The results showed that the proposed framework with new factors improve the detection performance with 31% increase in recall compared to traditional patterns. Moreover, the results suggests that the importance of unstructured data and soft information of high-tech corporates should be emphasized to improve risk detection accuracy.

4 - A Dynamic Neural Network with Convolutional Layers
Toru Amagai, Eishi Chiba, Taiki Otsuka, Masanori Higashihara

In the field of machine learning, it is well known that the performance of a neural network increases with the number of layers. However, as the number of layers increases, the computational cost also increases. This phenomenon results in a trade-off between the performance and the computational cost in static neural networks. In this paper, we aim to tackle this trade-off by developing a neural network with low computational cost and high performance, and present a new dynamic neural network with convolutional layers. The initial network consists of one convolutional layer and two fully connected layers. During training, one fully connected layer is deleted, and one convolutional layer and one fully connected layer are added. Since the presented method adds convolutional layers during a training process, it has the potential for achieving low computational cost and high performance. Computational experimentation is carried out to show the image classification performance of the presented method compared with existing methods.

■ TF-10

Tuesday, 18:00-19:40 - Room 10

Knowledge Analytics

Stream: Knowledge Work and Knowledge Analytics
Invited session
Chair: *A. D. Amar*
Chair: *Santanu Roy*

1 - Fostering decision-making in practice in the teaching process (Study Module: Decision-making in practice for knowledge management)
Ruizan Mekvabidze

In practice, there are many different decision-making methodologies, and technologies of decision-making that use OR methods and analytics for getting solution and assessing the results of decisions. The teaching of decision-making technology in practice (DMTinP) in the frame of a modern competitive educational environment has to direct to a new approach of knowledge creation with the realization of important components of teaching environment (globalization, ICT, economic, business, politics, program software...) through requirements and outcomes with a certain estimation of the decision situation. In the study process, DMTinP, using the process analytics and operation research methods might be considered as a group of activities such as measurement, collection of data, analysis, and assessment of the process and its context, model building, and optimizing. In this working paper, we consider the next issues for the study module for the MA students: • How can we foster decision-making processes in practice for the need of knowledge development on the basis of OR methods or business analytics or their combinations after formulating the problem, constructing a model and implementing its solution in the situation. • Discussing conceptual aspects • Discussing implementation aspects • Presentation of a syllabus of the study module of DMTinP for MA students. At the same time, DMTinP involves using a value of parameters of the process.

2 - Overall Airline Revenue Model with Customer Choice Behavior for a Single Flight Leg
Muzaffer Buyruk, Ertan Güner

After applying reservation limits to seat inventories and determining the number of seats for each fare class to optimize revenue gains, airlines have increased their revenues with ancillary products. Ancillary revenues were estimated to rise from 22,6 billion dollars in 2010 to 109,5 billion dollars in 2019 (IdeaWorksCompany, 2018, 2019). In this study, we offer an overall airline model with a customer choice behavior by extending the fare-locking option model in the literature and incorporating the other ancillary revenue products.

We make three general research contributions to the literature. Firstly, to the best of our knowledge, a customer choice behavior model where the subset of fare products is selected in the presence of a fare-locking option over a single-flight leg has not been studied previously in the literature. Secondly, for the first time, we extend the fare-locking model to include the other ancillary products. Third, our study proposes linear programming approximations to determine the upper bound of an intractable dynamic program.

Our work, first, introduces a dynamic programming model to identify the optimal sets and find the optimal expected revenue. Secondly, because the dynamic model, which also keeps a record of the fare-locking reservations, is intractable due to the high-dimensional state variable, we develop a deterministic linear programming model that gives the upper bound of the dynamic program. Lastly, we conduct numerical analyses.

3 - Evaluating Human Behaviour in Response to AI Recommendations for Judgemental Forecasting
Naghmeh Khosrowabadi, Kai Hoberg, Christina Imdahl

Various advanced systems deploy artificial intelligence (AI) and machine learning (ML) to improve supply chain forecasting. However, planners need to become familiar with these systems and trust them, considering real-world complexities and challenges the systems must adapt to. Planners tend to intervene based on their experience or information, which the systems may not capture. In this context, we study planners' adjustments to AI-generated demand forecasts. We collect a large amount of data from a leading AI provider and a large European retailer. Our dataset contains 30 million forecasts at the SKU-store-day level for 2019, plus variables related to products, weather, and holidays. Our two-phases analysis aims to first identify drivers of adjustments using random forest, a well-known ML algorithm. Second, we investigate when adjustments occur and whether they enhance the accuracy. We illustrate the relations between variables using decision trees. We find an important role for price, freshness, and discounts in making adjustments. We show that most large positive adjustments are more frequent but inaccurate, while most large negative adjustments are accurate but fewer in number. Thus, the planners do not substantially contribute to accuracy. Our findings provide insights for the better use of human knowledge in judgemental forecasting.

4 - Genetic programming algorithm for concurrent real-time optimization of detecting unexpected tasks in IoT design process
Adam Górski, Maciej Ogorzałek

Internet of Things (IoT) is internet based network consisted of billions devices called things. During the work some elements of the network must execute tasks. However not every task can be predicted at the beginning of IoT design process. Therefore detection and assignment of unexpected tasks is a very practical aspect of IoT design process. When unexpected situation appear in most cases there is more than one way to solve it. Therefore the optimization that must be done is made in two phases concurrently. Each phase impacts another in real-time. Modifications made in one phase cause modifications in the second one. The first phase is responsible for choosing the subtasks enable to execute unexpected task. The second phase chooses the resources to execute the tasks. To solve this problem we propose genetic programming solution. The algorithm starts from randomly generated genotypes. Each genotype is a tree which contains designing decisions. The next generations of individuals are made using genetic operators: selection, crossover and mutation. The algorithm ends when in ϵ next generations better solution was not found.

■ TF-11

Tuesday, 18:00-19:40 - Room 11

Risk management

Stream: Financial Mathematics and OR
Invited session
Chair: *Katarzyna Romaniuk*

1 - Insurance portfolio strategies with time varying multiples based on good and bad volatility dynamics
Jean-Luc Prigent, Hachmi Ben Ameur, Wael Louhichi

We propose an important extension of one of the two main portfolio insurance strategies, namely the Constant Proportion Portfolio Insurance (CPPI) strategy. In our model, the conditional multiple is determined using key factors governing the return process; namely the good (upside market) and bad (downside market) volatilities. For the CPPI method, the predictability of volatility is crucial to the choice of rebalancing. For example, the predictability of bad volatility helps to better manage the gap risk while taking account of good volatility improves the portfolio performance. Our empirical analysis is mainly conducted on S&P 500 as risky asset. We also perform a back test of the strategies, using a sliding window method to dynamically estimate model parameters based on the last two years of daily returns. We show that models exploiting these findings lead to significantly better out-of-sample performance. Our results underline the very significant interests of introducing time varying multiples based on good and bad volatilities, from both the theoretical and operational points of view.

2 - Why do not firms shift risk near distress? A theoretical explanation and an application to the case of DB pension funds insured by the PBGC
Katarzyna Romaniuk

It is generally accepted that theoretically, firms near distress should shift risk. However, it seems that the opposite behavior occurs in practice: firms rather decrease risk-taking. The main argument put forward by the literature to explain this behavior is that the risk-shifting incentive is being opposed by the risk-management incentive (Rauh, 2009). We propose a new argument based on the interplay of Ross's (2004) effects of convexity, translation and magnification. An application is then built in the case of a defined benefit pension fund insured by the Pension Benefit Guarantee Corporation.

3 - Multivariate Statistical Modeling of COVID Vaccine Development Companies Stock Investment Strategy
Chi-hong Ho, Chi-Feng Ho

In 2020, wall street experienced a large market crash. The COVID-19 pandemic was the large factor that caused this crash. The reason that the market crashed was most investors looked down on the future market prospect and they sold lots out lots of stocks affected by a coronavirus and it caused the stock price to drop quickly. After July, Moderna and other biotech companies opened the results on the COVID vaccine development, and also, the Trump Government booked 100 million vaccines from Moderna. Therefore, investing in biotech companies was a good choice. For the investors, the purpose of investment is to lower the cost and gain more money. The author found 22 COVID vaccine development companies on the web. After it, the author used a Financial Statement to exclude some bad-looking companies. In this project, the authors defined the problems which are hard to pick the right COVID vaccine development stocks. The idea of the project is to help investors to find the best solution for picking the right stocks and timing to earn money. The target customers are investors who are interested in the stock market. This project can help them to do easy

analysis. The authors developed further four models: Outlier detection, PCA-SPC model, Eigenvalue & heating map, Confident Ellipse, which could help with determining the best timing in stock market investment.

4 - The performance of Compliant stocks during the COVID-19 crisis
Amel Farhat, *Amal Hili*

The outbreak of the COVID-19 pandemic led to a sharp decline in the market value of the equity markets. The purpose of this paper is to answer the following question: Do Compliant firms outperform the Non-Compliant during the COVID-19 pandemic? A compliant firm must satisfy the qualitative and quantitative criteria defined by Islamic law. Previous research focused on the performance of Compliant mutual funds, banks, and market indexes. Our paper stands out by sorting the cross-section of individual firms into Compliant and Non-Compliant firms and by analyzing the stock performance of each group during the COVID-19 crisis. Our empirical investigation is twofold: First, it includes quarterly cross-sectional regressions during the first two quarters of 2020. We show that the effect of firms' compliance on abnormal returns is positive and significant during both quarters. We also provide evidence that the out-performance of Compliant stock returns during the pandemic is not explained by a higher risk. Second, it uses difference-in-difference regressions of daily abnormal returns and volatility on the interaction between the Compliant dummy variable and PostCOVID dummy which equals 1 during the crisis period and zero otherwise. We find that Compliant stocks perform better during the pandemic and that this out-performance is not associated with higher risk as Compliant stocks are evidenced to be less volatile than their Non-Compliant peers during the COVID-19 period.

Tuesday, 21:30-23:00

■ TG-01

Tuesday, 21:30-23:00 - Room 1

IFORS Representatives Meeting

Stream: IFORS Sessions
Invited session

Wednesday, 8:00-9:40

■ WA-01

Wednesday, 8:00-9:40 - Room 1

Keynote: Karen Smilowitz

Stream: Keynotes
Keynote session
Chair: Taraneh Sowlati

1 - On the use of operations research methods in public school systems
Karen Smilowitz

Operations research methods have been used to improve operations in public school systems for over fifty years. The talk will explore connections between evolving issues in public education and advances in optimization, computing and geographic information systems, beginning with early work motivated by Supreme Court decisions to desegregate schools. We will also discuss how the limitations of early models and solution approaches hindered their applicability. The years since have seen new research directions to address additional challenges related to the design of school attendance boundaries and leverage emerging advances in technology. The talk will end with a reflection on current issues facing public school districts, including school busing and return-to-school plans amid the COVID-19 pandemic, and the ways in which operations research can be part of these discussions.

Dr. Karen Smilowitz is the James N. and Margie M. Krebs Professor in Industrial Engineering and Management Science at Northwestern University, with a joint appointment in the Operations group at the Kellogg School of Business. Dr. Smilowitz is an expert in modeling and solution approaches for logistics and transportation systems in both commercial and nonprofit applications. Dr. Smilowitz is the founder of the Northwestern Initiative on Humanitarian and Nonprofit Logistics. She has been instrumental in promoting the use of operations research within the humanitarian and nonprofit sectors through the Woodrow Wilson International Center for Scholars, the American Association for the Advancement of Science, and the National Academy of Engineering, as well as various media outlets. Dr. Smilowitz is the Editor-in-Chief of Transportation Science.

■ WA-02

Wednesday, 8:00-9:40 - Room 2

Supply Chains 1

Stream: Supply Chain Management
Invited session
Chair: Kosuke Kawakami

1 - Disruption mitigation strategies in a multi-tier supply chain
Joong Son, Rickard Enstroem

This paper studies the effectiveness of disruption mitigation strategies in a multi-tier supply chain. In light of the COVID-19 and its impact on the global economy, it has become imperative that every business identify the source of vulnerability in its supply chain by conducting a detailed mapping of each node and link in the network. Businesses seldom track their supply chain beyond tier 1 suppliers, often creating panic reactions when high-impact low-probability disruptions occur in the upstream. This research investigates the impact of the source of disruption (i.e., the relative position of the disrupted nodes within the supply chain) and proposes appropriate mitigation strategies contingent on the source. Two types of mitigation strategies are examined, a proactive one aimed to limit the disruption frequency and a reactive one aimed to facilitate faster recovery to the normal state. Analytical framework of supply disruptions and mitigation approaches is provided along with numerical results to assess the effectiveness of each approach under different scenarios. Results indicate that proactive approaches provide better protection in terms of product availability measures when disruptions occur upstream, whereas reactive approaches show better effectiveness when disruptive events occur downstream. As an important future research stream, this paper proposes a distributed information approach to enhance transparency on supply chain provenance.

2 - Congestion-focused approach to the layout design problem of a semiconductor fab modeling and simulation
Gwangjae Yu, John Fowler

In designing a facility layout, the classical approach has been to minimize the flow-weighted distance of materials through the automated material handling system (AMHS). However, the distance-focused approach sometimes yields one major issue, traffic congestion, which leads to the question if it is truly a good criterion to design a layout. In this study, we analyze semiconductor FAB design to understand the system dynamics and find a possible explanation that causes such congestion. Then, we propose a "balancing the flow" approach that focuses on minimizing the congestion. Finally, we compare the performance of the two methods through simulation of semiconductor FAB layouts to suggest under what conditions each method leads to a better design.

3 - Seasonal inventory management model for raw materials in steel industry
Kosuke Kawakami, Hirokazu Kobayashi, Kazuhide Nakata

We developed a seasonal inventory management model for raw materials such as iron ore and coal for multiple suppliers and multiple mills. The Japan steel industry annually imports more than 100 million tons of raw material by maritime transportations. Once these raw materials arrive, they are transported to domestic mills and stored in yards. A critical problem facing the industry is the limited capacity of the yards, which leads to high demurrage costs while ships wait for space to open up in the yards before they can unload. To reduce the demurrage cost, we need to keep the inventory level as low as possible. However, inventory levels that are too low may lead to inventory shortage due to seasonal supply disruptions that delay the supply of raw materials. Since both excess and depleted inventory levels lead to an increase in cost, we need to determine proper inventory levels. To solve this problem, we developed an inventory management model that considers variations on the supply side. Such variations should be observable if we take a look at the ship operations, so our concept is to model the probability distribution of ship arrival intervals by brand groups and mills. We divided ship operations into two stages: arrival at all mills and arrival at individual mills. We modeled the former as a nonhomogeneous Poisson process and the latter as a nonhomogeneous Gamma process. Our proposed model enabled us to reduce the inventory level by 14% in the summer and 6% in the winter.

■ WA-03

Wednesday, 8:00-9:40 - Room 3

Logistics, Transportation and Traffic 5

Stream: Logistics, Transportation and Traffic (contributed)
Contributed session
Chair: Rogers Kayisinga

1 - Computational decision support for ride-sharing policies: An integrated activity-travel demand and vehicle scheduling approach
Taehooie Kim, Xuesong Zhou, Ram Pendyala

Integrated modeling frameworks supported by activity-based approaches and dynamic traffic assignment models have been developed to represent the complex interrelationships between travel demand and network flows. With the advent of advanced technologies and mobility-on-demand services and the increased accessibility much richer travel and traffic data sets, there is both a need and an opportunity to further capture potential travel behaviors induced by the emerging mobility services within a traffic network. This research aims to address the issue utilizing novel integrated approach. The hierarchical structure of the activity-based travel demand model, denoted by computation graphs visualizing mathematical functions to effectively analyze the marginal effect of transport policies or congestion pricing, is formalized. Using the activity-travel graph, a network-based representation of coupled location and travel activities, vertices of state, time of travel, and location of agents, and edges indicating different activity types, is designed. This conceptual framework enables transportation planners and agencies to recognize the transition in travel demand and network flows in real time and mitigate the traffic congestion by constructing a shared-ride network system. In this study we estimate the likelihood of selecting ride-hailing services and the impact on the decision making within the real-world Phoenix network to propose a new price policy, mitigating a traffic bottleneck.

2 - Primal column generation framework for vehicle and crew scheduling problems
Ilyas Himmich, Issmail El Hallaoui, Francois Soumis

The primal adjacency-based algorithm and the multi-directional dynamic programming algorithm are two exact methods that have recently been developed to efficiently solve the shortest path problem with resource constraints. These methods are primal in the sense that they are able to produce sequences of feasible solutions using iterative exploration of the search space. Since the shortest path problem with resource constraints often appears as a subproblem in the solution of vehicle and crew scheduling problems using column generation, we propose a new Primal Column Generation framework that embeds these primal methods in a column generation scheme. The Primal Column Generation solves at each iteration a sequence of appropriate restricted subproblems and stops solving the subproblems when there is no need to continue. This approach introduces a large degree of flexibility, and allows performing good cost improvements in a very limited time. Computational experiments on vehicle and crew scheduling problem instances show that the proposed approach is able to find optimal solutions while reducing the time spent solving the subproblems by factors of up to seven compared to the standard column generation algorithm. This leads to significant improvements in the overall solution times, with an average reduction factor of 3.5.

3 - Evaluating the importance weight on airline selection attributes based on MCDM
Rogers Kayisinga

This study focuses on assessing the importance weighting for attributes that passengers primarily consider when choosing an airline. As the airline's business model is rapidly changing, lots of ancillary services are being introduced by airlines. Due to the change of passengers' choice behavior on air travel, the traditional airline choice attributes have been changed. In this study, we will deal to conduct an analysis of the importance of airline selection attributes perceived by customers in the changing airline markets being introduced various ancillary services using the MCDM model. The various types of business models for airlines can be developed with this study.

■ WA-04

Wednesday, 8:00-9:40 - Room 4

Prescriptive Models in Scheduling

Stream: Scheduling, Timetabling and Project Management
Invited session
Chair: Alexander Benavides

1 - Optimization of steel production planning considering continuous-casting and rolling processes
Nelson Torres, Eduardo Moreno

Steel is a widely used material with applications from home appliance to large construction projects. Because of its versality, production plants are also very different, and there is no single optimization tool used to schedule production in steel plants. Our goal is to schedule coils (orders of steel) by a MIP model, minimizing the total cost of production, considering a plant with four stages of production: steelmaking, continuous casting, transferring and rolling. Due to this configuration, we need to consider several operational and security requirements in the model. We use the setup of the Nucor facility in Alabama, US, where schedules are generated manually by their operators. A day usually has 2 batches of 100-150 coils that have to be casted in two parallel casters. We propose a coil-based model to help schedulers generate near-optimal solutions in an operationally feasible time, which is a more specific approach than heat-based models where coils are grouped based on their grade and scheduled without some coil unique considerations. Because of the large number of variables and constraints involved in our coil-based model, we consider heuristics and cuts in order to strengthen the model and get to good feasible solutions faster. We also propose a two-stage approach where we split constraints in order to reduce solve times to get near-optimal solutions. We have been able to improve up to 20% on the costs compared with the past schedules provided by the company.

2 - Speeding up resource constraint evaluation with machine learning for the airline crew rostering problem
Michael Zhang, Andrea Raith, Andrew J Mason, Oliver Weide, Olga Perederieieva

When airlines solve a crew rostering problem, the solutions obtained must respect the airline industry's many rules and regulations. We use a column generation based solution method with resource constrained shortest path problems (RCSPP) as subproblems to solve the crew rostering problem. Typically, the rules are modelled as constraints and resources in the RCSPP. The number and specifics of the rules may vary over time and between airlines, and they can be a burden to reimplement in RCSPP every time a change is necessary. We work with a commercial partner who uses a complex and highly configurable external rule evaluator to calculate resource constraints. The rule evaluator provides a level of abstraction between the RCSPP implementation and the resource constraints to handle the various airline requirements. Calling this rule evaluator can be computationally expensive when paired with the NP-Hard nature of solving RCSPP problems. We use large amounts of data obtained during the solution process and apply machine learning (ML) techniques to explore heuristic ways to decrease the computational cost of calling the rule evaluator. We explore how well our ML models can identify and discard infeasible partial RCSPP solutions as opposed to calling the rule evaluator. We integrate our approach into the overall solution process and evaluate the effects of our predictive models' inclusion when applied to real-world problem instances.

3 - Algorithms for Resource Constraint Project Scheduling in underground mining operations
Diego Fuentes Guerra, Rodrigo A. Carrasco, Eduardo Moreno

The Resources Constraint Project Scheduling Problem (RCPSP) is one of the most reviewed topics by both the scheduling area and combinatorial optimization. Specifically, this problem is NP-Hard. Given the complexity of this problem, this research seeks to give some insight regarding the calculated solution. Specifically, it seeks to have a notion of proximity to the optimal solution. In this work we propose an approximation algorithm that can provide a solution to the RCPSP in short execution times, giving good solutions, demonstrating that the solution has a maximum gap with respect to the optimum. One of the bases in this research is the use of mathematical models that can formulate precisely the RCPSP with modifications. That is why, at first a time-indexed mathematical model is used, to later give way to a intervals-indexed formulation, which provides greater efficiency when solving the problem. Finally, we propose to use α-points, which

later allows us to propose α-intervals technique. Together, these two methodologies allow for a faster and more useful approximation algorithm. We use real underground mine instances, at the moment we are using two instances: one considering 3644 blocks and 3960 time units, and the second one with 14160 blocks and 3660 time units. It is concluded that the proposed algorithm used in the interval-indexed delivers satisfactory results when the time-indexed model does not.

4 - A fast non-permutation method for flow shop scheduling with heterogeneous workers
Alexander Benavides

The Heterogeneous Flow Shop Scheduling Problem (Het-FSSP) is composed of two subproblems that must be solved together: the assignment of heterogeneous workers to workstation machines, and the corresponding job scheduling problem in that flow shop. The processing time of each job on each machine depends on the assigned worker. This environment is inspired in Sheltered Workcenters for Disabled. The minimization of makespan aims to maintain high productivity in such environment. Optimal non-permutational schedules show shorter makespans than the best-possible permutational schedules. Recently, Benavides & Ritt (Comp Oper Res, 2018. doi:10.1016/j.cor.2018.07.017) proposed an accelerated calculation of makespans when inserting jobs in non-permutational flow shop schedules, similar to the acceleration of Taillard (Eur J Oper Res, 1990. doi:10.1016/0377-2217(90)90090-X) for permutational schedules. When we proposed the Het-FSSP and a scatter search with path relinking to solve it (Benavides et al., Eur J Oper Res, 2014. doi:10.1016/j.ejor.2014.02.012), the non-permutational accelerations were not available. Here we propose the integration of the non-permutational accelerations within a scatter search for the Het-FSSP. To do this, we replace the path relinking of the scatter search with an iterated greedy algorithm that uses the non-permutational accelerations. Our computational results show that the new method finds better solutions. We also indicate possible future research lines.

■ WA-05

Wednesday, 8:00-9:40 - Room 5

Military OR 1

Stream: Applications of OR (contributed)
Contributed session
Chair: *Uyen Bao*

1 - Selection of Line of Action for offensive operation of Brazilian Marines using the PrOPPAGA method
Felipe dos Santos, Marcos Santos

The military planning process is a tool that aims to aid the Commander of the Military Unit in the formulation and choice of which action plan to adopt. To solve their problem, the Commander and his Staff follow a sequence of three stages, subdivided into several phases, where they develop specific activities. In this work, the focus will be the "Comparison of Lines of Action (LA)", where several alternatives are presented to the Commander for one of them to be adopted during Operation. The application of the Multicriteria Decision-Making method "Priority Observed from the Presumption of Gaussian Attitude of Alternatives" (PrOPPAGA) to assist in structuring decision-making allows a clearer interpretation of the distinction between the possible LA to be adopted by an Amphibious Unit to the course of Land Operations. This structuring confers greater credibility with the troop, regarding the decision made by the Unit Commander. The greater the confidence of the troop in the decisions of its Commander, the greater the ability of this Commander to exert his influence on the troop, facilitating the individual and collective training of the Unit. The article concluded that, among the options presented and respecting the criteria considered, one of them is the best option. This conclusion contributes to society by subsidizing, in a structured way, the Commander's decision, increasing his confidence with his subordinates and, consequently, improving the response capacity of the troop.

2 - Optimal Component Layout for Minimal Vulnerability of Weapon Systems
Seungwon Baik, Shu-Cherng Fang

Vulnerability is one of the major features of weapon systems. Lower vulnerability guarantees the survivability and the sustainability of weapon systems on the battlefield. The vulnerability of a weapon system is greatly affected by how the components are laid out inside the weapon system. In this study, we deal with a mathematical model achieving an optimal component layout of weapon systems. The Vulnerable Area method is widely used to calculate vulnerability, but it can hardly be adopted in a mathematical model because of its complexity. Thus, we propose a new grid approximation scheme to define vulnerability. It is easily taken in the mathematical model and converges to the results of the Vulnerable Area method as the density of the grid increases. An MINLP (Mixed Integer Non-Linear Programming) model with the grid approximation scheme is formulated and solved through a convexification mechanism. This enables us to obtain the exact optimal solution of the MINLP model efficiently. The results are illustrated by some examples.

3 - The Use of Value-Focused Thinking for Assessing anti-RPAS strategies: A Study in the Brazilian Navy
Miguel Moreira, Marcelo Zawadzki, Marcos dos Santos, Carlos Francisco Simoes Gomes

The advance of military technologies has been enabling revolutionary capabilities to be employed by military forces. In this context, the Remotely Piloted Aircraft Systems (RPAS), mainly due to their versatility, has been considered a promising and desirable alternative to manned flights. Capabilities provided by RPAS vary from deploying weapons in far-away wars to tracking/monitoring in surveillance missions, among many others. However, if on the one hand, military forces can exploit the capabilities allowed by the use of RPAS, on the other hand, these forces must also be concerned about how to prevent the hostile use of these tools, by any opponent forces. Therefore, we propose the use of the Value-Focused Thinking (VFT) approach for analyzing different strategies to be employed for detecting and intercepting RPAS considered threatening to an allied military force. The VFT approach has three main benefits in this scenario: First, it allows a clear understanding of the problem, leading to the proper elicitation of the fundamental objectives. Second, it permits the generation of high-value strategies for being considered by the decision-makers. Third, it enables a framework that supports the assessment of the strategies providing not only the identification of promising solutions but also the opportunities for improving these strategies. We discuss the usage of the VFT approach and the benefits risen from this use, considering a case study conducted in the Brazilian Navy.

4 - Safe intercept times in short-range ballistic missile defence
Uyen Bao, Peter Dobias, Brittany Astles

In terminal ballistic missile defense, the defender aims to intercept a re-entry vehicle before it reaches the intended target. Ideally, the intercept location would be at a safe distance and at a safe height from the defended location. Typically, a re-entry vehicle travels at a speed of approximately1.5 km/sec and follows a nearly ballistic trajectory (for simplicity, we ignore the terminal maneuver effects). For short range re-entry vehicles, we can ignore earth curvature and use the gravitational acceleration g=0.098 km/[U+3016]sec[U+3017]2. Corresponding to the desired safe distance and safe height, there are two respective intercept times, and these two times are different. To obtain the distance intercept time is nontrivial, while the height intercept time can be obtained in a straightforward manner. Knowing the intercept times and the intercept locations allows us to estimate the outcomes in a short-range ballistic missile defense.

In this paper, we provide the derivations and the algorithms for both intercept times. We show that the algorithms are robust in the sense that they work under different circumstances and they converge efficiently with minimal assumptions. In future work, we will further expand this work for intermediate and long-range ballistic missiles, and potentially for air-breathing missiles.

■ WA-06

Wednesday, 8:00-9:40 - Room 6

Games and Applications 3

Stream: Dynamics and Games
Invited session
Chair: XuCheng Liu

1 - Decentralized Resource Allocation for Interdependent Infrastructures Resilience: A Cooperative Game Approach
Shima Mohebbi, Katherine Barnett, Babak Aslani

Interdependent critical infrastructures are governed by several sectors working together to maintain social, economic, and environmental well-being. Although many models focus on a centralized view for networks for the restoration planning of these networks, rarely is there only one decision-maker for the infrastructure networks. In the decentralized decision-making paradigm, individual decision-makers need to decide how to prioritize areas of the network and eventually improve the aggregated infrastructure systems resilience. There is a dearth of quantitative studies analyzing resource allocation decisions considering both decentralized and cooperative aspects. This paper aims to propose a coalitional game theory approach to address decentralized resource allocation for interdependent water distribution and road networks. In particular, combining coalitional game theory with weighted graphs creates an order of repair for each node in the coalitions. Subsequently, the decision-makers can pass the information on to the master problem, reducing the complexity of the resource allocation problem for the interdependent networks. The proposed approach is applied to water distribution and transportation networks in the City of Tampa, FL. We compare the decentralized solutions to centralized solutions in different scenarios to demonstrate the feasibility of our approach for the city-scale networks.

2 - Effects of two contracts on the platform's incentive to share information
Bo Li, Xue Chen, Ruidong Zhao

In this paper, we investigate the effects of reselling and agency contracts on the platform's incentive to share information when considering two scenarios, the recommendation scenario, and the non-recommendation scenario. The equilibrium solutions are obtained and compared. We find that for the reselling contract, the platform prefers to withhold demand information in the recommendation and non-recommendation scenarios. However, the platform voluntarily shares this information under the agency contract for the two scenarios. Further, the platform's optimal strategy depends on the commission rate, the platform's recommendation efficiency, and the level of information accuracy. Intuitively, a lower commission rate induces the platform to prefer the reselling contract in the recommendation and non-recommendation scenarios. However, a higher commission rate does not always make the platform choose the agency contract. The recommendation efficiency and the level of information accuracy affect the platform's optimal strategy. Then, given the platform's optimal strategy, there are Pareto optimal regions that make the manufacturer better off. That is, the platform and the manufacturer achieve a win-win situation. Finally, in an extension of the model, this paper shows the platform's optimal strategy when a hybrid contract is used, which also demonstrates the robustness of the results.

3 - Stochastic Game Theoretical Model of Advertising Decisions
Ayushi Dubey, , Rahul Marathe

Comparative advertising is the form of advertising in which a brand tries to disparage the rival brands, directly or indirectly, by name, illustration or other distinctive information in an attempt to increase its market share.We consider a scenario in which a brand manager wants to design an ad-strategy for a firm and has to take a decision on what marketing mix (based on the intensity of campaign we consider Direct comparative, In-Direct comparative and Non-Comparative advertisements) to choose for the advertising campaign. This decision cannot be taken unilaterally, as rival firm's strategy will affect the market share of the brand. Therefore, we attempt to find an equilibrium ad-strategy for a brand, keeping in mind the rival brand's strategy which will maximize the brand's marginal market share. To solve this problem we use a stochastic game-theoretic model for advertising decisions between two rival brands.

4 - Sewage Discharge In A Line: Optimization And Cooperation
XuCheng Liu

For a group of companies allocated along the linear river, we study the problem of their sewage discharge. There are two purposes in this paper: one is optimizing the sewage discharge to maximize total benefits, another is estimating whether the cooperation can generate among these companies or not. To achieve the two purposes, first, we use the greedy strategy to get the optimal sewage discharge. Then by using cooperative game theory and considering the externality of game, we prove mathematically that the core is non-empty. In the process of proving, we have identified the reduced convexity of sewage discharge game. In the following study, we generalize the sewage discharge game to games with reduced convexity, and the result demonstrate that if the characteristic function is reduced convexity, then the core of game is non-empty and the downstream incremantal distribution satisfies coalitional stability constraints and maximizes the total payoff allocated to all nodes. Moreover, our study also has two extensions worth considering, and we have a discussion at the end of this paper.

■ WA-07

Wednesday, 8:00-9:40 - Room 7

OR in Health, Medicine and Life Sciences 2

Stream: OR in Health, Medicine and Life Sciences (contributed)
Contributed session
Chair: Chang Won Lee

1 - On the Statistical Properties of Hospital Length of Stay
Nassim Dehouche, Sorawit Viravan, Ubolrat Santawat, Nungruethai Torsuwan, Sakuna Taijan, Atthakorn Intharakosum, Yongyut Sirivatanauksorn

Through a study of 46,364 electronic health records over four medical specialty departments (Pediatrics, Obstetrics/Gynecology, Surgery, and Rehabilitation Medicine) in the largest hospital in Thailand (Siriraj Hospital in Bangkok), we show that the distribution of hospital Length of Stay (LOS) exhibits heavy tails that are consistent with a subexponential distribution. We analyze some empirical properties of such a distribution that are of relevance to cost and resource planning, notably the concentration of resource consumption among a minority of admissions/patients, an increasing residual LOS, where the longer a patient has been admitted, the longer they would, counter-intuitively, be expected to remain admitted, and a slow convergence of the Law of Large Numbers, making empirical estimates of moments (e.g. mean, variance) unreliable. Consequently, we propose a novel Beta-Geometric model that exhibits a good fit with observed data and reproduces these empirical properties of LOS. Finally, we use this model to propose an approach to threshold detection, patient clustering, and to make practical recommendation for the pricing and management of LOS.

2 - Equitable and Efficient Heathcare Resource Distribution
John Hooker, Ozgun Elci, Peter Zhang

We formulate equitable and efficient distribution of healthcare or other resources as an optimization problem, subject to budgetary and other

constraints that typically appear in practice. The objective is to maximize social welfare functions that balance equity and total utility, such as alpha fairness, proportional fairness, Kalai-Smorodinksy bargaining, and recently proposed threshold functions that combine a utilitarian criterion with Rawlsian maximin or leximax fairness. We derive sometimes surprising structural properties of the optimal solutions that provide managerial insight, while demonstrating the importance of considering equity and efficiency together. We illustrate the results on healthcare resource allocation and other problems.

3 - Identifying the relations between accessibility and efficiency in Healthcare Network Design Problems
Edgar Duarte-Forero, *Gustavo Bula*

The healthcare network design problem (HNDP) aims to coordinate available resources to provide efficient services to a population. Most healthcare network optimization models focus on either minimizing operational costs or improving service coverage for patients. A growing interest in clinical pathways (CPWs) entails the inclusion of patient accessibility as an objective in HNDP. In this work, it is considered the evaluation of accessibility in configurations of healthcare networks and its relation with the efficiency of healthcare networks. The research method consists of two stages. First, a Mixed Integer Linear Programming model is proposed to design a hierarchical healthcare network for CPWs minimizing total operational costs. After obtaining a solution by analytical methods, accessibility for patients is calculated applying the Two Steps Floating Catchment Area approach. Computational experiments reflect that while an increase in covering distance for patients reduces the overall cost for the system, accessibility measurement are influenced by allocation of resources at facility locations rather than the number of available facilities.

4 - Exploring Global Healthcare Supply Chain System in COVID19
Chang Won Lee, *Hee Kyung Kim*

This study is to present a global Healthcare Supply Chain System in COVID19 crisis. Various case studies are provided and analyzed to synthesize the findings in terms of quality, access and cost perspectives. The study will provide healthcare decision-makers and policymakers with significant insights to improve the global healthcare systems.

■ WA-08

Wednesday, 8:00-9:40 - Room 8

Meta-Analytics in Supply Chain and Logistics

Stream: Meta-Analytics: A Marriage of Metaheuristics and Analytics
Invited session

Chair: *Haibo Wang*
Chair: *Yuning Chen*
Chair: *Yu Wang*

1 - A Bibliometric Review on Arc Routing Problems
Chen'ge Wei, *Ada Che*

Arc Routing Problem (ARP) is a classical combinatorial optimization problem, it goes back to the celebrated Königsberg Bridge Problem solved by Euler. From the 1970s to the present, ARP has attracted more and more researchers' attention, and its application scope has become wider and wider, and the related literature has increased greatly, especially since 2012. Different from previous reviews, this paper quantitatively analyzed ARP related literature. We selected 482 articles published since 1975 from the Web of Science Core Collection. The methods of bibliometric was applied to analyze these articles and explore the relationship between literatures, authors, institutions and countries, conclude production of them. The development and present situation of ARP are studied. By establishing article co-citation network, using clustering analysis, topological parameter analysis and PageRank, the well performance literatures in the network and closely related clusters are found. The literature co-citation network is divided into 14 clusters, each with obvious research tendency. The changes of research theme based on keywords over time are also mentioned. Several software tools have been designed to bibliometric analysis, Bibliometrix, CiteSpace and Gephi are used in this study. The research results are displayed visually. The research results are helpful to understand the research status of ARP and have a positive impact on the follow-up development.

2 - A decomposed data analysis approach on city sustainable development performance: a network DEA-model with slack-based measure
Bowen Sun, *Haibo Wang*, *Gary Kochenberger*

This paper concerns the evaluation of urban sustainable development in China. We propose a framework using a network data envelopment analysis (DEA) model with slack-based measure to analyze compositional data on urban development to obtain the weight and contribution of different factors. The results are compared with an existing Urban Sustainability Index system. We also evaluate the efficiency of resources invested in the city to achieve long-term and sustainable development. Furthermore, the 284 cities in China were grouped in different criteria to present the result of eco-efficiency and sub-efficiency on urban sustainable development. An ANOVA approach is also conducted to reveal the difference among cities in different regions and clusters. This article shed new light on the understanding of urban sustainable construction and development in China.

3 - A Self-Learning Hyper-Heuristic Method for Strategic Mine Planning
Yassine Yaakoubi, *Roussos Dimitrakopoulos*

Hyper-heuristics have emerged as a way to raise the level of generality of local search, unlike many approaches that may perform better but for which it's up to the user to tailor them to a given instance. This is of unique interest when solving large-scale stochastic combinatorial optimization problems where the size and complexity of industrial-problem instances make exact methods impossible to use, thus promoting approximate methods. The production scheduling of industrial mining complexes falls under this category of problems, managing the extraction of materials from multiple mines and treating them using interconnected processing facilities. To address the need for self-managed solution approaches that are able to tackle large-scale instances without resorting to aggregation, the proposed herein self-learning hyper-heuristic is a multi-neighborhood simulated annealing algorithm used in conjunction with reinforcement learning (RL), where the selection of a perturbation (low-level heuristic) is made in self-adaptive learning. By defining a neighborhood structure, the RL agent uses all related heuristics' past performance and learns how to guide the search for better solutions. Multiple state-of-the-art agents have been implemented and incorporated into the RL framework to study the robustness of the proposed method, and results show its effectiveness on multiple real-sized mining complexes, reducing the number of iterations by 30-50% and computational time by 30-45%.

4 - Adaptive Large Neighborhood Search for the Multi-Compartment Capacitated Arc Routing Problem
Yu Wang, *Min Wen*

Waste collection is becoming an increasingly complex task due to the rapid growth of the amount of global waste. It also comes with high operation cost, accounting for about two-thirds of the total cost in waste management process. To protect the environment and save the energy, it is important to classify the waste and collect them separately by using trucks with different compartments. This work studies the routing problem of collecting multiple types of waste, the Multi-Compartment Capacitated Arc Routing Problem (MCCARP). The objective is to minimize the overall waste collection cost without exceeding the capacity of each compartment on the vehicles. We present a Mixed Integer Programming model as well as an Adaptive Large Neighborhood Search (ALNS) heuristic for the problem. We have also generated new MCCARP benchmark instances and compared the performance of the MIP model with that of the ALNS. Computational results show that

the ALNS can find near optimal solutions to the small instances and high quality solutions to medium and large size instances within short computational times. We have also tested our ALNS on Capacitated Arc Routing Problem (CARP), a special case of the MCCARP, and compared our results on CARP benchmark instances with that of the state-of-the-art algorithm for CARP in the literature. We can produce equally good solutions within shorter computational times.

■ WA-09

Wednesday, 8:00-9:40 - Room 9

Decision Analysis and Decision Support Systems 1

Stream: Decision Analysis and Decision Support Systems (contributed)
Contributed session
Chair: *Jiahui Zhang*

1 - Overcoming anchoring effects in multimodal input elicitation to extract more accurate crowd estimates
Yeawon Yoo, Adolfo R. Escobedo

In various areas of group decision-making and crowdsourcing, independent human judgments are gathered and then aggregated with the goal of obtaining a wiser collective judgment. It is well known that the choice of input elicitation and the aggregation method employed can significantly affect the quality of the collective judgment. In fact, there is a longstanding debate whether it is better to use ordinal or cardinal information in many of these contexts. This study considers the use of both of these types of inputs by conducting a crowdsourced experiment where participants are asked to estimate the number of dots within a set of images in two ways: ordinal (ranking) and cardinal (numerical) estimates. First, participants are asked to order multiple images based on the number of dots they contain. Second, participants are asked to estimate the number of dots in each of the images. The latter task is implemented as an A/B test; in one setting, cardinal estimates are elicited by showing the images from the ordinal estimation but showing one image at a time in a randomized order. In the other setting, cardinal estimates are elicited by showing the images at once in the order previously specified by the participant. This is done to test the anchoring effect on cardinal estimates from the ordinal estimates. We find that asking cardinal estimates independent from the ordinal estimates helps to achieve better collective accuracy. Moreover, improved ordinal and cardinal estimations a

2 - An AHP-Promethee model for prioritizing investment projects based on the perspectives of the Balanced Scorecard
Adalberto Manoel Junior, Cristiano Torezzan

The decision-making process on investment projects is a strategic concern in industrial organizations, mainly because the involvement of high monetary values and the incorporation of assets that are not easily transferable. In general, the selection of projects requires the analysis of a set of alternatives that exceed the availability of resources. Usually, in practice, companies apply economic engineering methods to select the most appropriate portfolio based on a financial perspective. However, it has been verified by many studies that focusing only on financial results is not enough to assure long-term success. In this work it is proposed a multicriteria approach, based on a hybrid AHP-Promethee method that considers the four perspectives of the Balanced Scorecard (BSC) strategic planning model as the main criteria. This approach allows for the thoughtful inclusion of non-economic qualitative and quantitative factors in order to select the best investment project options. The proposal was validated through a case study of prioritizing investments in an industrial company. The study counted with the participation of 30 specialists to elicit the weights and subcriteria for each perspective of the BSC. The results proved that the proposal is feasible and allows a composition of a more balanced portfolio of investments, in contrast to the exclusive use of the financial perspective.

3 - Persuasive Narratives on Crowdfunding Platforms: Effect on Donations for Medical Appeal
Junhong Wu

Online crowdfunding has emerged as an increasingly popular tool to raise funds for medical treatment. Medical Crowdfunding campaigns can use language tools to attract donor. The persuasiveness of language is an important factor affecting the subjective judgment of donors. Different styles of verbal persuasion will change donors' perception of patients' conditions, thus affecting their willingness to donate. Construct a corpus of persuasive styles with the help of text mining methods, and according to Aristotle's theory of persuasion, the characteristics of rational appeal, emotional appeal and credibility appeal are constructed. Finally, establish an econometric model of the influence of language persuasion style on project financing. Results from the econometric analysis using over 30,000 campaigns benefiting critical patient reveal that both rational and credibility have positive effects on donations.

4 - Representing and Modeling Group Option-Generation Process
Jiahui Zhang, Chen Wang, Lefei Li

Generating options is crucial to making good decisions. Prior research on creating options has designed experiments to investigate how different interventions (e.g., value-focused brainstorming) affect the quantity and quality of the alternatives generated by an individual or a group. In this paper, we propose a novel empirical method that characterizes the group option-generation process in real-world decision scenarios. Using transcripts of the brainstorming stage in a high-school science and technology contest, we apply natural language processing to represent two cognitive spaces of decision issues (including context, objectives and options) and technology implementation separately. We then build a mutually exciting Hawkes process to capture the exploitation-exploration tradeoff among decision issues and the transitions between decision issues and technical realization. We find that each team exhibits a mixture of three thinking types, Mechanic, Propeller, and Thinker, each type leading to different levels of novelty and depth. This empirical method provides rich insights into each team's option-generation process, and facilitates data-driven analysis of their navigation strategies in the cognitive spaces.

■ WA-10

Wednesday, 8:00-9:40 - Room 10

IFORS - Sustainability Analytics and Modeling: Meet the Editor-in-Chief

Stream: Journals
Invited session
Chair: *Elise Miller-Hooks*

Wednesday, 10:00-11:40

■ WB-01

Wednesday, 10:00-11:40 - Room 1

Keynote: Wotao Yin

Stream: Keynotes
Keynote session
Chair: Thomas Kalinowski

1 - Learning to Optimize
Wotao Yin

Many applications require repeatedly solving a certain type of optimization problem, each time with new but similar data. "Learning to optimize" or L2O is an approach to develop algorithms that solve these similar problems much faster. L2O-generated algorithms have achieved significant success in signal processing and inverse-problem applications. On LPs, SAT problems, and MIPs, L2O shows promising progress in many aspects. This talk introduces the motivation for L2O and overviews different types of L2O approaches for continuous optimization. We will cover model-based approaches, which are derived from general-purpose optimization algorithms but involve (possibly many) tunable parameters, as well as model-free approaches, which use recurrent neural networks and other deep learning architectures to build algorithms. We will briefly go through L2O approaches based on plug-and-plays, safeguarding, and fixed-point networks, which are hybrid classic-learning optimization methods.

■ WB-02

Wednesday, 10:00-11:40 - Room 2

Agricultural Supply Chains

Stream: Supply Chain Management
Invited session
Chair: Leonardo Talero-Sarmiento

1 - Multi-Product Multi-Region Supply Chain Optimisation for Seasonal Crops
Harry Sisley, Paul Corry

There is an increasing demand for seasonal crops year-round, even when they are considered out of season. This problem can be addressed by continually moving production throughout the year to climates where the crops are in season. Management of this type of supply chain for a business on a national scale is a challenging task. In this paper, we create a supply chain model that simultaneously manages the production of multiple crops across many growing regions. Production is set to satisfy the demand of multiple end-products while considering the throughput capacity of the packing plants and each growing region's harvest capacity. A time delay may be applied when moving between stages of the supply chain due to the geographic scale being modelled. The model determines the optimal planting plan, which satisfies the demand for all products year-round at a minimal cost. Numerical experiments demonstrate the capability of the model for addressing seasonal crop production.

2 - A bi-objective multi-warehouse inventory model for agri-fresh products with lateral transshipment
Regina Berretta, Parichehr Paam

We propose a bi-objective multi-warehouse inventory optimization model for agri-fresh products allowing lateral transshipments between warehouses. Initially, we extended a previous developed MILP model by allowing transshipment between warehouses. We tested a number of randomly generated instances using Gurobi optimization under three different scenarios based on the value of transshipment costs compared with holding costs (lower, similar or higher). The results show that considering lateral transshipments decrease costs in all scenarios. Increasing transshipment cost, the overall objective function decreases because of the reduction in holding and deterioration costs. Next, we converted the model into a bi-objective one, as there was a conflict between two cost components of the objective function: energy cost of warehouses and product deterioration cost. In the bi-objective model, the first objective minimizes energy costs of warehouses, preparation costs of warehouses, inventory holding costs and transshipment costs. The second objective minimizes the quantity of deteriorated products. We calculated the weighted sum of both objectives using nine different combinations of weights for the two objective functions and tested on the same instances. The resulted pareto fronts provide a decision-making scheme for managers to decide on the best trade-off between warehousing and inventory costs (first objective) and the quantity of deteriorated products (second objective).

3 - A theoretical framework for Theobroma Cacao yield maximization based on centered-user design, mathematical programming, and smart farming technologies.
Leonardo Talero-Sarmiento, Henry Lamos

Cocoa is a highly globalized commodity traded worldwide, cultivated mainly by smallholder farmers, and influences distinct economic sectors due to the high value for processing and consuming countries. However, in developing countries, farmers face difficulties such as half-done Good Agricultural Practices, lack of information for decision-making, low-quality planting materials, and rudimentary technology and tools. Considering the application of social O.R., which could contribute at the production level by assisting in developing appropriate centered-user designed management systems for production units, this works proposes a theoretical framework for optimizing Theobroma Cacao yield harvested in a specific site in Colombia, based on integrating three research domains as follows. The First, assessing cocoa productivity in a site-specific farm under different soil conditions, irrigation, fertilization, diseases, and environment, based on statistical and machine learning models. The Second is developing a mathematical model involving operational research techniques to improve managerial decision-making in cocoa field operations under uncertainty. The Third is deploying a knowledge-based technical management systems solution in cocoa farming, considering technological infrastructure constraints and user-centered design.

■ WB-03

Wednesday, 10:00-11:40 - Room 3

Logistics, Transportation and Traffic 9

Stream: Logistics, Transportation and Traffic (contributed)
Contributed session
Chair: Avnish Malde

1 - Urban deliveries using electric van-based robot system with en-route charging
Shaohua Yu, Jakob Puchinger, Shudong Sun

We present a two-echelon electric van-based robot delivery system with en-route charging for last-mile delivery. Robots can visit areas with van access restrictions, such as pedestrianized areas or university campuses. The time during which electric vans are carrying robots can be used effectively to recharge the robots, thereby increasing the efficiency of distribution systems. To model the proposed system, we present a mixed-integer program. We note that the energy transfer from a van to its robot needs time and will cause the available travel distance of a van to decrease and that of a robot to increase. Focusing on the new time-distance-energy trade-off problem, which increases the difficulty checking the feasibility of any given route, we further propose

a greedy route evaluation approach and a linear programming-based route evaluation method. An adaptive large neighborhood search algorithm is presented for solving larger instances. We performed four types of computational experiments. First, we used parameter tuning to determine the parameters. Second, we evaluated the performance of two proposed route evaluation approaches. Third, we conducted an ALNS experiment to see the overall performance of the proposed algorithm. Fourth, we performed a sensitivity analysis to determine the impact of related charging modes, maximum battery capacities, and charging rate.

2 - Optimization of cargo allocation in rail transport: structuring and application of an integer linear programming model
Valeriana Cunha, Catarina Barbosa Careta, Jose Vicente Caixeta-Filho

Rail transport plays a key role in global logistics operations. One of the challenges faced by the sector's companies is to efficiently optimize load distribution and positioning within freight cars, as improper allocations can increase operating costs and reduce modal competitiveness. Losses from improper distribution range from impacts on the operation's direct costs, to the need to compensate customers for damages arising from improper loading. Among the direct costs, it is important to highlight losses caused by delay due to inefficient freight distribution among and within railcars slowing loading and unloading. To address costs generated by improper freight distribution, this paper proposes an Integer Linear Programming model designed to optimize load allocation. The model is run using data from a Brazilian railroad operator. With the results obtained, decision makers can visualize the optimal solution for the modeled situation, and through sensitivity analysis, evaluate strategies available when adapting to unforeseen contingencies. The model's application would also facilitate the creation of a pragmatic set of benchmarks and other indicators for use in freight transport operations to better define realistic goals.

3 - Optimal transportation mode selection and capacity allocation under uncertainty
Avnish Malde, Tugce Isik

We consider the overseas supply chain of a manufacturing company with long lead-times and multiple transportation modes, where orders are placed using forecasted demand. The forecast error, which is the difference between forecasted and actual demand quantity, is considered an uncertain parameter. We also assume that the amount of excess inventory at the beginning of each period is uncertain. Order quantities for each transportation mode must be determined. We model this problem using a two-stage stochastic programming approach to minimize the overall expected order procurement, inventory holding, and backorder costs under demand and inventory uncertainty. We use Sample Average Approximation (SAA) method to solve our two-stage stochastic program. To generate the samples in each replication of an SAA, we use the stratified sampling technique called Latin Hypercube Sampling (LHS) to generate random samples from a continuous distribution. Further, we use scenario decomposition based method, Progressive Hedging Algorithm (PHA), to solve the two-stage stochastic programming problem generated in each replication of an SAA. We evaluate the performance of our solution algorithm at different levels of uncertainty and different PHA parameter settings via a numerical study.

■ WB-04

Wednesday, 10:00-11:40 - Room 4

Scheduling applications 2

Stream: Scheduling, Timetabling and Project Management
Invited session
Chair: *Pierre Baptiste*

1 - Nurse scheduling using linear integer programming and random forests to predict well-being
Yoan Villeneuve, Sara Séguin, Julien Maitre

For the past decade, the healthcare system of the Province of Québec, in Canada, has dealt with multiple issues regarding the nurses, especially concerning their schedules and increase in workload. Mostly in hospitals, nurses are showing signs of burnout because of overtime, increased workload and bad scheduling. The aim of this project is to propose a viable solution for the nurse scheduling problem by using both optimization and machine learning. First, random forests are used to predict a score for each nurse. This score predicts the risk of a nurse skipping work based on her past schedules. This parameter is then used in a linear integer optimization model to generate optimized schedules based on the nurses preference. The score influences the nurse satisfaction towards her own schedule. Numerical results are conducted on real data provided by a local healthcare establishment. Findings show that the proposed method allows to create fair schedules compared to the actual method used to schedule nurses.

2 - Stochastic programming approach for unidirectional quay crane scheduling problem with uncertainty
Hongming Li, Ning Zhu, Shoufeng Ma, Chenyi Fu

Quay crane scheduling is a key aspect of container terminal operation, which can be regarded as a decision-making process with uncertainty. In this study, we investigate the unidirectional quay crane scheduling problem for a stochastic processing time which requires that all the quay cranes move in the same direction either from bow to stern or vice versa throughout the planning horizon. The problem is formulated as a two-stage stochastic programming model, where the first-stage decision variables correspond to the assignment of tasks to quay cranes and the second-stage decision variables are related to the generation of schedules. To solve the stochastic programming model, an integer L-shaped method is presented for small-sized instances, and a simulated annealing algorithm is presented for large-sized instances to obtain near-optimal solutions. Numerical experiments show that the integer L-shaped method and simulated annealing algorithm could efficiently solve the unidirectional quay crane scheduling problem with uncertainty. The results also indicate that the stochastic model has distinct advantages in terms of shortening the completion time of vessels and improving the service level of container terminals compared with the expected value problem solutions.

3 - A 2-approximation list-scheduling algorithm for a single-machine scheduling problem with a non-renewable resource
Susumu Hashimoto, Shinji Mizuno

We study a single machine scheduling problem with a non-renewable resource. In this problem, every job needs to consume some resources to process. The resources are supplied in fixed quantities at fixed times. The concept of non-renewable resources includes typical constraints of the real factories, such as raw materials, intermediate products, and money. The objective function is the total weighted completion time. This problem is known as an NP-hard problem, even if every job has the same processing time, and its weight is proportional to the amount of its resource requirement. For this problem, it has been proved that a list-scheduling algorithm is a 3-approximation algorithm and conjectured that the actual approximation ratio is 2. We prove the conjecture, and besides, we show that there is no problem for which the approximation ratio of the algorithm is exactly 2.

4 - Minimization of the Mean completion time in non-permutation flow shop with ready dates, due dates, and variable proportion of missing operations
Pierre Baptiste, Randa Ouchene, Djamal Rebaine

We study the minimization of the mean completion time (work in progress) in a flow shop with ready dates, due dates, and missing operations. We only consider feasible solutions (ready and due dates must be respected). We tackle two questions: the cost of a restriction to permutations flow shops, and how this cost is affected by the proportion of missing operations. There is no benchmark for this problem so we designed a protocol to create instances from those of Taillard, by

adding ready and due dates and missing operations. First, we implement a branch and bound scheme and we study the ratio between optimal solutions in permutation and non-permutation flow-shop scheduling with respect to the mean finish time with ready and due dates in small instances. Results are comparable to the already known ones for the Makespan. Second, we study the behaviour of this ratio when the proportion of missing operations increases. The missing operations are really missing; they are not considered as operations with a null processing time. The benefit of looking for non-permutation flow shop increases considerably when the proportion of missing operations increases. Finally, we propose heuristic algorithms (SPT, LPT, insertion rules, NEH algorithm, modified NEH algorithms, etc.). For small instances, heuristics are close to optimal schedules obtained with the branch and bound. We compare the behaviour of those heuristics with increasing proportions of missing operations in lager problems.

■ WB-05

Wednesday, 10:00-11:40 - Room 5

Stochastic simulation and its applications

Stream: Simulation, Stochastic Programming and Modeling
Invited session
Chair: *Chuljin Park*

1 - Extremal kriging for extremal quantile metamodeling
Heelang Ryu, *Kyoung-Kuk Kim*

Constructing a metamodel for an extreme risk measure is crucial in the high-tech industry such as semiconductor manufacturing, but it is hard to obtain a reliable mean response surface with only a few extremal data points at each design point. This paper proposes a kriging method for quantiles of rare probabilities. Our designed response surface regresses based on the Brown-Resnick processes, which is the max-limit process of Gaussian processes. The performance of our proposed method is illustrated by several numerical examples.

2 - One-dimensional stochastic root finding using Bayes decisions
Chuljin Park, *Dong Hyun Kim*, *Seong-Hee Kim*

We consider a problem of locating a point such that a given function at the point equals zero. We assume that the function can be observed with noise in a one-dimensional space and the level of the noise is relatively large compared with the values of the function. A new approach, namely the trisection algorithm with Bayes decisions (TAB), is proposed to solve the target problem. We demonstrate how the algorithm works and provide some numerical results to show its performance.

3 - Agent-based evolving network modeling- a new simulation technique for study of diseases spread over complex networks at low prevalence
Chaitra Gopalappa

We present the agent-based evolving network modeling(ABENM), a new technique for simulating epidemic outbreaks over complex contact networks at low prevalence. As current agent-based network modeling (ABNM) consists of simulating the network of all infected and susceptible persons, they are computationally infeasible for studying certain questions at low prevalence, including endemic diseases such as HIV and TB, or in the early stages of newly emerging disease outbreaks such as COVID-19, Ebola, and SARS. ABENM simulates only infected persons and their immediate contacts as agents in a network and all other susceptible persons as compartmental model. New algorithms, using concepts from graph theory, stochastic processes, and optimization, maintain the network dynamics over time, including evolving the network, i.e., transitioning contacts of newly infected persons from compartmental to the network. We apply ABENM to HIV where contacts follow a scale-free network, for potential use for cluster analyses in conjunction with molecular cluster detection and response to new disease outbreaks. Molecular clusters are groups of HIV infections that are genetically similar, indicating rapid HIV transmission and where interventions are needed to prevent future new infections. As surveillance data are only available for cases that are diagnosed and reported, a model is a critical tool to understand the true size of clusters and assess key questions to inform effective response strategies.

4 - Analysis of Response Rate and Speed in Mail Survey: Markov Chain Monte Carlo Approach
Young H. Chun, *Edward Watson*

Survey research such as mail or online questionnaires is one of the most important tools for empirical research. Various curve-fitting methods have been widely used to predict the cumulative number of responses that have been received during a given time period. However, some of those response models are based on simplifying assumptions that are not valid in many practical situations. In this paper, we first propose a probabilistic response model that has many desirable properties. Our response model has three meaningful parameters - (i) an ultimate response rate of recipients, (ii) a delay rate of respondents, and (iii) an average delivery time of responses. Assuming that we have prior information about these model parameters, we then use the Markov chain Monte Carlo (MCMC) method to estimate those model parameters. With a 17-week mail survey data, we finally test our response model and show its outstanding performance over other conventional curve-fitting methods.

■ WB-06

Wednesday, 10:00-11:40 - Room 6

Network design

Stream: Combinatorial Optimization
Invited session
Chair: *Liang Chen*

1 - MPEC-based mixed-integer programming formulation for nonlinear network design
Arvind Raghunathan, *Sreekanth Rajagopalan*

We present a novel mixed-integer nonlinear programming (MINLP) formulation for global optimization of nonlinear network design that is based on an equivalent MPEC (mathematical programming with equilibrium constraints) formulation. Although the MINLP is convex in structure, the lack of a regularity condition necessitates a customized LP/NLP branch-and-bound algorithm for efficient optimization of the problem. We compare the computational performance of our MINLP formulation with two other recent MINLP formulations on a library of water distribution network (WDN) problems, wherein the least cost design of networks for a given nodal demands is sought by choosing appropriate diameter sizes for the edges that still satisfy the physical (nonlinear) flow-pressure drop relations and other bound constraints on flows and pressure heads. We also implement pre-processing techniques and custom heuristics within the LP/NLP-BB and compare their overall impact on computational performance. We also present extensions to the formulation to address other related network design and operational problems.

2 - New Formulations for the Steiner Tree and Network Design
Trilochan Sastry

Building on ongoing work on formulations for the TSP, we present polynomial formulations for the Steiner Tree. Existing formulations use multi commodity flows from the root node to all other terminal nodes. In addition we introduce two other sets of auxiliary variables. One tracks the number of commodities flowing on each edge, and another are vertex variables that track the degree of each vertex. The utility of this comes when all these three sets of variables are linked to each other.

3 - An exact separation algorithm for the unsplittable flow capacitated network design arc-set polyhedron
Liang Chen, Wei-Kun Chen, Yu-Hong Dai

In this talk, we concentrate on generating cutting planes for the unsplittable capacitated network design problem. We use the unsplittable flow arc-set polyhedron of the considered problem as a substructure and generate cutting planes by solving the separation problem over it. A brute-force algorithm, called exact separation algorithm, is employed in solving the separation problem of the considered polyhedron such that the constructed inequality guarantees to be facet-defining. To relieve the computational burden, we show that, in some special cases, a closed form of the separation problem can be derived. Furthermore, a new technique is presented to accelerate the exact separation algorithm, which significantly decreases the number of iterations in the algorithm. Finally, a comprehensive computational study on the unsplittable capacitated network design problem is presented to demonstrate the effectiveness of the proposed algorithm.

■ WB-07

Wednesday, 10:00-11:40 - Room 7

Energy, Environment and Climate 3

Stream: Energy, Environment and Climate (contributed)
Contributed session
Chair: *Dongyeon Jeong*

1 - Global Environmental Efficiency in GDP, CO_2 and PM2.5–Using Meta Stochastic Frontier Analysis
Ziyao Li, Sangmok Kang

This paper estimates the metafrontier environmental efficiency (MEE) of 164 countries for the period 1998-2018, using the Meta Stochastic Input Distance Function. We followed the two-step meta stochastic frontier approach by Huang et al. (2014) and converted it into a new definition - environmental gap ratio (EGR). We find that CO2 emissions are closely related to GDP, labor, capital, and PM2.5 emissions. We categorize 164 countries into 4 income groups and the result shows that both the EGR and MEE for the high-income group are low, but the group efficiency is higher than other groups. The environmental gap within the 4 groups is relatively small. Also, MEE changed very slowly, and we need to get a long-term plan to improve environmental efficiency.

2 - Enhancing the Value of Solar Electricity as Solar and Storage Penetrations Increase
James Hyungkwan Kim

It is well known that the market value of PV, including energy and capacity, declines with increasing penetration, a fact that has been observed empirically in California and modeled in a wide range of studies. The existing solar projects have been shielded from this erosion in market value by the long-term, fixed-price PPAs. However, in some markets, the solar power purchasers have bought a product increasingly less-valuable, or entering a shorter contract term than it once. The decreasing market value of PV with higher penetration potentially limits the economic attractiveness of solar and it could restrict future demand for solar projects. This study is to have a better understanding of which grid-friendly PV options can help stem the value decline. We conduct a comparison analysis of grid-friendly PV options to increase the value of solar energy as penetrations increase. Under this study, we track the wholesale electricity market value of solar over time across multiple regional ISOs. Additionally, leveraging the projected future wholesale price estimates for multiple regions of the country under both low and high renewable energy futures, we evaluate the increased market value of grid-friendly PV options in various regions and with varying penetrations of wind and solar. The results can provide guidance regarding how grid-friendly PV system may change the market value as renewable penetration increases in the other ISOs.

3 - Assessing the behavioral response of public fast charging station users to the EV 'hogging' penalty policy.
Seongwon Hong, Jiyong Eom

To prevent after-charge-idling at public charge facilities for Electric Vehicles (EVs), Korean government has enacted a law to impose fines on vehicles that uses public-fast-charger longer than one hour (Hogging). This study aims to analyze how the duration usage of public-fast-charger change before and after the policy. By panel regression models, individual-level change of charge duration and hogging duration has both proved to be significantly decreased. The decrement was shown largest in morning, which showed longest mean connection duration to avoid risk. The hogging duration showed significance decrease only in metropolitan area. Charge efficiency of fast-chargers are slightly increased as the average charge rate has significantly increased after the policy implementation. Therefore, the implemented policy significantly reduced the targeted action and proved that it was partially successful in increasing the efficiency of the infrastructure.

4 - Missing Data Imputation using Mixture Factor Analysis for Building Electric Load Data
Dongyeon Jeong, Chiwoo Park, Young Myoung Ko

We propose a missing data imputation method for building electric loads using the mixture factor analysis (MFA). The missing data problem in electric load data arises inevitably from malfunctions of Internet-of-things (IoT) and complex networks, cyber-attacks, etc. Those missing data may cause inaccurate building status analysis and future electric load forecast. So, it may hinder efficiency of the building operations. There are many existing imputation models for time series data: mean imputation, interpolation, moving average, and deep learning-based model. However, most of them are developed for general purposes and do not consider characteristics from building data analysis. Building electric load is cyclical depending on cyclical human activities and building types, such as commercial or academic buildings. To take advantage of electric load curves with cyclical patterns, we develop an imputation method to find patterns using MFA through the expectation-maximization (EM) algorithm. We infer the missing values with the estimated MFA and observed data. We compare the proposed method with existing models for the real building data and show that our method outperforms them.

■ WB-08

Wednesday, 10:00-11:40 - Room 8

Machine Learning, Data Mining and Analytics 1

Stream: Machine Learning, Data Mining and Analytics (contributed)
Contributed session
Chair: *Yan Xu*

1 - A Classification Model for Predicting Employee Historical Records: A Case Study in Data Migration
Raymond Freth Lagria

The Human Resource Development Office (HRDO) of the University of the Philippines (UP) Diliman aims to provide responsive and excellent service in the administration of effective human resource management through proper implementation of policies in all human resource related activities. Recently, the HRDO made efforts in improving their current HR processes by building an integrated information system. The information system's goal is to automate most of the major processes to make processing times more efficient. There are around 400,000 employee historical records that need to be migrated from the old system into the new information system. It was determined that all 400,000 historical records need to be normalized into 2 tables. One of the major issues is the splitting of the said records into primary employee records and entitlement records. In the current system, primary

and entitlement records are stored in one table which hinders efficient report generation and stable database structure. Given the amount of time in migration, the proponent generated a classification model that predicts which records are primary and entitlement records. Using decision trees and random forests, initial analysis shows 97.79% and 99% accuracies respectively using the holdout method. An in-depth case study is explored and utilizes different methods for the verification and validation of the model. This can greatly decrease the efforts to perform manual tagging of employee records.

2 - Machine Learning, Logit and Structure: Analyses including Noncompensatory Linear Models
Steven Shugan

Interest and research in Machine Learning methods (MLM) have exploded. MLM clearly provide new capabilities and extraordinary flexibility while sifting through trillions of potential relationships in massive data. Sequentially estimating restrictive theory-based specifications seem outmoded. We show, despite that flexibility, popular MLM can gain substantially from imposition of theory-based structure, even by simply adding a new variable that is a linear function of existing variables. Business analyses often include linear relationships, interaction effects, imbalanced data, suppressor variables, confounds, and what we call noncompensatory relationships. Despite popular belief, we first show that Logit models can easily out-predict popular MLM when these factors are present, even when the true underlying data generator is linear. Even when MLM predict nearly as well as Logit models, MLM fail to discover the true underlying linear relationships as evidence by poor predictions for critical test observations. We show imposing simple structure, such as linear functions of existing variables, greatly improves the predictive accuracy MLM. Otherwise, Logit models can easily out-predict popular MLM. Finally, using motion picture data, we show that adding theory-dictated structure greatly improves predictive accuracy. Consequently, machine learning approaches can greatly benefit from imposition theory-dictated structure.

3 - A Wisdom of Crowds Approach for Enhancing Object Detection Capabilities
Romena Yasmin, Joshua Grassel, Adolfo R. Escobedo

Aggregating human judgements from multiple sources to reach an informed decision that is superior to using a single judgment is referred to as "wisdom of the crowd." For each use case, there are various input elicitation methods as well as aggregation methods for extracting insights from those inputs, each with varying degrees of success. An area of study where the wisdom of crowds has received little attention is object detection using human inputs. Automated object detection with computer algorithms is known to be sensitive and often yields a low accuracy. In this research, we explore how to apply "wisdom of the crowd" to object detection by crowdsourcing human judgements with the goal of classifying images as either positive (containing the specified object), or negative (not containing the specified object). Users are presented an image with the following input elicitations: positive or negative classification (binary); confidence in classification (scale from 0-100%); and what they believe the majority of other users responded to the binary classification. The images used for the study were generated by combining items from the MPEG7 image dataset into a single image according to multiple parameters such as object density and color.

4 - Novel Optimization Methods for Deep Learning
Yan Xu

Deep learning models are widely used to allow computers to perform human-like tasks, such as recognizing speech, identifying image objects or making predictions. Optimization is one of the most important components of deep learning systems. The quality of optimization solutions and the speed of obtaining solutions have significant impact on the effectiveness of deep learning models. However, the optimization problems arising in deep learning are often extremely complex and of huge scale. Solving those optimization problems efficiently is a challenging task. In this talk, we first introduce the various optimization algorithms implemented in SAS deep learning software. Then, we present two novel optimization algorithms: Minibatch L-BFGS and TRish with Momentum. The computational results suggest that these new algorithms are robustness and efficient for training deep learning models.

■ WB-09

Wednesday, 10:00-11:40 - Room 9

Advances in Electricity System Modelling

Stream: OR in Electricity Sector
Invited session
Chair: *Eunshin Byon*

1 - The effects of a massive penetration of electric vehicles on the solar power-system infrastructure expansion planning
Enzo Sauma, Francisco Manriquez, Jose Aguado, Sebastián De La Torre, Javier Contreras

We analyze the impact of the massification of Electric Vehicles (EVs) in Chile on the solar power expansion planning in the year 2030. We employ a long-term generation and transmission expansion co-optimization model that use representative days. We found that smart charging schemes for EVs have an important correlation with the hourly available solar power generation. The analysis is illustrated using the main Chilean power grid. The numerical results show that a massive penetration of EVs in the Chilean power generation system will heavily encourage solar power capacity investments.

2 - Variance reduction method for reliability analysis in wind energy
Eunshin Byon, Shuoran Li, Young Myoung Ko

To help wind turbine reliability analysis in a design stage, aeroelastic simulators have been developed to generate stochastic load responses imposed on a wind turbine. However, crude Monte Carlo sampling to simulate the extreme load associated with a small load exceeding probability is computationally prohibitive, and the estimation results are highly uncertain. This study develops a computationally efficient variance reduction method for the reliability estimation with the stochastic simulation model, where the simulation output is not uniquely determined given a certain input. The result can be useful for determining a resistance level in the reliability-based design.

3 - Mixed-integer second-order cone programming relaxation of the reactive optimal power flow problem
Sezen Ece Kayacık, Burak Kocuk

The reactive optimal power flow (ROPF) problem is a variant of the well-known optimal power flow (OPF) problem in which discrete decisions, such as shunt susceptance and tap ratio, are considered. Due to the presence of these discrete variables in the ROPF problem, it can be formulated as a mixed-integer nonlinear programming (MINLP) problem. The resulting MINLP problem is difficult to solve and the literature has primarily focused on several heuristic methods. The systematic treatment of the ROPF problem is quite limited. In this talk, we propose a new MINLP formulation for the ROPF problem along with its mixed-integer second-order cone programming (MISOCP) relaxation and an improved MISOCP relaxation with an outer-approximation of arctangent constraints. We also test the accuracy and efficiency of our approach with an SDP-based relaxation from the literature on difficult test cases from NESTA library and obtain promising results.

4 - A Sensitivity Analysis for the Transmission expansion planning problem using power flow tracing based on the correlation between generation and isolated loads.
Sandra Milena Mejía García, Laura Escobar

This paper presents the implementation of a sensitivity analysis to find behaviors related to the correlation between the demand and generation for the transmission expansion planning problem when each of the power loads are analyzed independently. To find the characteristics on the power system grid and the impact it generates, and how it changes the behavior of the transmission system. Finding interesting results, illustrating a series of unexpected results. The tests are carried out using the reduced linear disjunctive mathematical model implemented in AMPL and solved with the CPLEX solver to find the optimal solutions and grid behavior for the Colombian 2012 test system.

■ WB-10

Wednesday, 10:00-11:40 - Room 10

Integrated Energy and Environmental Management

Stream: Low-Carbon Energy Transition
Invited session
Chair: Erin Baker

1 - Integration of top-down and bottom-up model to evaluate GHG mitigation potential in Korea
Yong-Gun Kim

This study investigates the role of power sector and renewable energies in Korean GHG mitigation targets, based on an integrated model linking a Computable general equilibrium (CGE) model with a power sector optimization model. We assess the impacts of various GHG mitigation scenarios and economy-wide carbon prices on the macro economic performance and energy mix in power sectors. The simulation results show that the solar and wind power technologies play a significant role in achieving deep GHG mitigation targets in Korea. We also found that substantial amount of power storage capacity is needed to support the large scale deployment of variable renewable energies.

2 - Analysis of renewable energy penetration scenarios in the Korean electricity sector based on KIER-TIMES model
Jaewon Choi, Hansung Kim, Hyungkyu Cheon, Sang Yong Park, Dong Gu Choi

The energy transition towards renewable energy has recently become the central part of the energy policy on the power system in South Korea. We analyze the effects of key renewable technologies, solar PV and wind, on the transition based on various scenarios. We develop a TIMES model after building a reference energy system and collecting characteristic data for conventional and renewable generation technologies. The model also includes the dispatching and unit commitment features, a newly added in TIMES recently, for accurately modeling how the system would respond to the volatility of not only load but also variable nature of renewable energy. The results of model provide the traditional analysis regarding the evolution of energy and capacity mix and corresponding carbon reduction over the years. In addition, we can discuss the required capacity of the corresponding technologies to the variability, such as energy storage system and natural gas turbine, and their associated additional cost.

3 - Transitioning to a Low- to Zero-Carbon Energy System: An Integrated Assessment for Korea
Han Woong Kim, Haewon McJeon, Dawoon Jung, Hanju Lee, Jiyong Eom

By following the Paris Agreement, the Korean government submitted the National Determined Contribution (NDC) to UNFCCC and announced a vision for "2050 carbon neutrality". However, the pathways that could achieve "Carbon neutrality" by 2050 are still unclear, despite the efforts of the Korean government. To meet the climate change target, a dramatic transformation of the entire energy system must reduce GHG emissions from the energy sector. This study analyzes Korea's energy system decarbonization pathways to uphold the Paris Agreement. We use GCAM, an integrated assessment model, to evaluate the different implications of decarbonization pathways in Korea. Our results show that, in Korea, the decarbonization of the power sector is the most priority factor to ensure electrification of end-use sectors in achieving "2050 Net Zero Target ". The power sector transition to decarbonization needs a rapid scale-up with renewable energy and Carbon dioxide Capture and Storage technology to eliminate the remaining emissions from fossil fuel combustion. In addition, Negative Emission Technologies (NETs), such as bioenergy carbon capture and storage technology (BECCS), land use and land-use changes, and forestry (LULUCF), Direct Air Capture (DAC), are inevitable options to achieve Korea's "Net-Zero Target." All the evidence we found indicates that "2050 carbon neutrality" would not be achievable without a dramatic change in the Korean energy system.

4 - Environmental sustainability: Spillovers across industry sectors
Subrata Chakrabarty

Industry sectors whose organizations release toxic chemicals are often a subject of controversy because of the damage they cause to the natural environment and the reluctance of the organizations to engage in pollution control. Using institutional theory, this study argues that if the industry sector of a toxic-emitter (toxic chemical releasing organization) has business linkages with industry sectors that are technologically modern, then the toxic emitter would be under pressure to be more environmentally sustainable.

Wednesday, 12:00-13:40

■ WC-02

Wednesday, 12:00-13:40 - Room 2

Convex Optimization and Applications

Stream: Continuous Optimization
Invited session
Chair: *Cesar Uribe*
Chair: *Rasoul Etesami*
Chair: *Shin-ya Matsushita*

1 - Accelerated gradient method for convex-concave saddle-point problems
Donghwan Kim

Some recent machine learning problems, such as a generative adversarial network (GAN), require solving large-dimensional saddle-point problems. Gradient descent ascent type methods are widely used to solve such problems. This talk will present some recent progress on accelerating the gradient method for convex-concave saddle-point problems.

2 - Blended dynamics approach to distributed algorithms for the consensus optimization problem
Seungjoon Lee, Hyungbo Shim

In this talk, we introduce a novel concept of blended dynamics, which is recently developed to study the dynamical behavior of the nonlinear multi-agent systems (MAS). It is shown that the blended dynamics describes the emergent behavior of the MAS under strong coupling. Although the theory of blended dynamics is originally developed for the analysis of the nonlinear dynamical systems, it is established that the blended dynamics can be applied to the distributed optimization problems. In particular, continuous-time distributed optimization algorithms are proposed based on the blended dynamics to solve the consensus optimization problem. Convergence of the proposed algorithm is analyzed using classical techniques from the control theory and nonlinear system analysis. Furthermore, it is shown that the proposed approach also provides a systematic design method to convert centralized algorithms with separable structure into distributed algorithms. The proposed algorithm based on the blended dynamics approach does not require an initialization process and robust to changes in the network topology. Hence, the proposed algorithm allows the plug-and-play operation. Applications and advantages of the proposed approach are illustrated through examples. Specifically, a distributed algorithm for counting the total number of agents as well as a distributed algorithm for the economic dispatch problem is presented with numerical simulations.

3 - Proximal Splitting Algorithms for Optimization Problems
Shin-ya Matsushita

In this talk, we treat a minimization problem of which the objective function is the sum of convex functions. For solving such a problem, the proximal splitting algorithm is widely used. We investigate attractive properties of the proximal splitting algorithm with inertia.

■ WC-03

Wednesday, 12:00-13:40 - Room 3

Stochastic models in finance

Stream: Financial Mathematics and OR
Invited session
Chair: *Hiroaki Ishii*
Chair: *Katsunori Ano*
Chair: *Yongkil Ahn*

1 - Wiener Chaos Expansion for the pricing of contingent claims whose underlying assets follow jump processes
Kangyong Liu

Inspired by the Wiener Chaos Expansion method applied to contingent claims pricing problem concerning continuous Markov processes, we proposed a similar approach that can be effectively utilized in approximating Jump-type process. We used Charlier polynomial to describe our process as iterated integral with respect to centered Poisson random measure, formed a truncated third-order approximation. After that, we acquired the probability distribution and get a approximated closed-form solution of the price of corresponding contingent claim.

2 - Risk Evaluation of Liabilities by Using a Regime-Switching Interest Rate Model and Its Application to the Non-Maturity Deposits
Yukio Muromachi

We propose a stochastic interest rate model with a regime-switching property in order to evaluate the risk of various kinds of interest-rate sensitive liabilities synthetically. This is consistent with the recent policy, in the financial risk management, that there exist some stressed regimes. In our model, parameters included in the short rate process depend on a latent state, which transits between finite regimes with a Markovian property. A Monte Carlo simulation is used to generate many sample paths of the future short rates, and based on them, the interest rate risk is evaluated numerically. Since the term structures of interest rates in future are derived by using the no-arbitrage pricing method on each sample path, interest rates with various maturities can be used for modeling risks. Numerical examples show that the future interest rates do not decrease deeply to negative, rather behave as if they had a lower limit, and that they keep their present trends, while that there exists a small probability under which the future interest rates increase extremely. Applying of our model to the non-maturity deposits, we show that the present trend of the deposits volume is preserved, while that the drastic decrease happens with a small probability. More reasonable results will be obtained if the regime-dependence of the interest-rate sensitivities are also considered.

3 - What Factors Are Associated with Stock Price Jumps in High Frequency?
Yongkil Ahn

We analyze the complete tick-level stock trading records at the Taiwan Stock Exchange and explore what factors are principally associated with jumps in high frequency. Among the potential candidate variables suggested in the literature, liquidity proxies appear to be primarily associated with signed jumps in high frequency. The results from the least absolute shrinkage and selection operator (LASSO), the elastic net method, and principal component analysis further show that liquidity issues are more important than information or sentiment in understanding sudden and discontinuous price innovations to financial assets in high frequency.

■ WC-04

Wednesday, 12:00-13:40 - Room 4

Applied probability in queueing

Stream: Simulation, Stochastic Programming and Modeling
Invited session
Chair: *Hiroshi Toyoizumi*
Chair: *Katsunori Ano*

1 - A web-based impatient queueing simulator with R language
Masahiro Kobayashi, Atsushi Inoie

The queueing models with customer abandonment can be widely applied for many systems, for example, call centers and hospitals, and therefore, it is very important to analyse those systems. In the many cases, however, it is very difficult to evaluate the abandonment queueing models with theoretical approach since in real systems, the system behaviors are complicated. Hence, the numerical computation and computer simulation are used for evaluating the above-mentioned systems. In this paper, we present a tool for queueing simulation on the statistical computing environment R. The R is a famous programming language for statistical analysis and it is often used by researchers of science and engineering. Our simulation tool can evaluate a single queueing system where customer impatient occurs. In this tool, we can choose various types of customer inter-arrival time, service time and customer impatient time distributions such as exponential, Erlang and Weibull distributions. On the other hand, we can use non-parametric estimation of the above-mentioned probability distribution using the Kernel density estimation. Our simulation engine is programmed by C++ language and in R environment, it is called with Rcpp which is a R package connecting R and C++. We further provide a web-based graphical user interface that helps users interact with our simulation tool.

2 - Ninja queue and its application to theme park
Hiroshi Toyoizumi

We propose a new concept of queueing system called Ninja queue. On Ninja queues in the theme park, customers are allowed to place their multiple avatars in different/same queues when they arrive at the park. When an avatar of an customer reaches the service facility, the customer may enter to the attraction. When the customer places his/her avatar in the same queue, they can aggregate their waiting time and receive preferential treatment according to the aggregated waiting time. We analyse this Ninja queue and show its characteristic and compared it with ordinary queues.

3 - What's in a constraint? On the ambiguity of standard delay targets
Seung Bum Soh, Itai Gurvich

Service providers often formulate their staffing problems as satisfization problems, where staffing levels are minimized subject to quality of service constraints. These constraints are an indirect mechanism to capture, customers' disutility from waiting or, at least its structure. The extent to which they do capture such disutilities can be explored by comparing the solutions of the satisfization problem to those of problems where delay disutilities are modeled explicitly. We argue that standard satisfization formulations are ambiguous. In the single-class queue, the common staffing problem with constraints on averages has an optimal solution that is consistent with convex delay disutilities-FIFO policy- but also the LIFO solution that is consistent with concave costs. The formulation is, in this sense, underspecified. Yet, practitioners typically prescribe one out of these multiple solutions and, in making this choice, they implicitly impose a delay disutility structure. The choice of FIFO can be rationalized through convex delay disutilities while LIFO could be rationalized via concave disutilities. We seek to give a principled basis for these choices in a multi-class environment where the delay targets represent also differentiation across customer types. For the multi-class ASA formulation we show how the ambiguity is removed by either constraining the policy space or by augmenting the formulation.

■ WC-06

Wednesday, 12:00-13:40 - Room 6

Machine Learning, Data Mining and Analytics 4

Stream: Machine Learning, Data Mining and Analytics

(contributed)
Contributed session
Chair: Sunung Kim

1 - A reinforcement learning approach for a multi-item inventory control problem with a budget constraint
Daiki Min, Xia Jiun Lau, Nahee Park

This paper addresses a problem of optimizing multi-item optimal inventory decisions under a budget constraint. We consider a situation where a decision maker places an order for several items after observing the inventory level at the end of each period. The decision maker aims to minimize the total cost including inventory holding cost and backlog cost while satisfying the customer demand. In this decision process, the order quantity is constrained by a periodic budget. We first formulate this problem as a discrete-time Markov Decision Process (MDP) with a constrained action space. To overcome the dimensionality and ambiguity of the MDP model, we proposed a reinforcement learning approach for solving the MDP model. In particular, the proposed reinforcement learning procedure is allowed to handle a constrained action space by imposing penalties for constraint violations or incentives for constraint satisfactions on Q-values. The penalties and incentives are obtained by solving a quadratic optimization problem included in the reinforcement learning procedure. Numerical analysis compares the performance of the proposed method with others such as EOQ, reinforcement learning without the budget constraint and a heuristic method. The experimental results reveal that the proposed method lowers the total inventory cost while satisfying the budget constraint and customer demand.

2 - Theory of Simplicies Coveredness and Space Complex: Topological Data Clustering via Defining Persistent Interval
Jung Taekgeun, Hong Seo Ryoo

Topological Data Analysis (TDA) is data mining technique in the spotlight recently. TDA aims to discover meaningful information from topological shape of point cloud data. For defining the topological characteristic of data the method using concepts of n-th betti number (i.e. number of n-dimensional rooms) and persistency was introduced initially. Previous studies restricted range to 3-dimension of calculating n-th betti number without explaining reason and it is easy to guess that huge computation on high dimension is the reason of this restriction. Also mathematical definition and standard about persistency has ambiguity to applying to data analysis. In this research, by discovering some properties about simplicial complex and using geometric probability, we gave mathematical reason that range of calculating n-th betti number can be restricted. Using restricted dimension, we newly defined persistent interval which can be clearly applied to data analysis and achieve computation reduction. We also developed topological clustering method SoPS (Serching of Persistent Structure) based on persistent interval and line search optimization. Last part of this research, we showed superiority of SoPS. Our achievements contribute to algebraic topology study in aspect of theoretical and also big data analysis research in aspect of practicality.

3 - Logical Analysis of Sociological Data: Case Study of 'Participatory Surveys for Public Deliberation on Shin-Gori Nuclear Reactors No. 5 & 6'
Sunung Kim, Hong Seo Ryoo

This research deals with a mathematical data analysis of a public deliberation held to make a policy decision on whether to continue or permanently suspend a construction of a new nuclear power plant in South Korea, 2017. The result of the deliberation was decided to resume the construction of power plants. The main consideration of the previous research in the decision was identifying the impact of individual factors such as age, gender, or supporting parties. However, analysis using the individual factor cannot represent complex real-world phenomena, which also interrupt observing the real intention of the society. For a precise understanding of the decision-making intertwined with various factors, a new paradigm for analyzing sociological data using Logical Analysis of Data(LAD) is utilized. LAD is a supervised learning methodology based on Boolean logic and combinatorial optimization

that gives the interpretable knowledge composed of combinations of multiple factors in the form of human language as a pattern. 'Results of Participatory Surveys for Public Deliberation on Shin-Gori Nuclear Reactors No. 5 & 6' is referred which includes a four-time survey to decide whether to resume the construction or not. We adopt several techniques such as variable fixing, homogeneity relaxation to consider noise in surveys and generate the pattern reflects real phenomena well. Finally, we show the utility of our analysis scheme and patterns compared with traditional methodologies.

Wednesday, 14:00-15:40

■ WD-01

Wednesday, 14:00-15:40 - Room 1

Keynote: Joseph Wu

Stream: Keynotes
Keynote session
Chair: Goutam Dutta

1 - Nowcasting epidemics of novel pathogens: lessons from COVID-19
Joseph Wu

Epidemic nowcasting broadly refers to assessing the current state by understanding key pathogenic, epidemiologic, clinical and socio-behavioral characteristics of an ongoing outbreak. Its primary objective is to provide situational awareness and inform decisions on control responses. In the event of large-scale sustained emergencies, such as the COVID-19 pandemic, scientists need to constantly update their aims and analytics with respect to the rapidly evolving emergence of new questions, data and findings in order to synthesize real-time evidence for policy decisions. In this lecture, I share my views on the functional aims, rationale, data requirements and challenges of nowcasting at different stages of an epidemic, drawing on the ongoing COVID-19 experience.

■ WD-02

Wednesday, 14:00-15:40 - Room 2

Sustainable Supply Chains

Stream: Supply Chain Management
Invited session
Chair: Sungyong Choi

1 - Fostering Green Transportation by Eco-Labels
Thomas Kirschstein, Christian Bierwirth, Herbert Kopfer

This paper deals with conceptualizing eco-labels for freight transportation services. Eco-labels are well known in many markets to signal the environmental performance of products and services to customers. In transportation markets, customers (shippers) get increasingly eco-sensitive due to the impact of transport on climate change. Also, transport emission allocation is currently under political discussion, which demands carriers to allocate the total emission caused by a transport process to the shipments moved in the process (see e.g. norm EN 16258, European Committee for Standardization 2013). To support shippers in getting orientation on the environmental performance of a service, eco-labels sound like promising instruments. In this talk, the signal qualities of eco-labeling systems for freight transportation services are studied systematically. Labeling design options are evaluated by assessing their (a) applicability for different kinds of transport technologies, (b) effectiveness in measuring the ecological impact, and (c) consistency for comparing different transport services and orders. Moreover, possible implementations of eco-labeling systems are investigated in the context of vehicle routing problems and intermodal transportation planning problems. In the latter, a generic labeling system is required to signal the environmental impact of combining different means of transport within a transport chain.

2 - Impact of Consumer Heterogeneity on Residential Adoption of Voluntary TOU tariffs
Dong Gu Choi, Michael Lim, Karthik Murali, Valerie Thomas

Residential consumers exhibit heterogeneous electricity consumption preferences, and may also differ in their demand-shifting flexibility. Consequently, utilities struggle to deploy voluntary Time-of-use (TOU) tariffs and are unable to generate adequate demand response. We determine optimal TOU pricing, and calibrate our model to examine TOU adoption trends in the US market.

3 - Life Cycle Assessment in supply chain design and planning models: challenges and opportunities
Bruna Mota, Ana Paula Barbosa-Póvoa, Ana Carvalho

Environmental concerns from several stakeholders have raised the pressure placed on companies regarding the evaluation of the environmental impact of their supply chains. Environmental data resulting from the application of life cycle assessment (LCA) methodologies has become part of the criteria included in supply chain management decisions. However, decisions taken within the application of LCA methodologies, such as system boundary definition or method selection, can significantly influence the obtained results. This work focuses on the application of LCA in supply chain design and planning, and particularly on the decisions taken in LCA's first step of goal and scope definition, exploring and demonstrating existing challenges and opportunities. ToBLoOM (Triple Bottom Line Optimization Modelling), a multi-objective mixed integer linear programming model developed for the design and planning of sustainable supply chains, is applied to a pulp and paper industrial case-study. Different scenarios are modelled to simulate different decisions taken at the goal and scope definition step and its impact in supply chain decision making is analysed. Managerial insights and methodological recommendations are derived in this context.

4 - Considering emission reduction coordination in a two-echelon supply chain
Sungyong Choi, Jooyol Maeng

There is a growing consensus that carbon emission accelerates global warming. The reduction of carbon emission is imperative and governments are under pressure to enact legislation to curb the amount of these emissions. Firms are responding to the threat of such legislation or to concerns raised by their own consumers or shareholders and also undertaking initiatives to reduce their carbon footprint. For effective regulations, the sustainability effort needs to be considered in supply chains. Different from the previous studies, we provide a two-echelon decentralized supply chain and its centralized channel. For contributions, we provided stylized centralized and decentralized models and various SCM coordination issues with cap-and-trade regulations. We also obtained the closed-form solutions for a few models studied.

■ WD-03

Wednesday, 14:00-15:40 - Room 3

Logistics, Transportation and Traffic 1

Stream: Logistics, Transportation and Traffic (contributed)
Contributed session
Chair: Zahra Ghandeharioun

1 - Network Traffic Model with Accidents
Marcel Kleiber, Stefan Weber

Traffic on road networks is a complex phenomenon. Accidents are rare events but may cause significant losses to the society. Based on a modular modeling approach, we propose a flexible and scalable network traffic model which describes the movement of vehicles subject to the risk of accidents. Specifically tailored importance sampling algorithms facilitate the efficient estimation of accidents and allow to quantify their impact on traffic flow. This enables a comprehensive study of risk and efficiency in traffic systems. Various case studies illustrate potential applications in the context of optimal design and operation. Engineering solutions can mitigate emerging risks only to a certain extent - both today and in the future. We, thus, complement the analysis by studying insurance solutions that cover residual risks financially. This yields a novel framework to study risk transfer instruments for emerging risks in (future) traffic systems.

2 - Towards flexible scheduling with autonomous vessels: Planning a public transportation system in Norway
Mario Guajardo, Julio C. Góez, Stein W. Wallace

In this talk we consider using autonomous vessels for transporting people on the coastal area of a Norwegian city. Typically, vessels are schedule with predefined arrival and departure times established by the management following some criteria or a model. We propose an approach aiming to enhance the system operation, moving from a full fixed schedule to a system that follows the demand. We propose an optimization model aiming to minimize the penalty assigned to the deviation from the targeted users' arrival times. While the system could be in principle implemented with manned boats, the uncertainty introduced by the demand response schedule may lead to confusion and errors by the crew, and also not be incompatible with labor agreements. For that reason, the use of autonomous vessels may become the key to respond more precisely to the demand.

3 - Ecological and economic evaluation of last-mile delivery concepts using a combined optimization and simulation approach
Maik Trott, , Niels-Fabian Baur, Christoph von Viebahn, Julia Rieck

This work combines mathematical optimization and agent-based simulation to evaluate sustainability-related aspects of the last-mile delivery. A city project from Hanover, Germany, that stipulates the use of special parking zones for carriers, was utilized as case study and evaluated in the course of our research. To evaluate the ecological and economic impact of courier, express and parcel services, we calculated both the emissions (i.e., CO2) and the total delivery time for different traditional last-mile delivery scenarios as well as for the given parking zone concept. For this purpose, we developed exact mathematical and heuristic solutions for the considered green capacitated vehicle routing problem. As a basis for our models, we used data from one of the largest service providers in Germany. Moreover, the results were validated by means of historical data from the service provider. Compared to the historical data, optimization potentials of up to 42% were predicted. The evaluation of the logistic scenarios demonstrated that traditional delivery methods in comparison to the parking concept generally lead to reduced emissions as well as better delivery time. One of the main reasons for this result is that with the parking zone concept the routes of the delivery staff increase and therefore fewer shipments per truck can be realized during working hours. Hence, from an economic perspective, the traditional delivery concept is more favorable than the parking zone concept.

4 - Optimized real time fleet management operations for on demand ride sharing systems
Zahra Ghandeharioun, Anastasios Kouvelas

Urban mobility is facing a paradigm shift towards providing more convenient, environmentally friendly and on-demand services. Shuttle ride sharing is considered nowadays an effective service for reducing traffic congestion and pollution and providing more available on demand mobility service; however, the operational strategies that can be used to optimize on-demand ridesharing have not been well investigated. Moreover, only a few studies in the literature provide reliable insights about capacitated ride-sharing systems. In the current work, we focus on solving the on-demand ride sharing service in a real-time framework, considering different optimization techniques. Moreover, our approach provides a framework for investigating different decision variables and cost functions to evaluate various management strategies. In this framework, we develop an event-based simulation engine that can be used in order to propose a real-time shuttle ride sharing search algorithm. The aim of the algorithm is to quickly decide between competing shuttle candidates that satisfy both the user inquiries and the problem constraints. This simulation engine can provide valuable insights regarding different cost functions and parameters variations. Moreover, by utilizing real trip data from the New York City

taxi database, we assess the feasibility of the proposed framework and evaluate the results for different strategies and optimization techniques.

■ WD-04

Wednesday, 14:00-15:40 - Room 4

Urban Operations Research II

Stream: Discrete Optimization and Urban Operations Research
Invited session
Chair: *Sunyong Eom*
Chair: *Shungo Koichi*

1 - Urban Core and Facility Location Model for Shrinking Cities
Sunyong Eom, Daisuke Hasegawa

The shrinking cities facing extreme population losses have attracted increasing attention not just in the US and European countries but also across many Asian countries such as Japan and South Korea. Many cities have implemented smart decline approaches that represent a plan for the reduced population by adjusting its size, infrastructure, and development pattern. Location Normalization Plan is an example of smart decline policies in Japan. It contains a spatial plan to create a compact and connected urban structure by designating the urban core with various service facilities and establishing a public transportation network. To make this plan, determining the locations of the urban core and necessary facilities with consideration of existing facilities and public networks is a critical problem. Many local cities in Japan, however, have made plans without coherent guidelines or quantitative evidence. This study aims to develop a model for the urban core and facility allocation model to support the decision-making process in the Location Normalization Plan. The main idea of the suggested model is forming urban cores so that the current public transportation network can afford to provide access to urban services such as supermarkets, hospitals, and welfare facilities. The results of this study clarify the desirable strategy for changing the distribution of service facilities for cities in Japan and can be applied to other countries.

2 - Area Proportion of Building Shadow Regarding the Site Ownership
Hiroko Watanabe, Yudai Honma

In this study, we focus on the location of the shadow caused by buildings in the sunshine environment of the city and show the area ratio of the shadow for each place. In Japan, the Building Standards Law restricts the shadows of middle-high-rise buildings from occurring outside of their own sites for long periods of time. This is called shadow regulation. On the other hand, there is a building height restriction defined by the width of the front road. This is a rule to secure sunshine and ventilation on the front road, but it does not specifically regulate the degree of shadow on the road site. The shadows created by buildings do not always fit on your own site, often also affect surrounding sites. In this study, we analyze the effects of shadows on own site and surrounding sites not only in the sunshine environment of buildings that satisfy the legal requirements, but also in the sunshine environment of the city. We analyze buildings and city blocks by the shadow simulation. First, we understand how the area and time of shadows on own site, surrounding sites and the road sites, change according to the site shape and building shape. Next, we grasp how the area and time of shadows on own site, surrounding sites and road sites for the shadows that occur in the city block. Finally, we consider how to optimize the sunshine environment. The results of this study help us understand how to optimize sunshine in building design.

3 - An IP-model for generating a monthly schedule of caregivers in a care home for the elderly
Shungo Koichi

We address the problem of generating a monthly schedule of caregivers, who are employed in a care home for the elderly in Japan. The caregivers work in several shifts such as the early, daytime, late, night and overnight shift to provide 24-hour service. To make a schedule, we have to assign them to each shift or give a day off with consideration for various attributes and conditions. For instance, there should be a car driver among the workers in the daytime shift to provide a home-visit care, and one has to take a day off after the day she/he worked in the overnight shift. By representing these conditions as an integer program appropriately, we are able to obtain an optimal schedule that gives as many days off as possible to the caregivers on the days they want to take off. Since a care work is hard, it is important to satisfy their preferences for days off as much as possible.

4 - Inverse Optimization Using Dual of the Shortest Path Problem for Estimation of Inclusive Link Cost
Hiroyuki Hasada, Daisuke Hasegawa, Yudai Honma

When moving from an origin to a destination in urban networks, we usually try to transport as efficiently as possible. Though its route often differs from the real shortest path, it should be the shortest path based on his/her inclusive link costs. The purpose of this research is to estimate such inclusive link costs from several observed paths. Our mathematical concept is an inverse problem (IP) of the shortest path problem (SP); the best path P for OD pair is given and find link cost so that P becomes its shortest path. Our objective function minimizes the gap between the cost of the observed path and that of the real shortest path. It requires us to solve two different SP in one formulation. However, we cannot simply join these two problems because one SP negates the other. For them to coexist, we focus on the dual problem of SP, which can be regarded as the maximization of the potential of nodes. Since one SP is normal minimization and another SP becomes a maximization, we can successfully join two objectives as linear programming. There are plenty of studies related to IP of SP, but few studies focus on such duality of SP. In addition to examining the theoretical characters of the problem, we also calculate a numerical example based on a small network with hypothetical path observations. In the field of urban planning, it is an important topic to understand how people recognize urban space.

■ WD-05

Wednesday, 14:00-15:40 - Room 5

Pricing and sourcing for supply chain risk management

Stream: Revenue Management and Pricing
Invited session
Chair: *Zhi Chen*

1 - Distributionally robust sourcing
Kai Pan, Ming Zhao, Nickolas Freeman

We consider the optimal sourcing problem when the available suppliers are subject to ambiguously correlated supply risks. The problem is motivated by the increasing severity of supply risks and difficulties on evaluating common sources of vulnerability in the upstream supply chain as reported by many surveys of goods-producing firms. In contrast to the majority of existing research, we propose a distributionally robust model that constitutes a promising approach for developing sourcing strategies without requiring an accurate estimate on the underlying correlation. We provide analytical results regarding the form of the worst-case disruption distribution that decision-makers may find appealing, especially when exact correlation information is unavailable, due to the severe consequences associated with supply chain risks. Moreover, we show how our distributionally robust model may be used to offer guidance on exerting additional efforts aimed at better understanding the prevailing correlation structure. An extensive numerical study further demonstrates the performance of our distributionally robust approach and shows how supplier characteristics and the type of supply uncertainty affect the optimal sourcing decision.

2 - Sharing the value-at-risk under distributional ambiguity
Zhi Chen, Weijun Xie

We consider the problem of risk sharing, where a coalition of homogeneous agents, each bearing a random cost, aggregates their costs and shares the value-at-risk of such a risky position. Due to limited distributional information in practice, the joint distribution of agents' random costs is difficult to acquire. The coalition, being aware of the distributional ambiguity, thus evaluates the worst-case value-at-risk within a commonly agreed ambiguity set of the possible joint distributions. Through the lens of cooperative game theory, we show that this coalitional worst-case value-at-risk is subadditive for the popular ambiguity sets in the distributionally robust optimization literature that are based on convex moments or Wasserstein distance to some reference distributions. In addition, we propose easy-to-compute core allocation schemes to share the worst-case value-at-risk. Our results can be readily extended to sharing the worst-case conditional value-at-risk under distributional ambiguity.

3 - A Belief-Robust Approach to Two-Type Screening
Jun Han, Thomas Weber

This paper considers the problem of second-degree price discrimination when the type distribution is unknown or imperfectly specified by means of an ambiguity set. As robustness measure we use a performance index, equivalent to relative regret, which quantifies the worst-case attainment ratio between actual payoff and ex-post optimal payoff. We provide a simple representation of this performance index, as the lower envelope of two extremal performance ratios, relative to beliefs that lie at the boundary of the ambiguity set. A characterization of the solution to the underlying robust identification problem is given, which leads to a robust product portfolio, for which we also determine the worst-case performance over all possible consumer types. For a standard linear-quadratic specification of the robust screening model, a worst-case performance index of 75% guarantees that the robust product portfolio exhibits a profitability that lies within a 25%-band of an ex-post optimal product portfolio, over all possible model parameters and beliefs. Finally, a numerical comparison benchmarks the robust solution against a number of alternative belief heuristics.

4 - How much to tell your customer? - A survey of three perspectives on selling strategies with incompletely specified products
Jochen Gönsch

Today's technology facilitates new selling strategies. One increasingly popular strategy uses incompletely specified products (ICSPs). The seller retains the right to specify some details of the product or service after the sale. The selling strategies' main advantages are an additional dimension for market segmentation and operational flexibility due to supply-side substitution possibilities. Since the strategy became popular with Priceline and Hotwire in the travel industry, it has increasingly been adopted by other industries with stochastic demand and limited capacity as well. It is actively researched from the perspectives of strategic operations management, empirics, and revenue management. This talk first describes the application of ICSPs in practice. Then, we introduce the different research communities that are active in this field and relate the terminology they use (e.g. opaque selling, flexible products, upgrades). The main part is an exhaustive review of the literature on selling ICSPs from the different perspectives. We see that strategic operations management has described advantages of ICSPs over other strategies in a variety of settings, but also identified countervailing effects. Today, empirical research is confined to hotels and airlines and largely disconnected from the other perspectives. Operational papers are ample, but mostly concerned with the availability of ICSPs. Research on operational (dynamic) pricing is surprisingly scarce.

■ WD-06

Wednesday, 14:00-15:40 - Room 6

Graphs and Networks 1

Stream: Graphs, Networks and Combinatorial Optimization with Applications (contributed)
Contributed session
Chair: Cahit Dede

1 - Combinatorial Scheduling for Adaptive Machine Learning in Cybersecurity
Nouri (Nourhan) Sakr, Cynthia Phillips, Ojas Parekh, Clifford Stein

In this paper, we study two different applications in cybersecurity: an adaptive ML problem and a game-theoretic model called PLADD. The common objective between both problems is to protect cybersystems against attacks by intelligent, adaptable and well-resourced adversaries while maintaining a cost budget. We introduce a novel combinatorial scheduling formulation to design useful defense strategies that meet this goal. Our work separates the formulation from the data-driven analysis and solution. As such, the scheduling formulation, which does not resemble any previously studied formulations from the scheduling literature, may be used as a new model by other researchers for different motivations. We keep the model generic enough for others to use, but design the algorithms that work best for our context and data. The formulation is inspired by stochastic programming and cast as a mixed integer program (MIP). We provide theoretical analysis, e.g. explore integrality gaps, exploit the combinatorial structure, prove NP-hardness, develop dynamic programming solutions for two-machine cases, then work towards data-driven heuristics using distribution assumptions and real data from Sandia National Labs.

2 - A Symbolic Approach to Shortest-Path Problems using Max-Algebra Tools
Mark Korenblit, Vadim Levit

Finding a shortest path in a graph is an essential problem that has applications in computer and communication networks, routing systems, scheduling, transportation, logic synthesis, etc. This work proposes a symbolic approach to shortest-path problems based on a presentation of a shortest-path algorithm as a symbolic expression. This expression includes edge weights that appear in the algorithm and the two binary ring operations: disjoint union and concatenation. The salient contribution of the proposed technique is in the adequate interpretation of the max-algebra tools. Max-algebra refers to the analogue of linear algebra developed for the pair of binary operations, which may be interpreted as the ring operations, on the one hand, or as min and plus operations, respectively, on the other hand. Thus, the search for the most efficient algorithm turns into the construction of the shortest expression. The advantages of this method, compared with classical numeric algorithms, are its stability, faster reaction to data renewal, and the possibility of parallel realizations. We solve the problem for some kinds of two-terminal directed acyclic graphs and show that for every graph there exists a symbolic shortest-path algorithm with quasi-polynomial complexity. We apply the proposed symbolic technique to the robotic line scheduling in order to ensure the minimum overall generalized cost for a product processing over the whole line.

3 - Maximum matching using Manhattan topology
Michal Stern, Nili Beck, Hila Ohana Brumer, Yuval Bercovich

Consider a weighted graph G=(V,E), where the distances between the vertices satisfy the Manhattan Topology. We aim to find a maximum matching on V, which is a maximum weighted set of edges, which are vertices disjoint. We present an O(|V|log|V|) time complexity algorithm for the case where the vertices of the graph reside on a grid, with up to three dimensions. This algorithm improves the time complexity of the well-known general algorithms of Edmonds and Gabow. When the graph lies on a one-dimensional grid, the vertices are located on a straight line, and the maximum matching problem is trivial and is solved using a greedy algorithm. The algorithm for the two-dimensional grid is based on the fact that the problem can be separable with respect to the two dimensions. In the first step of the algorithm, we consider only the x-coordinate, ignoring the y-coordinate of each point, thus reducing the grid into one line, which can be solved using the one-dimensional algorithm. In the second step of the algorithm we achieve the maximum also with respect to the y-coordinate using

the median of all y-coordinates. For the three-dimensional grid, we consider the case where the vertices reside on two parallel planes. We match vertices on opposite diagonals. On each diagonal, we solve by using the one-dimensional algorithm. Finally, we combine and adjust the solutions achieved for all the diagonals into one solution for the whole graph, using the median of all x-coordinates.

4 - Regular Borderenergetic Graphs
Cahit Dede, Ayse Dilek Maden

The energy of a graph is defined as the sum of the absolute values of the eigenvalues of its adjacency matrix. In this study, we focus on constructing non-complete borderenergetic graphs. That is, we report the graphs whose energy is equivalent to a complete graph's energy and this kind of graphs are called borderenergetic graphs. We mainly consider the line graphs of regular and strongly regular graphs. Firstly, we obtain a condition for the line graph of disconnected regular graph consisting of p copies of connected regular integral graph and q copies of complete graph to be borderenergetic. Also we present a condition for the line graph of strongly regular graphs to be borderenergetic. In addition, we obtain similar result for the complement of a strongly regular graph. Finally, we show by examples that there exist connected borderenergetic graphs, different from the complete graph.

■ WD-07

Wednesday, 14:00-15:40 - Room 7

Computational and simulation methods in finance

Stream: Computational and Simulation Methods in Finance
Invited session
Chair: Gerhard-Wilhelm Weber
Chair: *Milagros Baldemor*

1 - Moments of weighted averages of exchangeable random variables - a recursive algorithm with applications to finance
David Christen

The mathematical part of this paper uses combinatorial ideas to develop a recursive algorithm for the non-central moments of weighted sums of exchangeable random variables. The recursions hold for the case of finite sums as well as for the limiting case where the number of summands goes to infinity. The finance part illustrates the algorithm and gives applications to portfolio credit risk and expected utility.

2 - Improving Model Predictive Accuracy Using a Bayesian Approach: Application to PD Modelling of Mortgage Loans
Zheqi Wang, Jonathan Crook, Galina Andreeva

A new Bayesian informative prior selection method is proposed to include additional information to credit risk modelling and improve model performance. In the Bayesian informative prior selection method that we propose, we treat coefficients in the PD model as time series variables. We build ARIMA models to forecast the coefficient values in future time periods and use these ARIMA forecasts as Bayesian informative priors. We find that the Bayesian models using this prior selection method outperform both frequentist models and Bayesian models with other priors in terms of predictive accuracy.

3 - High-frequency trading with optimized financial portfolios by an annealing method
Yusuke Sugita, Arnab Chakrabarti, Takuya Okuyama, Masanao Yamaoka

We proposed a high-frequency trading method of ETF arbitrage based on a formulation of a quadratic unconstrained binary optimization (QUBO) problem. Due to the association between the QUBO problem and the Ising model in physics, the QUBO problem can be efficiently solved by the annealing machines implementing simulated or quantum annealing processes for the Ising model. In this work, we demonstrated that our annealing technology, CMOS annealing, can perform the optimization enough fast, and therefore the trades can be placed before the market data becomes stale.

For ETF arbitrage, it is required to create an index-mimicking portfolio that is tradable subject to real-world constraints. Therefore, first, we proposed a QUBO formulation whose optimal solution leads to such a desired portfolio. Next, using historical U.S. market data of an S&P500 index ETF and its constituent stocks, we showed that CMOS annealing can indeed solve the real-data QUBO problem in reasonable time. Furthermore, we showed that the trading simulation shows a positive return by gaining arbitrage opportunities between the ETF and the portfolio. In the presentation, we will also discuss possible extensions of this high-frequency portfolio optimization framework, e.g., how to account for practical trading constraints and market situations inside the QUBO formulation.

■ WD-08

Wednesday, 14:00-15:40 - Room 8

Business Operation in the Electricity Sector

Stream: OR in Electricity Sector
Invited session
Chair: Daiki Min

1 - Distribution Locational Marginal Pricing (DLMP) for Unbalanced Three Phase Networks
Saeed Mohammadi, Mohammad Reza Hesamzadeh, Derek Bunn

Distribution networks (DNs) are highly unbalanced considering unbalanced demands, feeders, expanding network, and continuous network adjustments as a result of outages which pose considerable operation challenges. Electricity networks are pursuing the theory of spot pricing which leads to employing distribution locational marginal pricing (DLMP) to support consumer's obligation to flexible operation. Vital response time to participate in short-time electricity markets in DNs with numerous buses makes linear programming (LP) the most practical model. Contrary to the linear lossless model of transmission networks, a lossless model cannot be employed in DNs with voltage limit, higher loss, reactive power flow, and working with ultimate consumers. This research presents an LP model to calculate DLMPs in fully unbalanced three-phase DNs. A detailed model is demonstrated for solar/wind units, storage systems, capacitors, overhead lines, cables, transformers, and voltage regulators. Outages and island operations are addressed which are crucial for dynamics of DNs. Uncertainties in DNs are recognized utilizing stochastic optimization and scenarios for uncertain parameters such as demands, solar energy, wind power, and prices. This accurate model deals with the losses and reveals voltages and DLMPs at each node-phase which is tested in several IEEE standard test feeders and probability density function of DLMPs are calculated through a proposed No U-Turn based algorithm.

2 - Data Analytics and Optimization for the Optimal Bidding of a Virtual Power Plant
Daeho Kim, Hyungkyu Cheon, Dong Gu Choi

As distributed energy resources (DERs) continue the emerging trend, a new cloud-based IT platform business model, the virtual power plant (VPP), has been introduced. Among several operational problems that beset the VPP, we focus on the optimal bidding problem in the Korean day-ahead market. We formulate a multi-stage stochastic programming model and use a stochastic dynamic programming-based solution

approach. This is the first study to derive an optimal bidding strategy under the incentive-based market structure, not the penalty-based market structure applied in prior studies. To describe the uncertainty of power supply from DERs, we establish frameworks to generate data-driven scenario trees or lattices. In addition, we apply heuristics and verify the performance and practicality through the test based on real data.

3 - Optimization and energy management of a residential Microgrid with Vehicle-to-Home (V2H) and Vehicle-to-Grid (V2G) energy services
Mohamed Saâd El Harrab, , Michel Nakhla

Renewable energy generates intermittent and weather dependent output which puts high constraints on the power grid. Aside from energy storage devices such as batteries, the introduction of Plug-in Electric Vehicles (PEVs) can play a major role in smoothing out the intermittent power supply. As mobile Energy Storage Systems (ESS), PEVs can deliver energy back to power grids and allow different discharging scenarios generally known as Vehicle-to-Anything (V2X).

Energy Management System (EMS) plays a key role in operating Microgrids (MG). For this work, we consider a residential grid-connected MG equipped with a photovoltaic system as renewable energy source and PEV battery. Based on Stochastic Optimization and Machine Learning approaches, we investigate different scenarios of the MG optimization considering various uncertainties (economical, operational) and constraints (power balance, generation, technical . . .). Taking into consideration electricity prices, PEV driver's behavior and the forecast of load curve and solar irradiance, the developed EMS optimizes the scheduling and the power dispatch of the MG considering V2G and V2H services.

The developed method allows to identify household's potential energy cost savings and the effectiveness of V2G and V2H strategies in operating the MG both in terms of cost savings and peak load reduction.

4 - Investment in power generation and transmission under uncertainty
Kazuya Ito, Makoto Tanaka, Ryuta Takashima

In this work, we analyze a decision-making problem of both transmission system operator and power generation in transmission lines and power plants. We develop a game theoretic real options model to derive the optimal investment timing and the capacity sizing under uncertainty. The power generation has two options for the investment, i.e., increasing the capacity of conventional fossil-fuel power plants or expanding the capacity of renewable energy resources such as wind power. We find that the expansion of renewable energy under FIP and reduction of installation cost of renewables are welfare energy enhancing.

■ WD-09

Wednesday, 14:00-15:40 - Room 9

Multiobjective Optimization 1

Stream: Multiobjective Optimization
Invited session
Chair: *Jacopo Pierotti*

1 - The weighted Tchebycheff weight set decomposition method for multiobjective discrete optimization problems
Stephan Helfrich, Tyler Perini, Pascal Halffmann, Natashia Boland, Stefan Ruzika

In order to find efficient solutions, or their nondominated images in multi-objective optimization problems, one often specifies preferences (weights) on the objectives and transforms the problem into a single-objective problem, the so-called scalarization. Weight set decomposition methods systematically explore and subdivide the parameter set of these scalarizations in order to find different nondominated images. So far, such approaches exist for the weighted sum scalarization, and thus are only capable of findinsg a strict subset of all nondominated images in general.

We introduce the weight set decomposition for the weighted Tchebycheff scalarization for multiobjective discrete optimization problems. We give a fundamental analysis of the weight set components and their intersections, including (non-)convexity properties, a polytopal subdivision and a dimensional study. Additionally, we show how these results can be used to enumerate all nondominated images while providing additional insights on the structure of the nondominated set, such as relative robustness of images and an adjacency concept between nondominated images.

2 - Generating a discrete representation of the Pareto front of nonlinear multi-objective optimization problems
Matthias Ehrgott, Azam Dolatnejad, Esmaile Khorram

The set of non-dominated points of a nonlinear multi-objective optimization problem provides a set of optimal trade-offs between conflicting objectives often called the Pareto front. Since this set is usually infinite, it is impossible to generate it completely in practice. Therefore, a discrete representation of the Pareto front is obtained. This representation should consist of a finite set of non-dominated points of small size that covers the entire Pareto front with an even distribution. We propose algorithms based on the Pascoletti-Serafini scalarization approach for this purpose. Our algorithms construct a discrete represntation of evenly distributed non-dominated points. We cnduct numerical tests on six test problems with cone-convex and non-convex Pareto sets. We show that our algorithms perform well in comparisons with the normal constraint, Benson, NSGA-II and MS-EMOA algorithms considering CPU time and metrics of the quality of approximations of Pareto sets.

3 - Interactive Algorithms for Finding Preferred Solutions under Weighted Tchebycheff Preference Functions
Gulsah Karakaya, Murat Koksalan

We develop interactive algorithms that guarantee to find the most preferred solution in multi-objective integer programming problems for a decision maker (DM) whose preferences are consistent with a weighted Tchebycheff preference function. The algorithms exploit the properties of the Tchebyceff function, select a pair of solutions to present the DM at each iteration, utilize the preference information to progress toward the most preferred solution, and eventually guarantee finding the most preferred solution. We consider different approaches for selecting the solutions to present to the DM and test their performances on several problems. We aim to reach the most preferred solution with minimum interaction with the DM and with minimum computational effort. We demonstrate that the algorithms work well in terms of both performance measures.

4 - The school bus routing problem for students with special needs
Jacopo Pierotti, Lina Simeonova, Theresia van Essen

The School Bus Routing Problem is a combinatorial optimization problem whose aim is to route a fleet of buses at minimal cost. These buses must depart from the school, collect the students and return to the school while respecting the vehicles' capacity and time limitations. When considering students with special needs (e.g. autism), attenders (i.e. dedicated staff) must be routed as well for assistance purposes. In addition, we consider the familiarity level of the students inside a bus to ensure a pleasant quality of service. We define the familiarity level as an index expressing how well each student knows the other riders (fellow students and attenders) on the same bus. Doing so, we can enforce a necessary minimum level of familiarity to be attained by the solution. As often happens in vehicle routing problems, this raises an interesting trade-off between minimizing travel costs and maximizing the quality of the service. In this presentation, we introduce a MILP model to obtain the Pareto front for small instances and a metaheuristic to estimate the Pareto front for real-life instances. These real-life

instances are based on data from a specialized school in the South-East of England.

■ WD-10

Wednesday, 14:00-15:40 - Room 10

Supply Chains 2

Stream: Supply Chain Management
Invited session
Chair: Lars Moench
Chair: John Fowler

1 - Agent-based experimental environment for planning functions in semiconductor supply chains
Lars Moench, Raphael Herding

The interaction of different planning functions in semiconductor supply chains (SSCs) is often not well understood since it is challenging to study the interplay of the related planning algorithms in a real-world setting due to the different software systems and decision-makers involved. The design and the implementation of a software agent-based experimental environment that allows for assessing distributed hierarchical and heterarchical planning situations is described. The proposed environment aims to deal with the large-scale, distributed planning problems in SSCs that are a result of the sheer size of the geographically distributed facilities and the involved supply chains, the pervasive presence of different kinds of uncertainties and the rapid pace of change. Web services implement parts of the planning functionality. It is shown by computational experiments for the interaction of master planning and demand fulfillment that the environment is highly scalable since it allows that the planning functionality is provided by cloud computing mechanisms.

2 - Production Flow Analysis in a Semiconductor Fab Using Machine Learning Techniques
Ivan Kristianto Singgih

In a semiconductor fab, wafer lots are processed in complex sequences with re-entrants and parallel machines. It is necessary to ensure smooth wafer lot flows by detecting potential disturbances in a real-time fashion to satisfy the wafer lots' demands. This study aims to identify production factors that significantly affect the system's throughput level and find the best prediction model. The contributions of this study are as follows: (1) this is the first study that applies machine learning techniques to identify important real-time factors that influence throughput in a semiconductor fab; (2) this study develops a test bed in the Anylogic software environment, based on the Intel minifab layout; and (3) this study proposes a data collection scheme for the production control mechanism. As a result, four models (adaptive boosting, gradient boosting, random forest, decision tree) with the best accuracies are selected, and a scheme to reduce the input data types considered in the models is also proposed. After the reduction, the accuracy of each selected model was more than 97.82%. It was found that data related to the machines' total idle times, processing steps, and machine E have notable influences on the throughput prediction.

3 - On the influence of collection cost on reverse channel configuration
Nora Dörmann, Jochen Gönsch

This talk revisits the impact of collection cost on a manufacturer's optimal reverse channel choice and complements previous research by Savaskan et al. (Savaskan RC, Bhattachary S, Van Wassenhove LN (2004) Closed-loop supply chain models with product remanufacturing. Management Science 50(2): 239-252) and Atasu et al. (Atasu A, Toktay LB, Van Wassenhove LN (2013): How collection cost structure drives a manufacturer's reverse channel choice. Production and Operations Management 22(5): 1089-1102.). A manufacturer who remanufactures his own products has the choice between managing collection of used products himself, let the retailer manage collection or involve a third party company to manage collection. In a stylized model, we consider a convex collection cost function depending on the collection rate. Contrary to previous literature, we analytically show that the manufacturer always prefers retailer-managed collection, independent of collection cost. The retailer will always choose a positive collection rate. If collection cost is above a certain threshold, not all used products will be collected and the manufacturer (almost) collects all channel profits. Third party-managed collection is always dominated. In extensions, we also consider a restriction to equilibria and a minimum collection rate, which may be imposed by regulation.

■ WD-11

Wednesday, 14:00-15:40 - Room 11

Data Envelopment Analysis

Stream: Data Science, Analytics and Performance Measurement (contributed)
Contributed session
Chair: Hong Ngoc Nguyen

1 - A Dominance Network approach for assessing efficiency using a multiperiod dataset
Laura Calzada-Infante, Sebastián Lozano

Dominance Network (DN) analysis is a technique that complements Data Envelopment Analysis (DEA) on the evaluation of the efficiency of Operating Units (OUs) by creating a network with all the dominance relationships (DR) of the evaluated OUs. The result is a weighted directed acyclic graph. DN analysis allows evaluating the relative position of each OU within the network as well as characterizing the dataset by computing different metrics at the node, component and network level. In addition, it allows visualizing the whole network as well as any particular subgraph (e.g. egonetworks). DN analysis is so flexible that it can be applied to multiple situations, but it has not been applied to multiperiod data yet, while it is supported in DEA. We examine the application of this methodology to a multiperiod dataset by using an intertemporal DN to compare the evolution of the efficiency of the OUs with time. The proposed approach identifies two types of DR: contemporaneous DR (among the OUs that belong to the same period), and non-contemporaneous DR (among OUs that belong to different periods). DN analysis allows computing multiple metrics to evaluate the relative position of all OUs in the DN from multiple perspectives (node level, component level and network level). Among them, a Malmquist productivity index that measures the productivity change of an OU between any two periods can be computed, keeping the circularity property.

2 - Food-for-all or Populism? Challenges of evaluating subsidized scheme
Magesh Nagarajan, Patturaja Selvaraj

Universal coverage provides equitable access to food often free or in subsidized prices for urban poor. In Tamil Nadu state (India) canteens were opened to provide hygienic, tasty food at subsidized price at 300 branches. The users come from diverse socio-economic profile as beneficiaries can self-select. This study aims at understanding the challenges of evaluating an untargeted scheme. Unlike targeting beneficiaries (e.g. Food stamps for poor), the health and nutritional changes pre- and post-scheme intervention could be measured and compared with alternatives like direct cash transfer, mid-day-meals, etc. On the other hand, universal self-selection with no registered beneficiaries is challenging to identify evaluation metrics. With standardized price and items in the food menu, each local authority act like a decision making unit (DMU) operating canteens and employing women from local Self-Help-Groups. Using interviews with operational managers, and secondary data such as number of footfalls, cost of ingredients, expenditure etc. a data envelopment analysis (DEA) was formulated to

compare performance of 9 local authorities. It was found that 77.7% of branches were inefficient. Further DEA using an audited data in 3 DMUs found that open market procurement of key ingredients such as cooking oil, black grams were determinants of inefficiency. The proposed empirical evaluation provides support for policy makers to identify inefficient branches and take corrective measures.

3 - School study-programs' performance and their determinants
Anna Mergoni, Kristof De Witte

In this paper we investigate the relationship between student's educational performance in secondary and higher education and the study program attended in secondary education. The data are provided by the Flemish Minister of Education and contain student-level information for the cohort of students born from 1991 to 1996 and attending a secondary school in Flanders. A 'Benefit of the Doubt' composite indicator is constructed to benchmark the study programs and to evaluate them in the best possible light. To individuate possible determinants of the study programs' performances a robust and conditional version of the indicator is also implemented. By conditioning for the socio-economic status of the students, we also avoid the bias caused by the self-selection of students coming from a higher background in specific study programs. Additionally, we investigate the determinants of the school's ability in teaching specific study programs by comparing the educational outcomes for cohorts of students in the same study program.

4 - Cost Efficiency in the Provision of Public Services under Demand Uncertainty
Hong Ngoc Nguyen, Chris O'Donnell

Public service managers generally make input choices in the face of uncertainty about the demand for their services. However, this is generally not taken into account in the assessment of efficiency. To account for the impact of demand uncertainty, it is convenient to partition the decision-making process into two distinct stages: the first stage is a resource planning stage under demand uncertainty, while the second stage is a production stage where chosen resources are used to meet realized demand. This paper focuses on the first stage, when demand is unknown. In this stage, managers seek to minimize the cost of producing planned output targets. This paper explains how data envelopment analysis (DEA) methods can be used to estimate associated measures of technical, allocative, and cost efficiency. It also presents how DEA can be used to measure the effects of demand uncertainty on costs. The methodology is applied to hospital data from Queensland (Australia). The estimates of efficiency are quite different from the estimates obtained using conventional methods that ignore demand uncertainty. The empirical results also indicate a significant effect of demand uncertainty on hospital costs.

Wednesday, 16:00-17:40

■ WE-01

Wednesday, 16:00-17:40 - Room 1

Keynote: Martin Bichler

Stream: Keynotes
Invited session
Chair: Efsun Kürüm

1 - Designing Markets with Complex Constraints
Martin Bichler

Market design has received significant attention in different disciplines. Apart from academic recognition via Nobel Prizes in the Economic Sciences, the field left its mark on applications ranging from industrial procurement, to spectrum sales, and school choice. However, fundamental design problems are still not well understood and many of them arise from complex constraints in practical market design applications. I will provide an introductory example of a market for fishery access rights to introduce computational problems in market design that arise from allocation and budget constraints. These problems touch on fundamental questions at the intersection of economics and computation and they require new theory and new methods to be developed.

■ WE-02

Wednesday, 16:00-17:40 - Room 2

Game Theoretic Analysis of Supply Chains

Stream: Supply Chain Management
Invited session
Chair: Mengmeng Li

1 - Partial Vertical Ownership and Information Exchange in a Supply Chain
Tal Avinadav, Noam Shamir

Partial vertical ownership describes a situation in which a firm holds financial shares either in its supplier (referred to as partial backward integration) or in its customer (partial forward integration). We study the effect of such financial interconnectedness on two operational decisions: capacity investment and information exchange. In our model, a retailer, who has superior information about the future market demand, possesses some level of passive financial holdings in the supplier. Although this passive financial investment does not enable the retailer to directly influence the supplier's operational decisions, it does affect the market equilibrium. Specifically, financial interconnectedness between the firms can result in the retailer financing the entire capacity in the market. In addition, we characterize the conditions that ensure information between the retailer and the supplier can be exchanged by "cheap-talk" communication. When "cheap talk" is not possible, we study the separating equilibrium that is achieved by the retailer's commitment to order in advance. Interestingly, this advance order can be either decreasing or increasing with respect to the level of the financial holdings.

2 - Store brand introduction in a two-echelon logistics system under diseconomies of scale
Shuai Heung, Wei Geng

Retailers attempt to introduce store brands to enhance their ability of negotiation and competitiveness. The Stackelberg model with a single manufacturer and retailer was established. Whose goal is to address the impact of diseconomies of scale on the strategy of retailer introducing the store brand. The equilibrium prices and demands of the two brands

have been calculated. The effects of the introducing of the store brand can be easily found by comparing the equilibrium result between the different models. Last but not least, based on the optimal profits of manufacturers and retailers in the two models, the appropriate choice to introduce the store brand for retailer has been analyzed. It shows that when the store brand is introduced by a retailer, only in two cases that the store brand benefits to retailer: (1) The potential market share of the store brand isn't so high and the size of diseconomies of scale is less at the same time. (2) The potential market share of store brand is high enough. Otherwise, the manufacturer's profit is always below the case without a store brand.

3 - Dynamic vs. static pricing in a dual-channel supply chain
Mengmeng Li, *Shinji Mizuno*

Understanding the benefits of dynamic pricing (DP) with respect to static pricing (SP) is of significant value to firms and researchers. Existing research of dynamic vs. static pricing problem focuses on a firm or a single-selling-channel supply chain. With the boom in e-commerce, however, dual-channel supply chain consisting of traditional retail and online direct channels has become a common business model. This work studies the dynamic vs. static pricing problem in a dual-channel supply chain with one manufacturer and one retailer, where the demand is stochastic and price sensitive. Four possible pricing strategies, i.e., both members take DP, retailer takes DP while manufacturer takes SP, retailer takes SP while manufacturer takes DP, and both members take SP, are considered. Under each of the pricing strategies, models are developed with stochastic dynamic programming to determine the optimal pricing and inventory decisions in every period so that each member's total expected discounted profit over the planning horizon is maximized. Results show that: base-stock inventory policies are optimal under different pricing strategies; the influences of manufacturer and retailer's initial inventory levels on optimal prices and base stock levels vary with pricing strategies; it is better for manufacturer to choose SP if retailer takes SP and to choose DP if retailer takes DP; it is better for retailer to choose SP no matter what type of the pricing strategies manufacturer takes.

■ WE-03

Wednesday, 16:00-17:40 - Room 3

Financial modelling

Stream: Financial Mathematics and OR
Invited session
Chair: Rosella Giacometti

1 - Tail risks in Vast portfolio selection
Rosella Giacometti, *Gabriele Torri*

In this work, we consider optimal asset allocations strategies based on tail measures i.e quantile and expectile.

In order to control estimation error and improve the out-of-sample performances of the models, we consider ridge and elastic-net regularization penalties. Simulations and real-world analyses on multiple datasets, allow to discuss pros and cons of the proposed methods. The results show that the ridge and elastic-net allocations are effective in improving the performances, especially in large portfolios, compared to the un-penalized ones.

2 - Systemic risk in insurance and banking sector: a microstructural approach
Gabriele Torri, *Rosella Giacometti*

Systemic risk and financial contagion are increasingly relevant in the modern financial system, and their measurement is of paramount importance for investors and regulators. Microstructural models based on balance sheet data are gaining popularity. This approach models directly the behaviours of the actors in a system (in the specific case banks and other financial institutions), on the basis of balance sheet and bilateral exposure data. The increased availability of regulatory data fostered the development of such models in recent year concerning the banking sector, while for the insurance sector the development is still limited. In this work we analyze the peculiarities of the insurance and reinsurance sector, proposing contagion models tailored to the characteristics of these companies, suitable for the measurement of systemic risk to support the decision-making process of regulators and investors.

3 - Tree-Based Ensemble Strategies for Predicting Loss Given Default of Bank Loans
Aida Salko

We investigate the performances of eight different tree-based ensemble techniques for predicting Loss Given Default of bank loans for Small and Medium Enterprises (SMEs) and large corporates. Using a unique dataset of defaulted loans in European banks, we show that these ensemble strategies lead to remarkable improvements in LGD prediction accuracy compared with regression trees. Random forest performance prevails among other tree-based ensembles. Additionally, we use SHapley Additive exPlanations (SHAP) method to analyze the contribution of individual risk drivers in prediction and provide some insights about their influence on model prediction through partial dependence plots. We find that the algorithm considers different important features for SMEs and large corporates. It is shown that the default amount, the reported entity sales followed by the industry sector, and macroeconomic environment turn out to be important drivers for an accurate prediction of LGD in the case of SMEs. On the other hand, for large corporates, including information regarding the entity reported financial information when training random forest algorithm, strongly enhance the forecasting performance of the model.

Keywords: Loss Given Default, Global Credit Data (GCD), Forecasting, Ensembles. JEL Classification: C53, G21, G32.

4 - Is ESG a key element in investment choices?
Rita D'Ecclesia, *Susanna Levantesi*, *Valeria D Amato*

Sustainable finance incorporates environmental, social, and governance (ESG) principles into business decisions and investment strategies. Incorporating these kinds of considerations in finance has become a key element in in recent years. ESG issues can have a material impact on firms' performance. The aim of the present paper is to assess if European ESG stocks listed in Euro Stoxx Europe 600 index show a better performance compared to traditional business company. We use a Machine Learning approach to assess ESG companies performance in the last decade. We firstly decompose the total return of each stock into its main components, then we use tree-based algorithms to evaluate the importance of each component in describing the ESG firm's financial performance.

■ WE-04

Wednesday, 16:00-17:40 - Room 4

Scheduling applications 1

Stream: Scheduling, Timetabling and Project Management
Invited session
Chair: Simon Emde

1 - Dynamic scheduling of aircraft landing
Mehmet Mutlu Yenisey, *Gülnar Çalışkan*

There is a significant increase in the amount of civil aviation traffic. The dynamic nature of airports requires computationally efficient algorithms to reschedule landings as including new air traffic events. Generally, the objective of Aircraft Landing Schedule Problem (ALS) is to minimize the deviation or minimize the penalty cost of earliness and lateness from target landing time. A multi-objective formulation takes account of runway throughput, earliness and lateness, and the

cost of fuel arising from aircraft maneuvers and additional flight time incurred to achieve the landing schedule. This study proposes four algorithms to dynamically schedule landing aircrafts on single runway. The proposed approach has unique Level1 (L1) and Level 2 (L2) procedures with Tabu Search, Simulated Annealing, Genetic Algorithm, Ant Colony Algorithm are used for ALS problem. The problem has two parts as sequencing and time assignment. For sequencing, the proposed 4 algorithms are used. The time assignment function assigns operation time for the aircraft and includes optimization process which is done by using level1 (L1) and level2 (L2) optimization operations. The proposed algorithms are implemented in C programming language. The ALS problem is solved for both the static and dynamic case with the test instances in OR library and Beasley's static case results. The overall results show that the proposed algorithms efficiently solve dynamic ALS problems.

2 - Solution methods for a combined workforce and project scheduling problem in disaster response
Niels-Fabian Baur, Julia Rieck

Due to climate change, the number of annual natural disasters worldwide is expected to increase. Even in highly developed countries, not all disasters can be prevented. It is therefore important to develop appropriate responses to disasters in addition to mitigation measures. For an appropriate response, activities, such as the construction of dams or the removal of debris, can be identified. They need to be carried out as a part of a disaster project and require resources as well as specific skills (e.g., driving licenses, physical fitness) to be processed. The more suitable resources are available, the faster the disaster can be handled and thus the damage can be minimized. Consequently, it is necessary to integrate professional and voluntary helpers who differ in their skills and can hence be assigned to different activities. Thus, an integrated workforce and project scheduling problem with scarce resources and time constraints arises that has been adapted to the considered issue of disaster management through some special features like variable activity durations, multiple skills, and stochastic components. Due to the complexity of the problem, an exact solution of realistic large-scale instances is not possible within a reasonable time. Therefore, we present a serial schedule generation scheme and a scatter search that can be embedded into a decision support system to solve the problem in a dynamic environment where workforces come and go regularly.

3 - A material flow based approach for scheduling dismantling projects
Marco Gehring, Rebekka Volk, Frank Schultmann

Bottlenecks in material flow handling onsite can impose a significant restriction on the schedule of large-scale projects. Thus, integrating material flows into scheduling models used in the planning process is of crucial importance. Nevertheless, for the particular case of dismantling projects, this integration has only been studied to a limited extent. Our contribution is an extension of the well-known resource-constrained project scheduling problem (RCPSP) by constraints on material flows released during the execution of project activities. We use operations for representing the processing of materials and cumulative resources for representing storage facilities. Fulfilling an essential requirement for practical application, even complex and highly branched material flow networks comprising various storage facilities can be modeled. To efficiently generate starting solutions, we propose a schedule generation scheme tailored to such problems' particular precedence structure. We study the schedule generation schemes' performance on generated test instances and compare it to the constraint programming solver IBM ILOG CP Optimizer.

4 - Multi-depot electric vehicle scheduling to minimize the fleet size
Simon Emde, Heiko Diefenbach, Christoph Glock

Electric vehicle scheduling is concerned with assigning a fleet of electrically powered vehicles to a set of timetabled trips. Since the range of these vehicles is limited, charging breaks need to be scheduled in-between trips, which require detours and time. This study is motivated by an electric vehicle scheduling problem with multiple charging stations in a novel in-plant logistics setting, but the model is in principle also applicable to other logistics and transportation settings with the objective of minimizing the required fleet size, such as public transportation. Contrary to previous works, we consider arbitrary battery charging, which, among other things, allows to model realistic non-linear charging. We present a MIP and an exact branch-and-check solution procedure. Our computational tests show that solving the MIP model with a standard solver (CPLEX) is insufficient for realistic instances in acceptable time, but that the branch-and-check approach performs well. Furthermore, we derive some insights into the influence of the charging mode and maximum battery capacity on the required fleet size. Lastly, we investigate if one centralized or multiple decentralized warehouses (with respective charging stations) are advantageous in an in-plant logistics setting.

■ WE-05

Wednesday, 16:00-17:40 - Room 5

OR, arts and creativity

Stream: Behavioral OR
Invited session
Chair: Gerhard-Wilhelm Weber
Chair: *Suryati Sitepu*

1 - An OR approach to create traditional Turkish art with the help of analytics and AI, inverse and forward problems
Gerhard-Wilhelm Weber, Meltem Atay, Suryati Sitepu

This study is the first and ongoing research on traditional art generation studies by our research group. We introduce a novel data collection of paper based on digital copies of traditional Turkish art named as Ebru (marbling). In the dataset there are 5 sub-classes of Ebru styles and about 200 samples per class; the total number of data is 1000. Ebru data were gathered from non-copyrighted digital copies of the real Ebru collections. We use Inverse and Forward Problems and AI. To introduce the dataset we used several supervised classification methodologies from machine learning and deep learning. Our best performing method is based on transfer learning; pre-trained and fine-tuned Inception-Resnet V2 model for 500 epochs using Adam optimizer with learning rate set to 0.0001, nesterov momentum 0.9, we obtained test accuracy of 92% and 0.92 loss. We also offer a novel architecture (SEDNet) to classify Ebru Dataset based on inception modules; it is an optimized-shallow version of Inception-Resnet V2 architecture. Our best performing model bases on transfer learning approaches with test accuracy of 92% and 0.46 loss. SEDNet is the unique model which we developed for classification task of this kind of art, resulting in test accuracy of 56% and 3.57 loss. We also developed novel strategies of generating new digital Ebrus by approaches of generative adversarial networks and we developed a novel architecture named as SEDGAN, specifically to generate digital Ebru art.

2 - Region-based image and video analysis with use of scalable morphological models
Ivan Reyer, Ksenia Aminova

A region-based approach to image and video analysis is considered. A "continuous" model of a segmented image or a video frame consisting of a set of nonoverlapping polygonal figures is constructed. Each polygon from the set approximates a homogeneous raster region within the image, with polygons of two neighbour regions having common fragments of boundary. A polygon in the model is represented as a triple structure including the boundary, the skeleton (medial axis), and the set of maximal inscribed disks (describing width variations of a shape). The model also includes a "markup" of skeleton points describing changes of skeletal representation at increase of the approximation accuracy value. Thus, a polygonal figure generates a family of variously detailed boundary-skeleton shape models. Obtained image models are compared by shape and color of polygons. To estimate the shape similarity, integral morphological features (the change

of boundary convexities' number at increase of the approximation accuracy value, medial width function, approximated Maragos spectrum etc.) are compared. The applications of the presented approach to high-resolution image analysis and video indexing and retrieval are discussed.

3 - How IoT can empower employees - a scenario-based approach
Hannes Reil, Marlen Rimbeck, Michael Leyer, Jutta Stumpf-Wollersheim

The research on Internet of Things (IoT) has shown the potential of IoT to reduce cost and to make processes more efficient and effective. There is however not much known about the impact on the activities of employees. The increase in information connectivity is expected to lead to more human-machine interactions which will have an impact on the activities of employees and result in changes. We adopt a framework for collaborative manufacturing work environments based on structural empowerment theory (SET) as relevant theoretical lens. It allows us to analyze the connection of employees to objects and to derive a better understanding how the intelligent cross-linking of objects associated with IoT affects the activities of the employees. For this purpose, we used a scenario-based design approach considering the dimensions of SET: access to information, access to resources, access to support and access to opportunities. The scenarios are based on 17 semi-structured interviews from different organizations and different representatives. The developed problem and activity scenarios show the as-is situation and how SET can be used to describe the change of employee's activities due to IoT. Moreover, it is shown in which way employees should be connected to intelligent things in the workplace. We also give advice to companies how the work activities could be enhanced with IoT by using an organizational framework.

4 - Consumer processing of online trust: a dynamic online consumer trust forming mechanism
Shanshan Huang, Cong Cao, Jun Yan, Mengxiang Li

This research study investigates online trust as a breakthrough point aiming at consumers in the B2C e-commerce model; as such, it examines specific factors that influence consumers' online trust. Based on a literature review and existing research results in relevant fields, with the Theory of Planned Behavior (TPB) as the theoretical underpinning, this study proposes a three-dimensional integrated trust model and identifies three factors that impact consumers' trust: personal attitude, online reviews and trusted third parties (TTPs). The required experimental data were obtained using random sampling and online questionnaires. The Partial Least Squares Structural Equation Modelling was used as the main analysis method to test the research hypotheses and to verify the validity of the online trust model. Moreover, the study investigated the mechanism and impact of different factors on consumers' trusting behaviours. This study points out that consumers' trust intention is influenced by personal attitudes, online reviews and TTPs. If a consumer's personal attitude is positive, the online review he or she perceives will be positive, too. The more comprehensive the services provided by TTPs are, the more intention a consumer has to trust, and vice versa. Moreover, the research results demonstrated that a consumer's personal attitude negatively influences his or her perceived social pressure from an online review, and exerts control over the TTP.

■ WE-06

Wednesday, 16:00-17:40 - Room 6

Supply chains for nanostores and warehouses

Stream: Logistics in new economies
Invited session
Chair: *Christopher Mejia-Argueta*
Chair: *Zeynep Turgay*

1 - Rethinking fresh food supply chains for low-income consumers in Brazil through nanostores
Cristiano Flores, Christopher Mejía-Argueta, Lars Sanches, André Duarte, Ricardo Cassel

Health problems related to obesity and undernourishment are a major global issue, especially among a lower-income population where the obesity rates are even higher. The lack of adequate health systems and a large percentage of poor people amplifies these issues in Brazil. A significant cause of malnutrition is the high intake of ultra-processed food items combined with a low intake of fruits and vegetables. Previous efforts to tackle the problem have failed or were not able to become sustainable in the long run. Previous research showed that low-income consumers are price sensitive and that a reduction in the demand for healthier food options decreased its accessibility creating the so-called Food Deserts. Our main goal is to build a financially sustainable fresh food access model linked to the low-income population. Results of a survey applied to 300 consumers in Brazil to evaluate the willingness of adoption of an access model based on a subscription of a basket of fresh food. We implemented advanced statistical modeling and concluded that consumers are willing to adopt a subscription model, especially if pre-selected products come directly from the farmers to a location of ease access to them with lower prices than other alternatives.

2 - Hybrid modeling for product supply strategies to Nanostores in Emerging Markets
Edgar Gutierrez, Christopher Mejía-Argueta, Luis Rabelo

Managing product supply to nanostores in emerging markets presents logistics and supply chain challenges that justify the use of advanced data driven decision-making methodologies and new distribution strategies by consumer package goods (CPGs) industries. These markets are characterized by diversity in population density, high fuel prices, poor road infrastructure, and variety in socio-economic conditions. In consequence, high transportation costs, difficulty to find parking and significant traffic effects due to weather conditions affects the daily delivery to hundreds of nanostores in the city. This research presents how leading-edge technologies like advance optimization, artificial intelligence and simulation among with supply chain strategies can help organizations to deal with these challenges. A case study is presented under the conditions of Bogota, Colombia. It discusses the main delivery issues in the city and provides guidelines and the mathematical support models for the last-mile delivery task. Hybrid modeling techniques (Mixed Integer Programming, Agent base modeling and Reinforcement Learning) are proposed to establish accurate predictions of estimated time of arrivals to each nanostore, fuel-efficient routes and schedules for vehicles, and reductions of service delivery time based on the dynamic behavior of the city.

3 - An algorithm-based solution approach for the integrated storage assignment with precedence constraints: a case study of large-size retail warehouses
Zeynep Turgay

The warehouses are the arteries of the retail chains as any disruption or deterioration in order lead times will compromise the service level of the stores. Order lead time is strongly affected by the picking production where picking production can be significantly reduced by optimizing the total travelling distance during order picking process. Therefore, warehouse design and order picking are an essential research topic of operations research discipline. Order routing is an operational problem and picker routes can be improved by classical CVRP problem. However, as shown by Elbert (2017) complex routes confuse the pickers whereas the improvement does not exceed 10% (de Koster et al., 2007) when compared to the heuristic routes followed by pickers. Therefore, we propose two computationally tractable storage assignment algorithms for the order items in a warehouse to obtain considerable improvements of up to 45% when compared to best indexing policy including frequency-based policy, ABC and COI policy. Besides, we effectively consider main practical considerations of the warehouses which are rarely considered in the literature of storage assignment: (1) large number of items (2) precedence constraint between items and (3) correlation between the ordering frequencies of the items. Finally, we will discuss our experience gained during piloting phase.

■ WE-07

Wednesday, 16:00-17:40 - Room 7

OR in Health, Medicine and Life Sciences 3

Stream: OR in Health, Medicine and Life Sciences (contributed)
Contributed session
Chair: *Emanuel Lopes*

1 - An Optimization Model of Green Vaccine Supply Chains and Application in Pharmaceutical Industry
Ilya Levner, Avi Herbon

During the treatment of influenza vaccination activities, in addition to standard medical and logistic operations, the main activities in Distribution Center (DC) and clinics should include also environment-aware operations. The objective of this paper is to minimize the total cost of vaccine storage and distribution operations at centralized DCs and at clinics so that the clinics are provided with vaccines under limited vaccines supplies, and environment-protection constraints. A linear programming model with integer variables is developed. The model is tested through computational experiments with real-life data. A possible application of this research is for optimizing vaccination plans for different subpopulations and various HMOs. Our vaccine supply chain model integrates the operational cost/benefit parameters of vaccination programs with the costs/benefits of green activities.

2 - Covid-19 crisis turned into an opportunity - pay-per-use model case study of a radiology diagnostic center in a public-private partnership
Amit Gupta

Purpose: This is a case study paper which evaluates a pay-per-use business model, adopted under distress by a private radiology diagnostic center of a public-private-partnership, due to the impact of Covid-19 in India. PPPs in healthcare work on the basic principle of high volume and low margins. Huge drop in patient scan volume, forced PPP diagnostic center to cut fixed costs by replacing onsite radiologists with a teleradiology company. Value: Due to the pay-per-use model: 1. The paper evaluates the cost-benefit achieved during the lockdown period of Mar-May 2020 2. The paper also studies cost-benefit, round-the-clock service availability and turn-around time during huge patient volume of second wave of Covid-19 (April 2021) Methodology: The actual revenues and expenses data was collected for pre-covid-19 and during first lockdown period. Also, the daily scan and report generation data was collected and analysed during second wave of covid-19. Findings: The radiologists' expenses came down to 10% of the revenues. Access to a team of radiologists boosted efficiency and reduced turn-around-time, alongwith substantial cost benefit.

3 - A Mixed Integer Linear Programming approach for optimal policy making for controlling COVID-19
Debajyoti Biswas, Laurent Alfandari

The COVID-19 pandemic has had an unprecedented impact on global health and the economy since its inception in December, 2019 in Wuhan, China. Non-pharmaceutical interventions (NPIs) like lockdowns and curfews have been deployed by affected countries for controlling the spread of infections. In this paper, we develop a mixed integer non-linear programming (MINLP) epidemic optimization model for computing the optimal sequence of NPIs over a planning horizon, considering shortages in doctors and hospital beds, under three different lockdown scenarios. We analyse two strategies - centralised (homogeneous decisions at the national level) and decentralised (decisions differentiated across regions), for three objectives separately - minimization of deaths, infections and cost, using actual pandemic data of France. We linearize the quadratic constraints and objective functions in the MINLP model and convert it to an MILP model. We prove analytically that the optimal sequence of NPIs always follows a strictly decreasing severity pattern. Using this property, we further simplify the MILP model into an Integer Linear Programming (ILP) model, reducing computational time up to 99 percent. Our numerical results establish that a decentralised strategy is more effective in controlling infections for a given severity budget, yielding up to 20 percent lesser infections, 15 percent lesser deaths and 60 percent lesser shortages in healthcare resources.

4 - Prediction of anxiety-related psychological state and VR sickness based on autonomic physiological responses during VR treatment in patients with social anxiety disorder
Joo Young Chun, Taesu Cheong, Chul-Hyun Cho

Social anxiety disorder (SAD) can accompany emotional symptoms as well as physical reactions. When feeling anxious, physical symptoms are manifested by hyperactivity of the autonomic nervous system. The assessment of SAD has problems with subjective psychological tests and real-time measurement is impossible. The purpose of this study is to predict the psychological test result related to the SAD result and VR sickness of patients by quantitative measuring of autonomic physical reactions. In this study, we try to predict the severity of psychological states and VR sickness in SAD patients by machine learning models based on only autonomic physical reactions during VR therapy sessions. In total, 32 individuals with SAD symptoms were enrolled in exposure therapy with VR participatory sessions. Physical reactions are successfully measured for 26 individuals. The physical reaction was measured during a total of 6 VR sessions and includes heart rate and galvanic skin response. Also, the participants did Simulator Sickness Questionnaire to measure VR sickness. Psychological scales were assessed through Internalized Shame Scale and Post-Event Rumination Scale. The physical reaction data is converted as a data frame that describes the shape of the time series data. K-means clustering, logistic regression, random forest, and support vector machine were used to classify and predict the severe and non-severe groups according to psychological tests and VR sickness in patients with SAD.

■ WE-08

Wednesday, 16:00-17:40 - Room 8

Data Science

Stream: Data Science, Analytics and Performance Measurement (contributed)
Contributed session
Chair: *Young Jun Jang*

1 - Data-science research in higher education; detecting academic dropout within first semester of study
Shoshana Yaakov

The impact of student retention on economic growth and reputation is crucial for higher educational institutions around the world. The innovation of this study is motivated by early detection of potential dropout students for the purpose of improving student retention and institutional success. This study will give an in-depth historical overview and provide theoretical models of studies regarding student attrition. Then, it will focus on building a prediction model for college dropouts from Azrieli College of Engineering in Jerusalem, based on data of approximately 7,000 students, with the intent of improving student retention within the first year, and even the first semester of study. The data collected includes matriculation and psychometric grades as well as first semester average, and other first and second semester course grades. The study is done according to the five-step method of data mining which uses an algorithm for reviewing, investigating, and analyzing an existing database to identify the main characteristics of the data, find links between them and draw conclusions. Based on the findings of the prediction model, student dropout is highly linked to first semester studies, specifically the number of course failed in the first semester, the number of logins to the school platform in first semester, the Calculus I grade, and finally, debt inccurred by the student. Using these findings, we can support potential dropout students and improve student dropout rates.

2 - Stock prediction with finance-specialized sentiment analysis using news and stock messages
Soyoung Jun, Jong Woo Kim

We propose an investment strategy based on finance-specialized sentiment analysis on stock-related text data. It aims to help investors build better strategies even in situations where stock trading complexity rapidly intensifies. The financial texts, which are known to affect investor sentiment, range from traditional media like economic news to user-created stock messages recently increased on social platforms. In the news, earnings expectation is indirectly generated with objective information, whereas stock messages indicate direct opinions from decision-making with multiple users. This study examines whether stock-relevant texts influence stock returns using the financial language model and which material has a greater impact between financial news and StockTwits. To verify the proposed approach's usefulness, our research model will be conducted with the finance-specialized sentiment analysis and six regressors. We will apply FinBERT, which is proven to understand better the semantic meaning of financial documents than a general-purpose language model. Then, we will compare the expected performance with different analytic models and market simulation to validate whether the boosted result on financial language processing is apparent in stock price prediction. This approach will help investors comprehend where the general sentiment comes from and recognize the importance of qualitative resources in establishing an investment strategy.

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2020S1A3A2A02093277).

3 - Unsupervised model for software contract renewal rate improvement
Shylu John, Bhavin Shah

Contract renewal plays a very important role in software companies in maintaining recurring revenue. In this study an attempt was made to improve contract renewal rate using reseller level data and used an unsupervised model to identify high- risk reseller clusters for B2B service contracts that are in the renewal stage. The proposed approach includes the development of a model to cluster resellers followed by testing, deployment of the solution and tracking its benefit. Three clustering methods such as K-means, Hierarchical, and DBSCAN were evaluated based on silhouette score; and K-means clustering model was selected for further study. The K-means model identified 4 clusters: 1) Loyal reseller with 90% renewal rate, 2) High performing resellers with 74% renewal rate, 3) Mediocre performer resellers with 45% renewal rate, and 4) Non-performing resellers with only 5% renewal rate. The model outcome was tested for 3 quarters using a champion-challenger experiment and followed a strategy of calling 50% customers each in low and medium performing clusters. The observed improvement in renewal rate for the selected test period was 4-7% with average quarterly incremental revenue of $220K. The factors such as contact days in advance, on-time analysis, and sales cycle length were also further studied to improve the renewal rate.

4 - Sensor based time series classification and interpretation using Convolutional Neural Network and WaveNet
Young Jun Jang, Jiho Kim, Hong-Chul Lee

Recently in the manufacturing industry, there is an increasing number of attempts to analyze the amount of equipment usage and effective resource allocation. In particular, it is important to classify usage patterns based on time series data that are accumulated in real-time by sensors equipment and to classify accurately by grouping similar patterns together. Moreover, time series classification is considered a challenging task, due to the characteristic of high dimensionality and temporal correlation. Many previous studies used the Distance-Based Classification algorithm for the time classification task, and it will be grouped based on similarity within the distance. In this study, the length of the data was reshaped to apply the time-series classification to the Convolutional Neural Network model. In addition, we propose the application of explainable artificial intelligence method that can further explain time series data after classification using deep learning models such as Convolution Neural Network and WaveNet. Then we applied Class Activation map to visualize and show the interpretability of its features. We conducted the experiment using the UCR 2018 time series dataset, through reducing the dimension of time series data, able to extract the feature and analyze the correlation between time series data. Our study proposes a deep learning model that provides an accurate classification for time series data and adds interpretability to the model.

■ WE-09

Wednesday, 16:00-17:40 - Room 9

OR and ethics and societal complexity

Stream: OR and Ethics
Invited session
Chair: *Dorien DeTombe*
Chair: *Cathal MacSwiney Brugha*

1 - Filaments of crime: informing policing via thresholded ridge estimation
Ben Moews, Jaime Argueta, Antonia Gieschen

We introduce a new method for reducing crime in hot spots and across cities through ridge estimation. In doing so, we explore the application of density ridges to hot spots and patrol optimization, and contribute to the policing literature in police patrolling and crime reduction strategies. We make use of the subspace-constrained mean shift algorithm, a recently introduced approach for ridge estimation further developed in cosmology, which we modify and extend for geospatial datasets and hot spot analysis. Our experiments extract density ridges of Part I crime incidents from the City of Chicago during the year 2018 and early 2019 to demonstrate the application to current data. Our results demonstrate nonlinear mode-following ridges in agreement with broader kernel density estimates. Using early 2019 incidents with predictive ridges extracted from 2018 data, we create multi-run confidence intervals and show that our patrol templates cover around 94% of incidents for 0.1-mile envelopes around ridges, quickly rising to near-complete coverage. We also develop and provide researchers, as well as practitioners, with a user-friendly and open-source software for fast geospatial density ridge estimation, and show that ridges following crime report densities can be used to enhance patrolling capabilities. Our empirical tests show the stability of ridges based on past data, offering an accessible way of identifying routes within hot spots instead of patrolling epicenters.

2 - Supply chain links the value chain: a nested model for sustainable decision-making
Adel Guitouni

Many corporations are disaggregating their operations and supply chains, and fine-slicing their global value chains. Value creation requires partnerships and collaborations across 'logical combination' of mainly independent and geographically dispersed actors, large and small; i.e., co-production networks (CPNs). Climate change and revelations about poor working conditions, unsustainable production practices, socio-economic inequalities, food contaminations and industrial destruction of natural habitats increased the disapproval of existing management and decision-making practices, theories and systems prevailing within industrial CPNs. The interwoven relationships between economic, social, and environmental dimensions led major corporations to recognise that the purpose of a corporation is to create value for all its stakeholders. 99% of CEOs consider that sustainability is important to the future success of their business, and 71% of them believe that business should contribute to the UN sustainable development goals. This paper reconsider the conventional understanding of decision-making within clusters of self-organized and vertically related but independent organisations such as CPNs. We investigate responsible decision-making and supporting technologies for sustainable production management within CPNs through the specification of a nested model of value management when goals are incommensurable, multi-criteria and pluralistic under spatial and temporal conditions.

3 - Leadership and Ethical Clashes at Boeing!
Jinyu Li

Boeing, one of the world's most successful aircraft manufacturers, has, within a two-year period experienced two tragic and deadly crashes of the 737 MAX, their most commercially successful airplane. This paper identifies the ethical factors within Boeing, particularly the management changes resulting from the merger with McDonnell-Douglas, and the changes in the corporate culture including the composition of the senior management team and their relationship with the FAA that contributed to Boeing's safety and quality issues. Based on chronological research of the factors that contributed to the 737 MAX crashes, this paper provides some management strategies for mitigating Boeing's ethical, quality, and safety risks, and also recommends a program to regain public confidence and trust.

4 - How does the government subsidize private innovation? When the innovator encroaches the supply chain
Jinglve Wang, Guohua Zhou

We study a supply chain with innovator encroachment in which innovation may be subsidized by a government. Current voices from scholars and practitioners have already pointed out that government subsidies have an uncertain influence on private innovation investment. Even so, there is neither theoretically nor empirically definitive guidance on the effectiveness of government subsidies in stimulating private innovation. In this paper, we develop five game-theoretic models and consider three forms of government subsidies to find out how government subsidies influence the optional decisions of the innovator and the manufacturer and how to keep the effectiveness of subsidies. Through comparative analyses, we establish a conception model to elaborate on how government subsidy regulate the competitive market. We also show that government subsidies do not always lead the innovators to set a high level of innovation goal and the impact of government subsidies on the goal depends mainly on the characteristics of innovation projects. Besides, we match subsidy types with the features of innovation projects to ensure government subsidies always crowd in private investment. Our results may explain why government subsidies almost always have an uncertain impact on private innovation investment and provide valuable advice for governments to encourage private innovation.

■ WE-10

Wednesday, 16:00-17:40 - Room 10

Data mining and statistics

Stream: Data Mining and Statistics
Invited session
Chair: *Meslin Silalahi*
Chair: *Gintautas Dzemyda*

1 - Data visualization using geometric multidimensional scaling
Gintautas Dzemyda, Martynas Sabaliauskas

Data visualization is an integral part of data science along with statistics, pattern recognition, machine learning, artificial intelligence, and data mining. Multidimensional scaling (MDS) is one of the most popular methods for dimensionality reduction and visual representation of multidimensional data for human decision. MDS minimizes multiextremal stress function, dependent on coordinates of data points in a lower dimensionality. A new idea (Geometric MDS) has been discovered to minimize the stress so that the step size and direction forward the minimum of the stress function are found analytically without reference to the analytical expression of the stress function, numerical evaluation of its derivatives and the linear search. It is proved that the direction coincides with the steepest descent direction, and the analytically found step size ensures almost the optimal step in this direction. The discovered option to minimize the stress function is examined, including the global minimization of the stress. According to the experiments, Geometric MDS gives better results as the stress minimization using majorization (SMACOF version of MDS). The advantage of Geometric MDS is that it uses the simplest stress function, and there is no need for its normalization depending on the number of data points and the scale of proximities. This research has received funding from the Research Council of Lithuania (LMTLT), agreement No S-MIP-20-19.

2 - Effects of connectivity on challenges in SME access to finance
Antonia Gieschen, Raffaella Calabrese, Belen Martin Barragan, Jake Ansell

Enabling Small and Medium-sized Enterprises (SMEs) to prosper through sufficient access to finance is an important issue for the UK economy. Despite their diversity, there are also dependencies and interconnections between them which affect their ability to access external finance. This dependency arises from both the business networks to which they belong and spatial spillovers, as well as business demographics such as their industrial sector or their intention to grow. Many of these dependencies are opaque to those exploring SME behaviour. Our aim is to investigate how these dependencies impact access to finance. We use a novel approach of combining spatial regression and clustering, by taking into account interconnections between SMEs. Previously, it has been established that there are spatial aspects to access to finance, with rural areas gaining relatively fewer acceptances than large urban centres. For defaults, spatial location in connection with interdependencies among SMEs has been used. However, this approach has so far not been employed for access to finance. We take advantage of survey data on 3,227 UK SMEs to provide evidence that spillover effects have a significant influence on access to finance for SMEs. The results of this paper call for tailored local policy making on a regional level to account for these differences.

3 - Prescription drugs forecast for chronic diseases based on refillable prescriptions
Jack Lin, Kwei-Long Huang

The growing trend of high prevalence of chronic diseases has forced pharmacies to handle more refillable prescriptions. Provided that the days of supply per refill and authorized number of refills are written in a refillable prescription, pharmacies can expect when a patient will return and the prescribed quantity of drug to be dispensed for each refill. The demand pattern for chronic diseases may then be observed through the refillable prescriptions being issued. In order to forecast the demand of drug in terms of equivalent drug category (or simply EDC), we build multiple time-series forecasting models based on the randomness and seasonality of historical data. We improve the accuracy by forecasting the demands of standard and refillable prescriptions separately based on the probability and timeliness of refill which represents patients' medication adherence. The total demand is obtained by combining the forecasted demands of fills and refills. Approximately 76% of time the models show improvements on the forecast accuracy with real-world datasets. The result shows factors found from different aspects of characteristics of drugs and medication adherence are effective tools to determine suitable drugs; especially the higher on-time rate, the better drug suitability. Furthermore, we apply multivariate time-series models on all members in an EDC to forecast demand of each drug.

4 - The Impact of Discounting on Consumer Behavior and Optimal Discounting Strategies
Minami Matsumura, Takashi Hasuike

In recent years, supermarkets have been facing concerns about labor shortages and revenue problems because of increasing labor costs and logistics costs. In the severe current competitive environment, there is a need to increase sales through optimal pricing strategies. In particular, "discounting" is one of the more effective pricing strategies because it not only temporarily increases the sales volume but also attracts customers due to the influence of the campaign. Therefore, this study discusses the optimal pricing strategy based on point-of-sale (POS) data, taking into account the negative impact of "discounting"

on consumers' purchasing behavior. The specific procedure is, using POS data, to predict consumer behavior based on the relationship between price and number of items sold, and then to seek the optimal discounting price, interval, etc. In this paper, we aim to create a more realistic model by assuming that discounting affects consumers' reference prices and using prospect theory to predict consumers' purchasing behavior. Furthermore, by optimizing strategies over the medium to long term, rather than short-term price fluctuations within a single day, we will investigate highly versatile pricing strategies that can be applied to many commodities. The proposed model is used to optimize the pricing strategy, including the discount price and the discount implementation interval.

■ WE-11

Wednesday, 16:00-17:40 - Room 11

Stochastic progamming methods and applications

Stream: Simulation, Stochastic Programming and Modeling
Invited session
Chair: *Jiangyue Gong*
Chair: *Jongheon Lee*

1 - Joint chance-constrained programs and the intersection of mixing sets through a submodularity lens

Dabeen Lee

A particularly important substructure in modeling joint linear chance-constrained programs with random right-hand sides and finite sample space is the intersection of mixing sets with common binary variables (and possibly a knapsack constraint). In this paper, we first revisit basic mixing sets by establishing a strong and previously unrecognized connection to submodularity. In particular, we show that mixing inequalities with binary variables are nothing but the polymatroid inequalities associated with a specific submodular function. This submodularity viewpoint enables us to unify and extend existing results on valid inequalities and convex hulls of the intersection of multiple mixing sets with common binary variables. Then, we study such intersections under an additional linking constraint lower bounding a linear function of the continuous variables. This is motivated by the desire to exploit the information encoded in the knapsack constraint arising in joint linear CCPs via the quantile cuts. We propose a new class of valid inequalities and characterize when this new class along with the mixing inequalities are sufficient to describe the convex hull.

2 - Approximation of a multistage stochastic programming problems by smoothed quantization

Martin Smid, *Vaclav Kozmik*

To date, no algorithm exists for solving general multistage problems with absolutely continuous Markov underlying random process. We propose a technique for approximation of such process, called smoothed quantization. At each stage, it consists of two steps. In the first step, the (conditional) distribution is approximated by its quantization, i. e. an atomic distribution with the probabilities equal to the exact (conditional) probabilities of pre-chosen regions surrounding its atoms; in the second step, the quantization is smoothed down by means of the exact unconditional distribution restricted to the regions. As a result, the dependence structure is roughly preserved and the problem is solvable by means of Markov SDDP; moreover, unconditional approximated distributions are close to those of the exact ones with the first-stage one equal to its original. To measure the accuracy of our approximation, we use the nested distance, which was specially designed for multistage stochastic programs by Pflug and Pichler (2012). We state an upper bound of the distance and we show that it converges in the one-dimensional case. Further, we discuss settings of the approximation's parameters so that the distance is kept small. We also discuss the case when the approximate problem is unbounded and propose a refinement of the approximation guaranteeing its boundedness. Finally, we apply our approximation technique to a real-life optimal production and emission trading problem.

3 - Partition-based two-stage risk-averse stochastic program

Jongheon Lee, *Kyungsik Lee*

Traditionally, a two-stage stochastic program is solved with a common finite support assumption, but the large number of scenarios makes it hard to solve and there also exists a potential risk of inaccurate estimation of the underlying distribution. In this talk, to mitigate these drawbacks, we present a partition-based two-stage risk-averse stochastic program with finite support, in which a set of scenarios is partitioned into several groups and the second stage cost function is defined as an expectation of a risk for each group. In particular, we consider a conditional value-at-risk for each group and the risk of the model can be controlled by choosing a quantile or constructing a partition. We first propose criteria and mathematical models for establishing a partition. In addition, by leveraging the fact that only a few scenarios are needed to represent the second stage cost, we propose a column-and-constraint generation based solution approach to solve the model exactly. Lastly, an adaptive partitioning scheme is proposed to do partitioning and solving in a unified scheme. We demonstrate our computational experiments to show the effectiveness of the model and efficiency of the proposed solution approach.

Wednesday, 18:00-19:40

■ WF-01

Wednesday, 18:00-19:40 - Room 1

Keynote: Mihaela van der Schaar

Stream: Keynotes
Keynote session
Chair: Wouter Verbeke

1 - Quantitative epistemology: conceiving a new human-machine partnership
Mihaela van der Schaar

Quantitative epistemology is a new and transformational area of research pioneered by our lab in Cambridge as a strand of machine learning aimed at understanding, supporting, and improving human decision-making. We are developing machine learning models that capture how humans acquire new information, how they pay attention to such information, how their beliefs may be represented, how their internal models may be structured, how these different levels of knowledge are leveraged in the form of actions, and how such knowledge is learned and updated over time. Because our approach is driven by observational data in studying knowledge as well as using machine learning methods for supporting and improving knowledge acquisition and its impact on decision-making, we call this "quantitative epistemology."

Our methods are aimed at studying human decision-making, identifying potential suboptimalities in beliefs and decision processes (such as cognitive biases, selective attention, imperfect retention of past experience, etc.), and understanding risk attitudes and their implications for learning and decision-making. This would allow us to construct decision support systems that provide humans with information pertinent to their intended actions, their possible alternatives and counterfactual outcomes, as well as other evidence to empower better decision-making.

■ WF-02

Wednesday, 18:00-19:40 - Room 2

Logistics, Transportation and Traffic 8

Stream: Logistics, Transportation and Traffic (contributed)
Contributed session
Chair: Rim Bhiri

1 - Strategic location problem for synchronized last-mile delivery with relaying drones
Kangbok Lee, Sunil Chopra, Seokwon Kim, Kyungduk Moon

The objective of this paper is to design a two-echelon distribution network for last-mile delivery with drones to minimize service time for all deliveries. We introduce a 'relaying operation' as a collaborative operation method of a truck and drones; a truck sequentially visits stations to deliver a batch of parcels for transshipment and a group of drones continually 'catch up' the station where a truck visits and deliver parcels from the station to final customers. The service time of a proposed network is reduced by strategically locating intermediate stations. For minimal service time, arrivals and departures of the two types of vehicles may be synchronized at each station. We propose a heuristic algorithm that alternately solves location problem and allocation problem. The performance of the proposed heuristic is satisfactory in solution quality and running time. We also identify the critical factor in location layout as well as service time from synchronization between the truck and the drones. Moreover, two extreme cases with fast and slow drones are theoretically modeled with ring and hexagonal layout, respectively, and their results are well-aligned with heuristic results. The estimated service time from the location decision is validated by scheduling drones with realized demand.

2 - Secondary full truck load marketplace in a physical internet environment
Claudio Szwarcfiter, Yossi Bukchin, Tal Raviv

We consider a full truck load (FTL) transportation marketplace consisting of a demand for shipments of standardized containers between a large set of terminals and a supply of occasional truck drivers who are willing to sell the service of their truck for transferring the containers between the terminals. A mediator sells transportation services between the terminals by acquiring services from the drivers and providing it to the shippers. A load can be transferred from its origin to its destination in several legs where the terminals are used as intermediate storage. This way, it is possible to provide efficient transportation between all the terminals in the network even when the supply does not match all the required origin-destination pairs. The mediator posts periodically the shipping prices to the shippers market and the transportation payments to the drivers, and later on, at the operational level, assigns containers to drivers. If the mediator is a profit maximizing firm, its objective is to maximize its revenue from the shippers net of its payments paid to the drivers and the compensations for delays. If the mediator is an authority that wishes to maximize the environmental and traffic benefits of economizing the FTL industry, its goal is to maximize the volume of the transportation services that it can provide.

3 - Parcel Delivery Using Physical Internet
Ido Orenstein, Tal Raviv

The small parcel delivery industry experiences a rapid growth, primarily driven by the growth of the e-commerce sector. We introduce a logistic model for the delivery of parcels to Service Points (SPs) that are used as drop off, pickup and intermediate storage locations. A parcel may be carried from its origin to its destination in several legs via several possible intermediate SPs. Such a system constitutes a physical internet (PI) service network. The PI is a generalization of the current practice of using a hierarchical network where the parcel can switch vehicles only in a large sorting facility (hub), and an SP is served by a single route. The PI service network topology presents an opportunity to improve the delivery process by reducing the total distance that the parcels are carried, while still exploiting the possibility of shipment consolidation. In addition, such a system may save a significant amount of resources that are associated (and tied for an extended period) with the construction and operation of a large sorting facility. In this paper, we develop tools to design and operate a successful PI for parcel delivery - a parcel routing mechanism, and a math heuristic for routing and scheduling the vehicles that transfer the parcels in the network. The efficiency of our algorithms and the advantage of the PI are demonstrated by a simulation study.

4 - A real case of improving logistic commercial process in a commercial company leaning on the SCOR model
Rim Bhiri, Bouthaina Maazoun

Due to the rapid and continuous progress, companies all over the world are restlessly competing to reach the highest levels. An important strategy to meet this goal is improving the supply chain processes. SCOR is one of the Supply Chain Operation Reference Models. In this frame, our research action is released to assimilate the delivery process of a commercial company with the SCOR Model, version 12. First, the mapping of processes were elaborated, and a specific process was deliberately selected to be the focus of this study because we came to an evidence that this very process had negative effects on the company. Then, all the data was collected and presented in a detailed flowchart. For more details, the procedure of commercial logistic process and the tasks included in each procedure were extracted. In addition, the tasks were analyzed in order to eliminate the un-useful ones, and add suitable tasks included in the SCOR model. After that, the order of the procedures was compared with the SCOR Model and reordered. The introduction of these changes had an obvious positive effect on the company. These changes were proven to be efficient since they led to minimizing the delivery deadlines indeed.

■ WF-03

Wednesday, 18:00-19:40 - Room 3

Healthcare delivery innovations

Stream: OR in Health, Medicine and Life Sciences
Invited session
Chair: *Song-Hee Kim*

1 - Optimal stopping for medical treatment with predictive information
Zhichao Zheng, Cheng Guang, Jingui Xie

Data availability and advancement in machine learning techniques make accurate prediction of the future a foreseeable reality. How to efficiently utilize the predictive information in a multistage medical decision-making environment, however, remains understudied. In this paper, we develop a discrete-time, finite-horizon Markov decision process model, incorporating perfect predictive information, to support decisions on medical treatment continuation. We extend our framework to a situation with prediction errors, using a partially observable Markov decision process. We characterize the structure of the optimal policies under both settings and show that knowing predictive information can lead to significantly different decision protocols. We calibrate and test our models with an extubation problem in an intensive care unit (ICU). Using a patient-level data set, we compare the performance of different extubation policies and demonstrate that incorporating predictive information can decrease extubation failure rate and reduce ICU length-of-stay of ventilated patients, especially for patients with poor initial conditions.

2 - The Operational Determinants of Relational Care Continuity: An Empirical Study of Primary Care in the UK
Michael Freeman, Harshita Kajaria-Montag

Problem Specification: Maintaining an ongoing relationship between a patient and provider, referred to as relational continuity (RC), is advocated as a cornerstone of primary care. While RC in primary care is known to confer many clinical and operational benefits, what remains less clear is which factors affect a primary care practice's ability to provide RC to its patients? This paper examines this question from an operations management perspective by exploring the relative importance of two operational factors that may explain variation in rates of RC between practices and over time: workload and workforce fragmentation.

Core Insight: We find that a sustained increase in workload - caused by demand growth - and increasing fragmentation of the workforce - due to a shift to part-time and agency work - causes significant heterogeneity between practices in their ability to provide RC. In fact, these factors alone can also explain more than 50% of the decline in RC over the past decade, with workforce fragmentation having a relatively greater impact than demand growth.

Practitioner Audience: This paper helps practice managers to identify the root cause of low rates of RC at their practice and the key operational levers that they can use to promote RC.

3 - A data-driven analysis of ambulance diversion regulation policies
Eric Park, Sarang Deo

We study the effect of a policy intervention intended to reduce ambulance diversions in LA County, CA. The intervention succeeded in its purpose of reducing the time EDs spent on diversion but did not reduce ambulances being diverted. A possible explanation for this outcome, identified by our empirical analysis, is a combination of the ambulance operator's imperfect compliance to the ED diversion signals and the decrease in frequency of ambulances facing EDs on diversion. We build a simulation model to investigate the efficiency of such policy intervention limiting ED time on diversion in ED networks with varying level of congestion and operator compliance to the ED diversion signals.

4 - Medication recommendations for diabetic patients using contrast-specific propensity scores
Joel Goh, Fanwen Meng, Melvin Leow, Donald Rubin

We consider the condition of dyslipidemia in diabetic patients and how physicians should choose between treatment with statins, fibrates, or non-pharmacologic interventions. We develop a new approach, based on contrast-specific propensity scores, to perform causal inference and obtain treatment recommendations.

■ WF-04

Wednesday, 18:00-19:40 - Room 4

Routing problems

Stream: Combinatorial Optimization
Invited session
Chair: *Dongqing Zhang*

1 - An application of the multi-depot heterogeneous fixed fleet open vehicle routing problem
Arild Hoff, Lars Magnus Hvattum, Ketil Danielsen

This talk presents an application of a multi-depot heterogeneous fixed fleet open vehicle routing problem. A contractor owns a fleet of vehicles with different capacities and running costs. The fleet is used to transport craftsmen from their homes to assigned project sites and back, with some of the craftsmen appointed as drivers while others are passengers. An optimization model is described that enables the contractor to minimize the transportation costs and a computational study shows that the model can be solved to optimality for realistically sized instances using a standard mixed-integer programming solver. A variant of the problem is also considered, where the assignment of craftsmen to projects is not fixed a priori. For this variant, several simple heuristic rules are investigated to generate project assignments, and computational results show that they are able to find improved assignments.

2 - The strengthening of a relaxed mixed-integer programming formulation for an arc routing problem using a graph augmentation procedure
Rafael Kendy Arakaki, Fábio Usberti

The open capacitated arc routing problem (OCARP) is a NP-hard problem aiming to find a minimum cost set of routes that service all edges demands. Each vehicle route has limited capacity. Routes are open in the sense they can start and finish at any node. Best known methods for OCARP are heuristics, but they do not provide optimality guarantees. This work presents the RF(k): a lower bounding method which can be used to assess the quality of heuristics. The RF(k) is a relaxed mixed-integer linear formulation where all routes are modeled by flows and capacity constraints are replaced by flow constraints. A parameterized graph augmenting procedure intelligently changes the graph arc set in order to improve the obtained lower bounds. We show that as parameter k increases the proposed formulation produces a better lower bound, but also becomes more computationally difficult to solve. Computational experiments reveal that our method consistently outperformed previous methods.

3 - Analytics and Machine Learning in Vehicle Routing Research
Ruibin Bai

The Vehicle Routing Problem (VRP) is one of the most intensively studied combinatorial optimisation problems for which numerous models and algorithms have been proposed. To tackle the complexities, uncertainties and dynamics involved in real-world VRP applications, Machine Learning (ML) methods have been used in combination with analytical approaches to enhance problem formulations and algorithmic performance across different problem solving scenarios. However, the relevant papers are scattered in several traditional research fields with very different, sometimes confusing, terminologies. This paper

presents a first, comprehensive review of hybrid methods that combine analytical techniques with ML tools in addressing VRP problems. Specifically, we review the emerging research streams on ML-assisted VRP modelling and ML-assisted VRP optimisation. We conclude that ML can be beneficial in enhancing VRP modelling, and improving the performance of algorithms for both online and offline VRP optimisations. Finally, challenges and future opportunities of VRP research are discussed.

4 - Optimal multi-step routing policy problem in stochastic networks with link travel time correlation
Dongqing Zhang, Zhaoxia Guo

This paper studies the problem of finding the optimal multi-step routing policies in a stochastic time-dependent network with temporally and spatially correlated link travel times. The problem needs to determine multiple road links to travel next at a road intersection, rather than the only link in traditional optimal routing policy problems. This extension not only helps the driver prepare in advance for driving operations, such as entering a left or right-turn lane, but also allows to integrate the driver's temporary travel decision into the following route. By setting the number of links to be pre-determined, this problem can be equivalent to a priori stochastic shortest path problem or a traditional optimal routing policy problem. We propose an exact algorithm to this problem based on the concept of decreasing order of time and analyse its complexity. Extensive numerical experiments using real-world link travel speed data show the effectiveness of the algorithm and the significance of pre-determining multiple road links.

■ WF-05

Wednesday, 18:00-19:40 - Room 5

Applications of metaheuristics and matheuristics

Stream: Metaheuristics
Invited session
Chair: Stelios Nikolakakis

1 - Multi-stage optimal design of subnetworks for automated vehicles with elastic multiclass demand using evolutionary metaheuristics
Bahman Madadi, Rob van Nes, Maaike Snelder, Bart van Arem

With the advent of automated vehicles (AVs), new infrastructure planning concepts such as subnetworks of AV-ready roads have been proposed to improve the performance of transportation networks and to promote the adoption of AVs. Yet these subnetworks should evolve over time in response to the growing AV demand, which necessitates a multi-stage modeling approach. In this study, we propose multi-stage deployment of AV-ready subnetworks and formulate it as a time-dependent network design problem, which is a bi-level mix-integer programming problem. The lower level is a simultaneous travel mode and route choice equilibrium with continuous decision variables and the upper level is a design problem including infrastructure decisions. The multi-stage approach is relevant for the transition period to full automation with a heterogeneous mix of vehicles of different automation levels. We use a case study of a real road network to demonstrate the concept. Since efficiency is a key factor for solving such large-scale problems, we develop two efficient tailored evolutionary metaheuristic algorithms to solve the problem, and compare their performance to a Genetic-algorithm-based solution. The results indicate that the proposed algorithms can efficiently solve the large-scale problem while satisfying constraints in all scenarios, and outperform Genetic algorithm with increasing number of time periods.

2 - A parallel genetic algorithm for strategic mine planning
Carlos Rey, Felipe Navarro, Nelson Morales, Carlos Contreras-Bolton, Víctor Parada

Strategic open-pit planning requires the definition of operational volumes (phases) and their scheduling for extraction over the lifetime of the mine, subject to pit-wall slope, capacity, and blending constraints. Most of the literature approaches the scheduling part, modeling it as mathematical models and developing specialized algorithms to solve them efficiently. However, the definition of phases has remained a poorly studied subject, addressed manually or indirectly through simplified models. This is paradoxical because phase definitions involve constructions that are final or very expensive to correct, while schedules could be adapted later depending on the circumstances and mine evolution. This work focuses on the phase definition problem, optimizing the phase definition while simplifying the scheduling aspects. For this, we develop a parallel genetic algorithm (PGA) based on the master-slave approach and apply it to well-known instances from the literature to show that it can find good solutions if compared to previously known results for these instances.

3 - A matheuristic algorithm for maritime inventory routing problem
Homayoun Shaabani, Arild Hoff, Lars Magnus Hvattum, Gilbert Laporte

Transportation and inventory management are two main components of the supply chain that will be more effective whenever they are performed in a coordinated manner. The inventory routing problem (IRP) is a complex logistic problem integrating inventory management and vehicle routing decisions in a way that a supplier delivers products to several customers subject to specified constraints. One of the most applicable modes of transportation is maritime transport, and when maritime vessels are responsible for transportation in an IRP then it becomes a maritime IRP (MIRP).

There are significant differences between IRP and MIRP. For example, in MIRP, each vessel will visit only a few ports, but in the classical IRP, each vehicle will normally visit a larger number of customers. Therefore, in the classical IRP, the demand of each customer is considerably smaller than the vehicle capacity, while in MIRP the loading or unloading quantity in each port includes a larger portion of the vessel capacity.

An efficient solution approach for large-sized instances of MIRP is required when looking at literature review of this field. Hence, we are going to present a matheuristic algorithm for MIRP which integrates a metaheuristic with mathematical programming.

4 - A biologically inspired meta-heuristic for solving large-scale production routing problems
Stelios Nikolakakis, Pantelis Lappas, Manolis Kritikos

The solution of the production routing problem aims at integrating and coordinating different supply chain activities (i.e., production management, inventory allocation and routing) within the supply chain network so as to minimize total supply chain costs. Due to the NP-hard nature of the problem, a biologically inspired and population based metaheuristic algorithm is proposed to obtain near-optimal feasible solutions. In particular, an evolutionary learning process has been designed for solving the problem based on sophisticated and novel population initialization and mutation methods. The proposed solution algorithm will be evaluated against well-known datasets to verify its effectiveness and convey meaningful insights into the production routing problem.

■ WF-06

Wednesday, 18:00-19:40 - Room 6

OR in Health, Medicine and Life Sciences 4

Stream: OR in Health, Medicine and Life Sciences (con-

tributed)
Contributed session
Chair: Isabel Mendez Fernandez

1 - Surgery department operating room management: a case study in a small hospital in Naples
Andrea Mancuso, Adriano Masone, Francesco Messina, Mara Morra, Antonio Sforza, Claudio Sterle

OR methodologies represent a valuable support tool for policy makers and healthcare providers in hospital activity planning and decision making. This work presents the first results of a research agreement between Department of Electrical Engineering and Information Technology of University 'Federico II' of Naples and the 'Betania Evangelical Hospital (BEH)'. The work is focused on the application of OR methodologies to support the BEH logistic processes, with particular reference to the management of the surgery department operating rooms. Given the BEH surgery department comprising several specialities which share a given number of operating rooms, we tackle the problem of determining the assignment of rooms and dates to a set of elective patients over a planning horizon and, simultaneously, defining the scheduling of the surgeries of each day and room. The problem is modelled by an ILP formulation derived from literature, taking into account different objective functions dealing with patient throughput and emergency, surgery complexity and postponements and personnel exploitation. The proposed formulation has been tested on several instance scenarios derived from real data provided by the hospital. Moreover, different speciality-to-room assignment policies have been analysed to provide useful managerial insights for effective usage of the hospital resources.

2 - Modular Dispatching and Redeployment System for Emergency Medical Services
Gaby Joe Hannoun, Monica Menendez

While advancements in vehicular and wireless communication technologies are shaping the future of our transportation system, emergency medical services (EMS) are not receiving enough research attention. Their operations are still plagued by response delays that can often be life-threatening. Dispatching and redeployment systems identify the best practices for the allocation of the resources to emergencies and stations. The existing systems are unfortunately insufficient and there is a growing need to embrace new technological solutions. This research introduces a smart system for EMS by leveraging the modular vehicular technology initially developed for transit systems. The system relies on the design of vehicular modules that can couple and decouple to transfer patients from a module to another during transport. A fleet of medical transport vehicles is deployed to cooperate with the life support vehicles by providing transport and hospital discharge tasks, thus allowing the life support vehicles to answer pending emergency requests earlier. We introduce a framework with an embedded optimization that generates the dispatching, redeployment and transfer decisions for an efficient real-time implementation of the system. The dynamic aspect of the real-world and the high level of uncertainty linked to the arrival of emergency requests are considered to better assess the applicability and benefits of this technology to EMS, in terms of response time and arrival time to hospitals.

3 - An Equitable Vaccine Allocation Problem
Ecem Yücesoy, Berna Akça, Sırma Karakaya, Asena Ayse Gevsek, Burcu Balcik

The world's struggle with the Covid-19 pandemic has been going on for more than a year. The countries face significant challenges to employ the available vaccines effectively. We address a vaccine allocation problem, in which a scarce amount of vaccines must be equitably allocated among different priority groups and geographical areas in a country. We present different allocation policies and a case study to compare the performance of each policy. The study is supported by the CONTRA project, which is funded by the Research Council of Norway.

4 - A home care routing and scheduling problem
Isabel Mendez Fernandez, Silvia Lorenzo-Freire, Ángel Manuel González Rueda

In this work we present a routing and scheduling problem for a home care business. The company has a set of caregivers who are in charge carrying out the users' services, and the goal of this problem is to obtain the best schedules for the caregivers. To do this we need to consider the users' soft and hard time windows, the affinity levels between caregivers and users, the caregivers hard time windows, their accorded working time and their maximum allowed working time. The problem has two different objectives: the users' welfare (that consists on the affinity and the penalization for carrying out services outside their soft time windows) and the schedules' cost (that is composed of the caregivers' overtime and their scheduled working time). These are conflicting objectives, because usually improving one of them results in the worsening of the other, and result in two strategies: one that prioritizes the cost (which the company uses when they start working in a new area) and another one that prioritizes the welfare (which the company uses when they are is already attending the users). To solve the problem, we propose a heuristic algorithm that combines the Adaptive Large Neighbourhood Search method, which is used to modify the routes, with two scheduling strategies, one for each of the aforementioned strategies.

■ WF-07

Wednesday, 18:00-19:40 - Room 7

Optimization in transportation and location

Stream: Innovative & Shared Mobility and Transportation
Invited session
Chair: Alp Arslan

1 - Capacity sharing between competing bicycle-sharing firms
Ziliang Jin, Wenxin Xu, Kai Pan

In this paper, we propose a capacity-sharing scheme for two competing bicycle-sharing firms to improve the profitability in the bicycle-sharing industry. We employ two-stage stochastic mixed integer linear programming models to study the interactions between the firms. Taking account of demand uncertainty and consumer behavior, our results show the effectiveness of the sharing scheme, and provide managerial insight. (The project is based on work supported by University Grants Commitee under General Research Fund)

2 - Distributionally robust drone deployment model and algorithms
Yuli Zhang, Xidong Liang, Yue Tian

The locations of drone depots are essential in the drone-based delivery system. This paper presents a two-stage distributionally robust drone deployment model when only conditional marginal probability distributions of demands are known. To handle the difficulty due to the second-stage binary knapsack problem, an approximation method is proposed by exploiting the submodularity of the relaxed second-stage problem.

3 - Branch and cut algorithm for hub location problems with uncertain setup cost and commodity demand
Yuan Gao

In this paper, we study a robust counterpart for uncapacitated hub location problems, in which the hub setup cost and commodity demand are both uncertain. We fomulate a mixed integer programming model with controlable conservatism level. A benders decomposition algorithm is integerated into a branch and bound framework to solve the model. Some properties of the model are analyzed, and then several skills are employed to speed up the branch and cut algorithm. Computational results illustrate the effectiveness and efficiency of the model and algorithm.

4 - Dynamic Driver Steering Problem in On-demand Meal Delivery Systems
Alp Arslan, Yousef Maknoon, Shadi Sharif Azadeh

One of the main challenges of on-demand meal delivery systems is to provide an on-time fulfillment service while using their delivery resources efficiently, particularly if the drivers are paid per hour. In case the platform has a predetermined capacity of the delivery resource, the dynamic capacity resizing against spatial and temporal demand variations throughout the day is not possible. Therefore, in this study, we investigate the impact of dynamic driver steering, where drivers can be repositioned with respect to future order arrivals. In particular, we propose a mechanism that governs the order-driver assignment decisions by driver relocations. We test our approach on several European cities using historical data of our industry partner. The results reveal that the dynamic driver steering framework increases on-time meal deliveries and decreases the mean order-to-delivery time, duration between order placement and order delivery.

■ WF-08

Wednesday, 18:00-19:40 - Room 8

Continuous Optimization 2

Stream: Continuous Optimization (contributed)
Contributed session
Chair: Lorenz Roebers

1 - An exact method for mixed-integer convex max-min programs
Suyog Nigudkar, Sachin Jayaswal, Ankur Sinha

Bi-level problems are a challenging class of problems, which is NP-Hard even for the simplest case in which the problems at both the levels are linear programs. In this work, we propose an exact approach to solve a difficult class of bi-level optimization problems. We study a mixed-integer max-min (bilevel) problem with a non-linear objective function and linear constraints. The variables at both the levels take integer values. Such a problem arises in the context of interdiction or in robust formulations of non-linear problems. The non-linearity in the objective function can arise due to congestion in the network post-interdiction of facilities or due to an inherent non-linear cost structure. The proposed solution approach is based on generating valid upper bounds and lower bounds to the original problem, and iteratively improving the bounds to converge to the global optimal. We obtain an upper bound using ideas from the X-Space algorithm (Tang. et al., 2016), and inner approximation to relax the original problem (X refers to the lower-level variables). New points are added on the fly by solving the lower bound problem, which gives a bi-level feasible solution to the problem. We apply our proposed algorithm to solve two application problems: (i) a quadratic capacitated facility interdiction problem for a single allocation case and (ii) a non-linear knapsack interdiction problem.

2 - A procedure of listing FJ points for a fractional programming problem
Syuuji Yamada

In this study, we consider a quadratic fractional programming problem (QFP) to minimize the ratio of two quadratic convex functions over a convex set defined by quadratic convex functions. It is known that fractional programming is one of the typical problems in Global Optimization. Several types of iterative methods for solving (QFP) have been proposed by many researchers. However, such algorithms are not effective in the case where the dimension of variables is so large. One of the difficulties in solving (QFP) is the complexity of the objective function. Hence, in order to overcome this drawback, we transform (QFP) into a quadratic reverse convex programing problem (QRC) minimizing a linear function over the area excluded the interior of a convex set from another convex set. Moreover, to find an approximate solution of (QRC), we introduce an algorithm for listing FJ (Fritz-John) points of (QRC). Since every locally optimal solution of (QRC) satisfies FJ conditions, we can calculate most of locally optimal solutions contained in the intersection of the boundaries of convex sets defining the feasible set by utilizing our algorithm. Furthermore, to improve calculation efficiency, we incorporate our algorithm into a branch-and-bound procedure for Lagrange multipliers of constraint functions. The proposed algorithm can calculate an approximate solution of large scale (QFP). The effectiveness of the proposed algorithm has been shown by the result of the computer experiment.

3 - On linear systems containing strict inequalities
José Vicente-Pérez, Margarita Rodríguez Álvarez

Firstly, we deal with linear systems containing finitely many weak and/or strict inequalities, whose solution sets are referred to as evenly convex polyhedral sets. The classical Motzkin theorem states that every (closed and convex) polyhedron is the Minkowski sum of a convex hull of finitely many points and a finitely generated cone. In this sense, similar representations for evenly convex polyhedra have been recently given in the literature by employing the standard version for classical polyhedra. We introduce a new dual cone that completely characterizes finite linear systems containing strict inequalities and it constitutes the key for obtaining a generalization of Motzkin theorem for evenly convex polyhedra. Secondly, we analyze whether our new dual tool can be applied to linear systems with infinitely many inequalities. The answer is positive and not surprising, as we characterize the nonemptiness of the set of stong Slater points of a given linear system, being this property fulfilled by finite linear systems.

4 - Non-SOS Putinar-like certificates of non-negativity: full and sparse
Lorenz Roebers, Juan Vera, Luis Zuluaga

Certificates of non-negativity such as Putinar's Positivstellensatz are a powerful tool for polynomial optimization. We propose a general approach for obtaining certificates of non-negativity. While most of the literature on structured certificates of non-negativity has concentrated on Sum-of-squares (SOS)-based certificates, we propose a general framework that allows one to construct certificates of non-negativity based on any class of non-negative polynomials satisfying some mild assumptions. In addition to classic certificates of non-negativity, this framework can be used for obtaining sparse certificates of non-negativity. For instance, we construct both full and sparse certificates based on SDSOS-, SAGE-, SONC- and SOS-polynomials.

Sparse certificates are often much more efficient to compute than the classic certificates of non-negativity, and we expect our work to close the gap between the applicability of SOS-based and other types of certificates.

■ WF-09

Wednesday, 18:00-19:40 - Room 9

Situational awareness for emergency management

Stream: Human Behavior in Disaster and Humanitarian Operations Management
Invited session
Chair: Chul Yoo
Chair: Sue Merchant

1 - Reconsideration of Complexity Management in Viable Systems: A Complexity Classification Model for Rapid Decision-making During Emergencies
Ayham Fattoum

Within soft OR, the Viable System Model (VSM) uses variety to measure and manage complexity. Research on the effectiveness of variety in addressing complexity and rapid decision-making during emergencies is rare. The interchangeable use of complexity and variety in the literature may suggest theoretical and practical confusion. The paper addresses the gaps and proposes operationally-useful definitions of complexity and variety - complexity being the actual and experienced states and variety being the potential (all possible) states. Also, the paper proposes a novel model that enables rapid decision-making during emergencies through prioritising and classifying complexity according to its impact on operations, association with the organisation, and magnitude. The model emerged from the analysis of qualitative data collected form a multi-agency emergency response system in the UK. The data was collected from meetings, workshops, interviews; and from observing a live drill that simulated a response to a disaster. The paper contributes to the theory and practice of VSM by enhancing its effectiveness in complexity management and rapid decision-making during emergencies.

2 - Exploring Millennials' Trust of Twitter as Disaster Early Warning System through Causal Loop Diagrams
Hilya Mudrika Arini, Fina Ananda

Early warning system (EWS) is essentially utilised in disaster management to minimise the number of causalities. To enhance the effectiveness of EWS, currently, social media platform, such as twitter, is commonly used by the government to share and update the real time status of natural disaster particularly for millennials generation, i.e. the generation who was born from 1983 to 1998. Accordingly, this study aims to explore millennials' trust of twitter as EWS using a conceptual model in system dynamics, namely causal loop diagram (CLD). There are 10 millennials consisting of five active users and five passive users of twitter who participate in this study. First, each participant is interviewed about (1) their perception of twitter as social media, (2) their understanding of EWS, (3) the factor affecting their trust to information in twitter, and (4) their trust of twitter as EWS. From this interview, the two initial CLDs are constructed and verified using focus group discussion (FGD). This study concludes that there are two different empirically verified CLDs exploring millennials' trust of twitter as EWS from the passive and active users. However, for active users, it is found that more factors, such as (1) the number of likes, (2) the probability of hoax information, and (3) the number of pop-up notifications, can affect them to trust to twitter as EWS than passive users.

3 - The Affect of Covid-19 Pandemic on the University Preferences of Applicants in Turkey
Önder Tombuş, Abbas Dündar, Ayşe Cilacı Tombuş

The University Education in Turkey is regulated by Council of Higher Education (YÖK) and applicants are placed according to a Central Selection and Placement Exam. More than 2 million candidates applied for the central exam and more than 600000 students have been placed to different universities in 81 cities. In this study we have examined how Covid-19 pandemic has affected the city preferences of students who have been placed. We examined the statistical data of more than 10000 different programs. The home city of the students who have been accepted to a program was analyzed and it was compared with the city preferences of students in previous years to estimate the affect of Covid-19 Pandemic on the mobility preferences of year 2020 applicants.

4 - Celebrating the international impact of OR/Analytics !
Sue Merchant

OR started life as a very practical discipline, having great impact in military applications initially, before spreading rapidly into government, industry and beyond. Today implemented OR/Analytics studies continue to be much in evidence across the world 'Saving lives, saving money, solving problems' (as INFORMS has recently described OR's impact). Indeed, every quarter IFORS News is delighted to be able to publish its Impact column containing a description of a piece of excellent implemented OR work. This talk will describe briefly a small selection of these studies from across the world to help showcase the value and breadth of OR work in recent years.

■ WF-10

Wednesday, 18:00-19:40 - Room 10

Mathematical models in macro- and microeconomics 1

Stream: Mathematical Models in Macro- and Microeconomics
Invited session
Chair: Gerhard-Wilhelm Weber

1 - The Owen-Shapley spatial power index with non symmetric issues
M. Josune Albizuri, Alex Goikoetxea

The Owen-Shapley spatial power index is introduced by Owen and Shapley(1989). This index is defined for simple games. It is supposed that there are several criteria to describe players, and each player is described by one point in the space. The set of players forms a constellation, a vector whose components are the locations of the players. In this setting we have spatial games, that is, simple games joint with the constellations formed by the players. And we have spatial power indices, that is, functions that give the power of the players for each simple game depending on the constellation formed by the players. The Owen-Shapley spatial power index is defined assuming that the issues for the players are represented by the unit vectors in the space, and that these issues are equally likely. More precisely, the Owen-Shapley spatial power index of a player is the probability that the player is pivotal at an issue, being all the issues equally likely. In this work we consider the case in which not all the issues are equally likely. We obtain the resulting family of power indices that measure power in all possible circumstances. Moreover, we are able to determine a set of axioms that gives this family of spatial power indices. Peters and Zarzuelo (2017) give a characterization for the original Owen-Shapley spatial power index, when all the issues are equally likely. We employ some axioms introduced by them and new ones in order to obtain the entire family.

2 - Using interval informing and selective bargaining to gain back the trust of bidders in order to optimize auction prices
Elif Ilgaz Cevik, H.Kutay Tinç

This paper concentrates on a particular case of auction optimization. The study was done on the buying auctions of one of the biggest telecommunication oligopolies of Turkey, in which bidders have lost trust to the current auctioning system due to the further bargaining processes taking place after most auctions. This loss of trust has resulted in unrealistic bids where the service providers prefer to wait for the bargaining part to make their real bids so as to hide it from their competitors. To achieve more advantageous results for the company from their auctions, we have suggested a change for the bidding process and another one for the post-bidding part. We introduce a new bidding method to encourage more aggressive bidding free from worries of other bidders' knowing one's exact bid, called interval informing, and discuss its advantages and limitations based on our auctions in question. Introducing another method for post-bidding to promote bidders' becoming more competitive by breaking the false belief of a bargain taking place with whichever bidder the company wishes, called selective bargaining, we observe how changing the company's current post-bidding approach affects the actual bidding process and outcomes.We reflect on our results and finalise with the decision of how the current system of auctioning in the company is to be changed based on our research.

3 - On the optimal development of the transmission system of the energy market
Olesya Grigoreva, Alexander Vasin

A dynamic model for the development of the transport network of the energy market in a given planning interval is proposed. A method for solving the problem of optimizing public welfare, reducing it to a finite set of auxiliary problems of convex programming, is specified. An auxiliary problem is considered with a fixed vector of line expansion indicators, which determines the line expansion schedule. It is shown that this problem is a special case of the well-known optimal control problem with discrete time with linear dynamics. For the initial dynamic problem, if the functions of the variable costs of the extension are independent of time, and discounting is not essential, then, for every expanding line, all extensions must be done in the initial periods of the planning interval. If, in addition, the functions of variable costs are linear, then all extensions are made in the first period of time. In this case, the dynamic problem is reduced to the static one. In general the demand functions endogenously depend on the previous development of the transmission system. The corresponding model is also considered. Finally, special features of modern electricity markets are considered, and the task of optimal network development for the wholesale market is formulated taking into account these features.

■ WF-11

Wednesday, 18:00-19:40 - Room 11

Problem Structuring Methods, Behaviour and Society

Stream: Behavioral OR
Invited session
Chair: *Leroy White*
Chair: *Violina Sarma*

1 - The Construction of Wicked Problems
Mike Yearworth, Leroy White

The use of Problem Structuring Methods (PSMs) to address wicked problems (Rittel and Webber, Churchman), messes (Ackoff), swamps (Rosenhead), in a plural/complex context (Jackson) tends to go without question within the OR community. However, what other methodologies exist in sources outside the systems/PSM/Soft OR corpus that address the same type of problems and what might this say about their nature? We approach this question through the use of citation analysis and present some details of alternative methodological approaches from different traditions. At the very least these suggest promising avenues for conversations to share experience by scholars and practitioners alike but also to prompt a re-evaluation of the scope of applicability of PSMs.

2 - Managerial inputs in forecast planning and decision-making
Violina Sarma, Emrah Demir, Anthony Beresford

Forecasting and planning form a crucial part of business decision-making. As different departments are involved in this process, managerial inputs can contrast and conflict with each other. To explore this topic of hierarchical forecasting, 6 cases from diverse industries and sector are selected. SWOTs of four themes: information sharing, time pressure, power and social value are generated and tested. AHP and ELECTRE is used to carry out multi-attribute decision analysis of managerial inputs on those themes. Results discuss findings across cases, sectors and distinct participant categories.

Wednesday, 22:00-23:00

■ WG-01

Wednesday, 22:00-23:00 - Room 1

IFORS History and Beyond

Stream: IFORS Sessions
Invited session
Chair: *Chang Won Lee*

1 - IFORS History and Beyond
"David" Chang Won Lee, Nelson Maculan, Sue Merchant, Michael Trick, Janny Leung

This session presents previous IFORS activities and more by Nelson Maculan, Sue Merchant, Michael Trick, and Janny Leung as well as some invited discussants. This session is open to all.

Thursday, 8:00-9:40

■ HA-01

Thursday, 8:00-9:40 - Room 1

Keynote: Erin Baker

Stream: Keynotes
Keynote session
Chair: Karla Hoffman

1 - Robust Portfolio Decision Analysis: Finding Common Ground When Experts and Models Disagree
Erin Baker

Inspired by challenges in designing energy technology policy in the face of climate change, we address the problem of decision making under "deep uncertainty." We focus on situations in which plausible beliefs and models exist, but are in disagreement, and illustrate how to find common ground in such cases. We introduce an approach we call Robust Portfolio Decision Analysis, building on Belief Dominance as a prescriptive operationalization of a concept that has appeared in the literature under a number of names. The Belief Dominance concept synthesizes multiple conflicting sources of information to uncover alternatives that are intelligent responses in the presence of many beliefs or models. We use this concept to determine the set of non-dominated portfolios and to identify corresponding robust individual alternatives, thereby uncovering viable alternatives that may not be revealed otherwise. Our approach is particularly appropriate with multiple stakeholders, as it helps identify common ground while leaving flexibility for negotiation. We develop a proof-of-concept application aimed at informing decisions over investments into clean energy technology R&D portfolios in the context of climate change. Using multiple large scale expert elicitation studies and multiple Integrated Assessment Models, we illustrate how Robust Portfolio Decision Analysis helps identify robust investments into individual technologies.

■ HA-02

Thursday, 8:00-9:40 - Room 2

Interior-Point Methods for Linear Programming

Stream: Continuous Optimization
Invited session
Chair: Aurelio Oliveira
Chair: *Jordi Castro*

1 - Stable system for Quadratic Programming.
Maria Gonzalez-Lima, Aurelio Oliveira, Danilo Oliveira

How to solve the linear systems that arise when using primal-dual interior point methods for solving optimization problems has been an issue of study since many decades ago. This is particularly important when dealing with large scale problems. Most approaches decompose the original linear system in smaller ones but ill-condition is usually added during this process. Even though this bad condition can be handled, the exactaness of the solution is always affected. Oliveira, Gonzalez-Lima, and Oliveira (COAP, 2013) introduced a way to solve the systems arising in Linear Programming by forming the so-called Stable system such that the solution of the optimization problem is very precise and the computational cost compites with classical approaches. In this talk we present an extension of the Stable system to Quadratic Programming and show preliminar numerical results about its performance.

2 - A new hybrid preconditioner for interior point methods
Aurelio Oliveira, Cecilia O. Castro, Manolo Heredia

This study concerns a hybrid approach that combines the Controlled Cholesky Factorization preconditioner and the Splitting preconditioner. This approach has shown good results. Some modifications are proposed in order to improve the performance of the hybrid preconditioner. In the Controlled Cholesky Factorization, the parameters that control the filling and the correction of diagonal faults are modified. It considers the relationship between the components from Controlled Cholesky Factorization obtained before and after the fault on the diagonal. In the Splitting preconditioner, in its turn, a sparse base is constructed through an appropriate ordering of the columns from constrained matrix optimization problem. In addition, a theoretical result is presented, which shows that, with the proposed ordering, the condition number of the preconditioned Normal Equation matrix with the Splitting preconditioner is uniformly limited by an amount that depends only on the original data of the problem and not on the iteration of the Interior Point Method. Numerical experiments with large scale problems, corroborate the robustness and computational efficiency from this approach.

3 - Implementation of interior-point methods for LP based on Krylov subspace iterative solvers with inner-iteration preconditioning
Ken Hayami, Yiran Cui, Takashi Tsuchiya, Keiichi Morikuni

We apply novel inner-iteration preconditioned Krylov subspace methods to the interior-point algorithm for linear programming (LP). Inner-iteration preconditioners recently proposed by Morikuni and Hayami enable us to overcome the severe ill-conditioning of linear equations solved in the final phase of interior-point iterations. The Krylov subspace methods do not suffer from rank-deficiency and therefore no preprocessing is necessary even if rows of the constraint matrix are not linearly independent. By means of these methods, a new interior-point recurrence is proposed in order to omit one matrix-vector product at each step. Extensive numerical experiments are conducted over diverse instances of 140 LP problems including the Netlib, QAPLIB, Mittelmann and Atomizer Basis Pursuit collections. The largest problem has 434,580 unknowns. It turns out that our implementation is more robust than the standard public domain solvers SeDuMi (Self-Dual Minimization), SDPT3 (Semidefinite Programming Toh-Todd-Tütüncü) and the LSMR iterative solver in PDCO (Primal-Dual Barrier Method for Convex Objectives) without increasing CPU time. The proposed interior-point method based on iterative solvers succeeds in solving a fairly large number of LP instances from benchmark libraries under the standard stopping criteria. The work also presents a fairly extensive benchmark test for several renowned solvers including direct and iterative solvers.

4 - A New Weight Reduction Algorithm for Linear Programming
Jair Da Silva, Carla Ghidini, Aurelio Oliveira

In this work, we present a new method for solving linear programming problems, which is a generalization of the Weight Reduction Algorithm proposed in the literature. Both methods are developed based on von Neumann's Algorithm (VNA) and inherit its main features, which are simplicity, iterations with low computational cost and fast initial convergence rate. On the other hand, VNA has the disadvantage of a slow convergence when solving certain linear programming problems. Thus, the Weight Reduction Algorithm is developed with the aim of improving the convergence, while maintaining the advantages of the VNA. In order to further improve the efficiency of these algorithms, we developed the Weight Reduction Algorithm for p Coordinates, which considers p variables of the problem to determine the direction in which the residue will be moved to approximate the origin. The results of the computational experiments performed with free access problems have shown that the proposed approach performs better than the known ones. Despite the improvements in relation to the Weight Reduction Algorithm, the new method is not practical to solve linear programming problems up to optimality. However, this method can be useful to work in combination with interior point methods, using its initial fast convergence rate. The next steps in this research are to measure the impact that this new method can have in this direction.

■ HA-03

Thursday, 8:00-9:40 - Room 3

Financial mathematics and OR 3

Stream: Financial Mathematics and OR
Invited session
Chair: Gerhard-Wilhelm Weber
Chair: *Lingfei Li*

1 - A two-step framework for arbitrage-free prediction of the implied volatility surface
Wenyong Zhang, *Lingfei Li*

We propose a two-step framework for predicting the implied volatility surface over time without static arbitrage. In the first step, we select features to represent the surface and predict them over time. In the second step, we use the predicted features to construct the implied volatility surface using a deep neural network (DNN) model by incorporating constraints that prevent static arbitrage. We consider three feature extraction methods: principal component analysis, variational autoencoder and sampling the surface, and we predict these features using LSTM. Using a long time series of implied volatility data for SP500 index options to train our models, we find that sampling the surface with DNN for surface construction achieves the smallest error in out-of-sample prediction. Furthermore, the DNN model for surface construction not only removes static arbitrage, but also significantly reduces the prediction error compared with a standard interpolation method.

2 - A General Approach for Parisian Stopping Times under Markov Processes
Gongqiu Zhang, *Lingfei Li*

We propose a method based on continuous time Markov chain approximation to compute the distribution of Parisian stopping times and price Parisian options under general one-dimensional Markov processes. We prove the convergence of the method under a general setting and obtain sharp estimate of the convergence rate for diffusion models. Our theoretical analysis reveals how to design the grid of the CTMC to achieve faster convergence. Numerical experiments are conducted to demonstrate the accuracy and efficiency of our method for both diffusion and jump models. Our method can solve a range of Parisian problems and we develop extensions for multi-sided Parisian stopping times, the joint distribution of Parisian stopping times and first passage times, Parisian bonds and for more complex models like regime-switching and stochastic volatility models.

3 - Re-discovery of the 1/N portfolio from a new perspective based on the euclidean distance
Soonbong Lee, *Hongseon Kim*, *Seongmoon Kim*

Applying portfolio selection models to practical investment is not likely to result in an optimal portfolio due to the estimation error of input parameters. Previous studies have presented various portfolio selection models to reduce the effects of the estimation error, but most models have not indicated better investment performance than the 1/N portfolio. This study newly illuminates the 1/N portfolio's superiority through the Euclidean distance, a new portfolio evaluation measure defined as the vector distance between any evaluated portfolio and the in-sample tangency portfolio, the latter of which is defined as an optimal reference portfolio. If the Euclidean distance is smaller, the portfolio is evaluated as closer to the in-sample tangency portfolio. First, this study theoretically proves that the diversification strategy of the 1/N portfolio decreases the upper limit of the Euclidean distance. Second, a simulation is performed to verify that the portfolio with a small Euclidean distance achieves a high and stable Sharpe ratio. Third, this study empirically compares the 1/N portfolio and five representative portfolio selection models in terms of performance measures related with returns and the Euclidean distance. The results indicate that the investment performance of the 1/N portfolio can be as comparable as that of the other portfolio models possibly due to the superiority of its Euclidean distance.

■ HA-04

Thursday, 8:00-9:40 - Room 4

Urban operations research I

Stream: Discrete Optimization and Urban Operations Research
Invited session
Chair: Hidetoshi Miura
Chair: *Yu Song*

1 - Simulation of allocation of community salon participants: proximity and self-stigma
Hongjik Kim, *Hiroyuki Usui*, *Yasushi Asami*, *Kimihiro Hino*

Community salons are places where older adults receive preventive healthcare and enjoy recreational activities. Some older adults hesitate to participate and opt for engaging in activities at facilities farther away because they do not want to be seen by their neighbors as being elderly who need support from others. The phenomenon can be conceptualized as self-stigma of community salon participation. Allocation of participants to achieve a smaller number of neighbors meeting at the same facility within shorter distance can be a solution to make it easy for people with self-stigma to attend activities at community salons. We propose an allocation problem considering both proximity and self-stigma, and test which geographical settings of facilities and residents bring more participation or more intergroup contact between those with and without self-stigma. Results from the simulation in a virtual city environment show that there could be a segregation of activity groups between people with and without self-stigma. From a comparison among solutions from different geographical settings of residents and facilities, a larger number of participants with self-stigma is expected especially in the case of concentrated residential location. On the other hand, the concentrated facility location has been found to be the geographical setting for more intergroup contact. The findings suggest that both proximity and self-stigma have to be considered for more social benefits.

2 - Mathematical analysis of renovation in the conservation of historic buildings
Kaori Isawa, *Hiroko Watanabe*, *Daisuke Hasegawa*, *Yudai Honma*

In post-war Japan, rapid changes in lifestyles due to the separation of jobs and housing, motorization, and other factors have led to urban development prioritizing economic activities. As a result, the uniform townscape has led to the loss of the region's unique culture and given negative impacts on resident consciousness, such as weakening of place attachment. Against this backdrop, the importance of architectural conservation has been recognized. On the other hand, it is known that the architectural conservation described above is extremely hard due to the trait of urban development. Architecture built after the 20th century has such a trend firmly because those have not been subject to Cultural property Administration in Japan. However, the method to avoid conflicting between architectural conservation and economy has not been systematized. In this study, we focus on the optimal policy for architectural conservation. Primarily, we consider the trade-off relationship between costs and revenues. Based on both a theoretical model and actual data survey, we clarify the essential characteristics of how the owner tends to renovate their buildings. The actual data used in this study were chosen based on two rules: 1) Subject sites are municipalities that have their own architectural conservation regulations, rules, guidelines, and more. 2) Subject properties are buildings that were conserved by the regulations and more.

3 - An Optimization Model for Class Re-organization Problem in Elementary Schools
Thitiwat Ruangsakorn, Yu Song

In Japanese elementary schools, classes are re-organized every new school year. In the process of re-organization, teachers are required to consider various factors, such as students' study scores, sports ability, musical talent, leadership, for the balance among the new classes. Currently, the operation is conducted manually, and it is a time-consuming task for teachers to calculating different combinations and making proposals every year. In order to save teacher's labor, this study proposes a formulation of the class re-assignment problem as a mathematical model and solves the mathematical model using Python and Gurobi optimizer. Numerical tests show the model provides satisfactory solutions. Since it is unrealistic for elementary school teachers to operate such a Python program, we are also designing a web application using Python as a background engine. Teachers may access the website, update students' data, and complete the re-organization work of their schools.

4 - Comparison of location strategies for competing franchise chains based on maximizing flow-capture
Hidetoshi Miura

This work considers a situation in which two competing franchise chains alternately determines location of stores on a linear city model. In each period, the decision-making chain determines the location of a new store in order to maximize flow-capture. We assume a linear segment as a city model and generation of flows coming from origins and going to destinations in the city. It is also assumed that flows stop and buy something only at the first store along the paths. Opening new stores by competing franchise chains starts from the initial state with no stores in the city model. We compare and investigate four location strategies for locating new stores: (1) maximization of franchise chain's own flow-capture, (2) maximization of new store's flow-capture, (3) minimization of competitor chain's flow-capture, (4) minimization of preceding competitor store's flow-capture. For all combinations of pairs of franchise chain's strategies, through numerical experiments of opening sixteen stores (each franchise chain opens eight stores), it became clear that the third strategy can catch the most flow-capture.

■ HA-05

Thursday, 8:00-9:40 - Room 5

Combinatorial Optimization 2

Stream: Combinatorial Optimization
Invited session
Chair: Liang Chen

1 - Encoding constraint satisfaction problems as QUBO
Philippe Codognet

The framework of QUBO (Quadratic Unconstrained Binary Optimization) has recently attracted much attention for formalizing combinatorial optimization problems, as QUBO problems are well-suited as input for Quantum Adiabatic Computation and Quantum Annealing, including machines such as the D-Wave or Fujitsu's Digital Annealer.

We propose to express in QUBO several Constraint Solving Problems (CSP), which have been shown to be very difficult to solve in practice by classical CSP techniques. This work builds on previous endeavors where CSP solving was reduced to the minimization of a global function and optimization was performed by local search techniques. Each constraint of the original problem can be expressed as a penalty function, and the (weighted) sum of all penalty functions (one for each constraint) will generate a global function to minimize. The CSP is then solvable if and only if the objective function can be minimized down to zero.

We consider CSPs such as the Magic Square problem (place numbers from 1 to NxN on NxN grid such that all lines, columns and diagonals add up to the same value) and the Costas Array problem (place N marks on a NxN grid such that there is exactly one mark per row and per column and all vectors joining the marks are different). These problems have been shown to be very difficult to solve even with a limited number of variables. (e.g. the existence of a solution for the Costas Array problem of size 32 is still unknown).

2 - Characterization of QUBO reformulations for the maximum k-colorable subgraph problem
Rodolfo Alexander Quintero Ospina, David E. Bernal, Tamás Terlaky, Luis Zuluaga

Adiabatic quantum computers have shown to outperform classical computers in solving some particular instances of NP-hard problems, for instance, the Graph partitioning problem. To do this, a Quadratic Unconstrained Binary Optimization (QUBO) formulation is needed. Given that many combinatorial problems can be formulated as QUBO instances (including famous NP-hard problems), 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.

3 - Integer optimization models for the generalized temporal knapsack problem.
Jongyoon Park, Kyungsik Lee

We consider a generalization of the temporal knapsack problem, where each item has time-varying multidimensional resource requirements that should be met by a combination of multiple types of discrete resources. This problem arises in practical applications from various domains including telecommunication and bio-industry. We first formally define the problem, and discuss the computational complexity of it. Then, we propose several MIP models and compare them in terms of the strength of LP bounds. We also propose heuristic algorithms for the problem with some computational results.

4 - An empirical quantification of the impact of choice constraints on generalizations of the 0-1 knapsack problem using CPLEX
Yun Lu, Francis Vasko

It has been well-known for some time that adding choice constraints to certain types of knapsack formulations improves the solution time for these problems when using integer programming solvers, but by how much? In this paper, by using the integer programming option of CPLEX, we provide comprehensive empirical and analytical evidence of the impact of choice constraints on two important categories of knapsack problems. Specifically, we show using multidimensional knapsack problems (MKP)and multi-demand multidimensional knapsack problems from Beasley's OR-Library that adding choice constraints reduces solution time by more than 99.9%. Additionally, using these same problem instances, we show that even if only some of the variables have choice constraints imposed on them, the CPLEX solution times are drastically reduced. These results provide motivation for operations research practitioners to check if choice constraints are applicable when solving real-world problems involving generalizations of the 0-1 knapsack problem.

■ HA-06

Thursday, 8:00-9:40 - Room 6

Metaheuristics 1

Stream: Metaheuristics
Invited session
Chair: Mauricio Resende

1 - Multi-parent biased random-key genetic algorithm with implicit path-relinking and some real-world applications
Mauricio Resende, Carlos Andrade, José Fernando Gonçalves, Rodrigo Toso

We present the Multi-Parent Biased Random-Key Genetic Algorithm with Implicit Path-Relinking (BRKGA-MP-IPR), a variant of the Biased Random-Key Genetic Algorithm that employs multiple (biased) parents to generate offspring instead of the usual two, and is hybridized with a novel, implicit path-relinking local search procedure. By operating over the standard unit hypercube, such path-relinking mechanism leverages the population representation of the BRKGA and thus provides complete independence between the local search procedure and the problem definition and implementation. This approach contrasts with traditional path-relinking procedures that are tied to the problem structure. Having both BRKGA and IPR operate over the same solution space not only makes the intensification/diversification paradigm more natural but also greatly simplifies the development effort from the perspective of the practitioner, as one only needs to develop a decoder to map unit random-key vectors to the solution space of the problem on hand. Apart from such key benefits, extensive computational experiments solving real-world problems, such as over-the-air software upgrade scheduling, network design problems, and combinatorial auctions, show that the BRKGA-MP-IPR offers performance benefits over the standard BRKGA as well as the BRKGA with multiple parents.

2 - A Kernel Search matheuristic to solve multiple well-known Vehicle Routing Problems
Diana Lucia Huerta Muñoz, Claudia Archetti, Gianfranco Guastaroba, Roger Z. Rios-Mercado, , M. Grazia Speranza

The Vehicle Routing Problem (VRP) is a family of problems which calls for the minimization of the total distribution cost satisfying some operational constraints. In this work, we study several well-known variants of VRPs. While the literature usually offers a specific solution method for each specific variant, we design and develop a unified solution framework that is capable of solving several of them. This algorithm is based on a Kernel Search matheuristic, which has shown a great performance in several combinatorial optimization problems. The main idea of this matheuristic is to identify promising subsets of decision variables and iteratively solve a restricted Mixed-Integer Linear Program on those subsets using a general-purpose solver. Computational experiments are carried out on benchmark instances to show the performance of the proposed matheuristic in comparison with state-of-the-art algorithms.

3 - Decomposition heuristics for the multi-plant lot-sizing problem
Maristela Santos, Fernanda Ueno, Marcos Furlan

This paper considers a lot-sizing problem that aims to produce multiple items in several distinct plants with limited resource capacities. For this well-known problem in the literature, we propose fix-and-optimize matheuristics and investigate the impact on the quality of the solutions considering classic partitions, for example, by period, as well as partitions constructed by unsupervised learning. The strategies for constructing the partition of variables by unsupervised learning were based on a work in the recent literature. Relax-and-fix heuristics with decomposition by period were used to obtain feasible initial solutions. Solution methods were implemented in Python integrated with the commercial LP/MIP solver Gurobi. Computational tests were performed using data from the literature and the solutions were compared.

4 - Cascade simulator for the very short-term hydro-energetic planning stage, considering unit commitment and operating constraints
Lais Schiavo, Pedro Campos, Igor Querino, Israel Amaral, Matheus Mendonça, Gustavo Lacerda, Douglas Vieira

The very short-term hydro-energetic planning stage is important for the correct operation of an electric system. For this kind of planning, it is important to consider environmental and operating constraints of each hydro-power plant, as well as the specific characteristics of each plant, in order to ensure that the agreed power generation can be carried out without any negative impact. However, complying with such a variety of constraints poses a significant challenge to simulation models. In this sense, a simulator must consider the unit commitment problem, in the context of hydroelectric generation. It consists of producing energy by dividing it in the best way among each generating unit (GU), satisfying several physical and operating constraints, such as the feasible operation levels for each GU. Solving this problem quickly and efficiently is essential for short-term energy planning, so this work seeks to present a simulator that applies a simple strategy that is capable of solving such problem for any plant, considering all the particularities involved, including non-linearities and discontinuities related to the generating units. The implemented algorithm has quick responses, and achieves results with mathematically proven optimality given some valid considerations. Furthermore, we run tests using real power plants and the results show that this simulator can achieve a feasible and efficient response. Support: ANEEL and Cemig.

■ HA-07

Thursday, 8:00-9:40 - Room 7

Extremal Problems on Graphs and Complex Networks

Stream: Graphs and Networks
Invited session
Chair: Kazuhiro Suzuki

1 - A Matroidal Approach for the Minimum Rank of a Graph
Illya Hicks, Boris Brimkov, Logan Smith

The minimum rank of a graph G is the minimum rank over all symmetric matrices whose sparsity pattern is the same as that of the adjacency matrix of G. We present a new combinatorial bound for the minimum rank of an arbitrary graph G based on enumerating certain subsets of vertices of G satisfying matroid theoretic properties. We also present some additional results about these sets of vertices which could be used to more quickly compute the proposed bound.

2 - Zero forcing in iterated line digraphs
Thomas Kalinowski, Daniela Ferrero, Sudeep Stephen

Zero forcing is a propagation process on a graph, or digraph, defined in linear algebra to provide a bound for the minimum rank problem. Independently, zero forcing was introduced in physics, computer science and network science, areas where line digraphs are frequently used as models. Zero forcing is also related to power domination, a propagation process that models the monitoring of electrical power networks. In this paper we study zero forcing in iterated line digraphs and provide a relationship between zero forcing and power domination in line digraphs. In particular, for regular iterated line digraphs we determine the minimum rank/maximum nullity, zero forcing number and power domination number, and provide constructions to attain them. We conclude that regular iterated line digraphs present optimal minimum rank/maximum nullity, zero forcing number and power domination number, and apply our results to determine those parameters on some families of digraphs often used in applications.

3 - Some extremal problems on graph theory
Chunhui Lai

Let f(n) be the maximum number of edges in a graph on n vertices in which no two cycles have the same length. P. Erdos raised the problem of determining f(n). Hajos conjectured that every simple even graph on n vertices can be decomposed into at most n/2 cycles. We present the problems, conjectures related to these problems and we summarize the know results.

4 - On the Relationship Between the Scale-Free Natures of a Complex Network and Its Spanning Tree
Kazuhiro Suzuki, Eishi Chiba

We focus on the relationship between the scale-free natures of both a complex network and its spanning tree. No theoretical results exist regarding this relationship, and only limited relationship results are known from computational experimentation. In this research, we investigate the relationship between their scale-free natures through computational experimentation. Specifically, we apply some spanning tree algorithms to a complex network, and study the scale-free nature of the obtained spanning trees. From our computational experimentation, we show that the spanning trees of a network created using the BA model are scale-free, and the spanning trees of both a random graph and a network created using the WS model are not scale-free.

■ HA-08

Thursday, 8:00-9:40 - Room 8

Advanced statistical methods in finance and actuarial sciences

Stream: Advanced Statistical Methods in Finance and Actuarial Sciences
Invited session
Chair: Efsun Kürüm

1 - Mean-Variance Portfolio Selection in Contagious Markets
Yang Shen

We consider a mean-variance portfolio selection problem in a financial market with contagion risk. The risky assets follow a jump-diffusion model, in which jumps are driven by a multivariate Hawkes process with mutual excitation effect. The mutual excitation feature of the Hawkes process captures the contagion risk in the sense that each price jump of an asset increases the likelihood of future jumps not only in the same asset but also in other assets. We apply the stochastic maximum principle, backward stochastic differential equation theory, and linear-quadratic control technique to solve the problem and obtain the efficient strategy and efficient frontier in semi-closed form, subject to a non-local partial differential equation. Numerical examples are provided to illustrate our results.

2 - Investment, strategic debt service, and liquidation
Takashi Shibata, Michi Nishihara, Yuan Tian

We develop a contingent claim model to examine the interaction between a firm's financing and investment decisions, on the condition that the firm has the options of strategic debt service and liquidation during the financial distress.We show the effects of strategic debt service under liquidation option.

3 - Liability-Driven Investment for Pension Funds: Stochastic Optimization with Real Assets
Chul Jang, Andrew Clare, Iqbal Owadally

Using a multi-stage stochastic programming method, we suggest an optimal liability-driven investment (LDI) strategy for a closed defined-benefit pension fund including real assets. The objective is to minimize or stabilize contributions, funding ratio, buyout cost, and expected shortfall. Over a 10-year planning horizon, the optimal LDI strategy with a key-rate duration-matching bond portfolio outperforms one with a duration-convexity matching bond portfolio or an aggregate bond index-tracking portfolio in terms of the objective measures. When real assets are introduced, the optimal LDI strategy includes significant investment in infrastructure and real estate, illiquidity notwithstanding. Nevertheless, delays in sales of real assets induced by illiquidity can increase downside risk.

■ HA-09

Thursday, 8:00-9:40 - Room 9

Deep Learning 1

Stream: Deep Learning
Invited session
Chair: Yuekai Sun

1 - Identifying Dynamics of Atmospheric Pollutants with Domain-Aware Modeling
Javier Rubio-Herrero, Carlos Ortiz Marrero, Wai-Tong Fan

Machine learning has invigorated atmospheric modeling techniques in the last years. Many of these models use a data-driven approach to forecast the spatial or temporal concentrations of chemical species. However, it is very often that the natural laws that govern these concentrations (either chemical or physical) remain hidden in this analysis. Using air quality data from Madrid, Spain, our work introduces a case study that, within the framework of sparse identification of nonlinear dynamics (SINDy), aims at building a data-driven model that explains the kinetics of some chemical reactions in the atmosphere. Our goals are the following: (1) Find systems of ordinary differential equations that model the dynamics of concentration of pollutants; (2) assess the performance and limitations of our model using stability analysis; (3) reconstruct the time series of pollutants not measured in certain air quality stations.

2 - How human activities affect water quality
Catherine Lee

We suggest a practical method to figure out how human activities affect water quality. Especially in this COVID-19 era, we witness that water quality is better than ever while human activities are significantly reduced. In order to account for the multiple variables that affect water quality and avoid using instrument variables explicitly, we utilize machine learning in this research. We first compare machine learning techniques such as support vector machine, logistic regression, and deep neural networks in a view of data wrangling. Then, we introduce our datasets: human tracking data from mobile phone companies in the U.S. as well as the state of New York and water quality in New York state. Since the effects of human activity are dealt with importance, we focus on New York state. Our proposed approach begins with implementing machine learnings to classify obtained datasets. Support vector machine and principal component analysis are used to deduct a water quality measure, which puts together conductance, salinity, dissolved oxygen, turbidity, and nitrogen concentration. Deep neural network drives us to see the relations among water quality, such as the above five factors, and human activity, which clearly reflects that increased human activity pollutes water supplies. We then find an optimal timing, how long the human activity affects the water quality in view of their correlation.

3 - Fixed Point Networks: Implicit Depth Models with Jacobian-Free Backprop
Wotao Yin

A growing trend in deep learning replaces fixed depth models by approximating the limit as network depth approaches infinity. This approach uses a portion of network weights to prescribe behavior by defining a limit condition. This makes network depth implicit, varying based on the provided data and error tolerance. Moreover, existing implicit models can be implemented and trained with fixed memory costs in exchange for additional computational costs. In particular, backpropagation through implicit depth models requires solving a Jacobian-based equation from the theorem's implicit function. We propose fixed-point networks (FPNs), a simple setup for implicit depth learning that guarantees convergence of forward propagation to a unique limit defined by network weights and input data. Our key contribution is to provide a new Jacobian-free backpropagation (JFB) scheme that circumvents the need to solve Jacobian-based equations while maintaining fixed memory costs. This makes FPNs much cheaper to train and easy to implement. Our numerical examples yield

state-of-the-art classification results for implicit depth models and outperform corresponding explicit models.

This is joint work with Samy Wu Fung, Howard Heaton, Qiuwei Li, Daniel McKenzie, and Stanley Osher

4 - SenSel: Sensitive Set Invariance for Enforcing Individual Fairness
Yuekai Sun

In this paper, we cast fair machine learning as invariant machine learning. We first formulate a version of individual fairness that enforces invariance on certain sensitive sets. We then design a transport-based regularizer that enforces this version of individual fairness and develop an algorithm to minimize the regularizer efficiently. Our theoretical results guarantee the proposed approach trains certifiably fair ML models. Finally, in the experimental studies we demonstrate improved fairness metrics in comparison to several recent fair training procedures on three ML tasks that are susceptible to algorithmic bias.

■ HA-10

Thursday, 8:00-9:40 - Room 10

Knowledge in Organizations

Stream: Knowledge Work and Knowledge Analytics
Invited session
Chair: A. D. Amar

1 - Structural Hole Analysis of Service Productivity Development in Chinese Knowledge-Intensive Service Sector
Dohoon Kim, Yunhan Liu

Compared to manufacturing, the nature of the service industries hinders the full utilization of automation and economies of scale, thereby limiting their productivity potentials. Emerging advanced technologies related to Industry 4.0, however, help the service industry overcome these inherent drawbacks. In many countries, this shift of industrial environment has led to the rapid development of the knowledge-intensive sector and built new driving forces for economic growth. This study utilizes China's industrial input/output (IO) data from 2002 to 2017 to develop directional and weighted IO networks and analyze the evolutionary path of the Chinese knowledge-intensive service sector. In particular, we present a performance analysis of service productivity in the following two ways: 1) In terms of network properties and measures, how do the technological spill-over effects affect the structural relationships around the knowledge-intensive service sector? 2) Based on the structural hole theory, how do the effective sizes of the industrial network relationship change? We found that the knowledge-intensive service sector has attained a positioning advantage for controlling transaction flows by bridging multiple industries or filling the gaps between industries. This implies that the service sector can gain more competitive advantage (at least) in terms of industrial structure than manufacturing sectors in the course of upgrading Chinese industries.

2 - Decoding Customer Churn in B2B Service Industry: A Case Study in the Middle East
Santanu Roy, Sneha Hotchandani, Rohit Rajan

Customer churn severely impacts business sustainability of B2B service firms. Churn analytics in such contexts has received limited acknowledgement in the literature. The present work attempts to fill this research gap by decoding the customer churn within the domain of a subscription-based firm in operation somewhere in the Middle-East, providing services to project-based business customers with a view to meet their within-company communication requirements, and had witnessed a steadily shrinking client base in the recent past. The majority of the churned customers were private firms operating in construction, wholesale and retail, and manufacturing sectors. A matter of concern was the fact that a significant percentage of these clients had churned after a subscription period of more than three years. The churned clients were contacted thereafter and the key rationale for this churn were identified, first at a broad level followed by a deep dive that led to the identification of critical operational issues plaguing the focal firm that impacted the business of its service clients. It was also observed that a majority of these customers had sought the intervention of the focal firm to resolve these operational issues but of no avail. Ironically, many of these churn factors were in fact the service promises that had initially pulled the client base to our focal firm. Finally, the churn destinations of these customers were tracked and their pull factors were identified.

3 - A Model of Successful Organizational Knowledge Development: An Empirical Study of the Fortune 1000 Companies
Jinyu Li, A. D. Amar

It is almost impossible to efficiently operate any contemporary organization without using knowledge as one of its important production factors. All organizations can learn from how other successful organizations develop, integrate and deploy knowledge in their operations. In this paper, we investigate how successful organizations create human and social capital as a production factor in the achievement of their goal. Through an analysis of the secondary data drawn from the top 100 and bottom 100 of the Fortune 1000 companies, we compare the performance of each of these groups and arrive at the results that should help any organization become able to contribute to a new, more robust understanding and development of the role of knowledge in its working. We identify external factors for modeling the employee knowledge and how what they bring before the start of their employment plays a role in its aggregation with the organization's internal knowledge, and the knowledge that the job requires. We also model its ability to change with the dynamism of the task requirements, changing work environment, technology evolution, such as IT and AI, and can they be trained to improve/advance their knowledge which in turn results in larger or better or advanced cumulated internal knowledge of an organization. The latter is the knowledge that can advance the organization in being effective in gaining the internal organizational knowledge.

4 - Revenue Growth Budget Items and the Timing of Their Effects in Knowledge-Intensive Organizations
A. D. Amar, Januj Juneja

This work goes over the selection process of two-hundred and fifty-five (255) factors that contribute to revenue growth in an organization and recognizes the ones that show the most impact on the sales growth. We next model growth and perform an empirical study on the knowledge-intensive organizations to derive some resource budgeting recommendations for the various computer industries to help management make decisions pertaining to the growth and performance. Our results show that the strategy to invest in research and development to grow the firm is not always the best use of the organization's resources for all knowledge-intensive organizations, through all the stages of their evolvement. In addition, the paper models the timing of the effect of the investments made in growth for the better planning of the revenue growth budgeting process. This work is one of the several papers coming out of this research on revenue growth and performance evaluation of the organization. We provide directions for the future research in this area.

Thursday, 10:00-11:40

■ HB-01

Thursday, 10:00-11:40 - Room 1

Sports analytics

Stream: OR in Sports
Invited session
Chair: John Forman

1 - Forecasting offensive performance of baseball players switching between Japan and the United States
Eric Gerber

Prediction of player performance is a key component in the construction of baseball team rosters. As a result, most prediction models are the proprietary property of team or industrial sports entities and little is known about them. As far as published models, the focus has been to separately model each outcome rather than jointly modeling them. This research introduces a joint modeling approach to predict seasonal plate appearance outcome vectors using a mixed-effects multinomial logistic-normal model. This model accounts for positive and negative correlations between outcomes, both across and within player seasons, and provides a joint posterior predictive outcome distribution from which uncertainty can be quantified. It is applied to the important, yet unaddressed, problem of predicting performance for players moving between the Japanese (NPB) and American (MLB) major leagues.

2 - Performance analysis of professional biathletes - an application of functional data analysis
Christoph Herrmann, David Lukas, Thomas Kirschstein

Sports performance analysis is a viable tool for coaches, trainers, and managers in many sports disciplines. In biathlon, performance is mostly analysed and modelled discretely. In this study, individual skiing performance levels of professional biathletes are analysed as continuous variables. Our data set consists of official race results of all women's races from 2008 to 2018 in the IBU World Cup, the IBU World Championships, and the Olympic Games. A two-phase approach based on a panel regression and a functional data analysis is used to analyse the variation of cross-country skiing performance of biathletes during a season. In the first phase, the observed skiing speeds in biathlon races are analysed for internal (e.g., skiing ability) and external (e.g. weather and snow conditions) factors. Afterwards, the residual performance levels are analysed as functional data. The panel regression results quantify the effects of environmental factors, like total climb, altitude, or snow temperature. It is found that wet snow and positive snow temperature noticeably slow down skiing speed. In the functional data analysis, individual performance level curves are characterized by periodical variations. In many teams, individual performance curves are similar, indicating coordinated training that aims to maximize the performance level at the season's highlights.

3 - Pre-COVID Home Advantage in Volleyball: A Multidimensional Analysis
John Forman, Edward Hope

Home advantage is a well establish phenomenon in sports, with a number of proposed causal factors both in terms of the advantage itself and its variability between sports. Although volleyball is one of the world's most popular sports, it has thus far received only limited examination on this subject. Using data from over 11,000 matches across more than 20 countries, with both proportionality tests and probit regression methods, this analysis provides a broad scope examination of home advantage in volleyball pre-COVID at both the match and set level with particular attention to sex, competitive level, and opponent strength as influencing factors. The findings confirm prior analysis that volleyball falls on the lower end of the home advantage spectrum. No variation is seen between competitive levels (professional, semi-pro, amateur), though male teams do exhibit a slightly stronger advantage. Noteworthy is the fact that while opponent strength is naturally a significant determinant in outcomes, home advantage is still clearly observed when controlling for that factor - with variations to that advantage based on the distance apart of the two teams involved. Additionally, while home advantage is observed in the first three sets (best-of-5 format), it disappears if teams reach the deciding set.

■ HB-02

Thursday, 10:00-11:40 - Room 2

New models and algorithms for decision under uncertainty

Stream: Continuous Optimization
Invited session
Chair: Man-Chung Yue

1 - Optimistic likelihood problems using geodesically convex optimization
Man-Chung Yue, Viet Anh Nguyen, Soroosh Shafieezadeh Abadeh, Daniel Kuhn, Wolfram Wiesemann

When evaluating the likelihood of an observation, the nominal distribution for the observation is estimated from data, which makes it susceptible to estimation errors. To alleviate this issue, we propose to replace the nominal distribution with an ambiguity set containing all distributions sufficiently close to the nominal distribution. When this proximity is measured by the Fisher-Rao distance or the KL-divergence, the emerging optimistic likelihood can be calculated efficiently using geodesically or standard convex optimization. We showcase the advantages of our optimistic likelihoods on a classification problem using real data-sets.

2 - The Dao of Robustness
Melvyn Sim, Daniel Zhuoyu Long, Minglong Zhou

We present a general framework for data-driven optimization called robustness optimization that favors solutions for which a risk-aware objective function would best attain an acceptable target even when the actual probability distribution deviates from the empirical distribution. Unlike robust optimization approaches, the decision maker does not have to size the ambiguity set, but specifies an acceptable target, or loss of optimality compared to the empirical optimization model, as a trade off for the model's ability to withstand greater uncertainty. We axiomatize the decision criterion associated with robustness optimization, termed as the fragility measure, and present its representation theorem. Focusing on Wasserstein distance measure with l1-norm, we present tractable robustness optimization models for risk-based linear optimization, combinatorial optimization, and linear optimization problems with recourse. Serendipitously, the insights to the approximation also provide a recipe for approximating solutions for hard stochastic optimization problems without relatively complete recourse. We perform numerical studies on a portfolio optimization problem and a network lot-sizing problem. We show that the solutions to the robustness optimization models are more effective in improving the out-of-sample performance evaluated on a variety of metrics, hence alleviating the Optimizer's Curse (Smith and Winkler 2006).

3 - Probabilistic Sequential Shrinking: A Best Arm Identification Algorithm for Stochastic Bandits with Corruptions
Wang-Chi Cheung

We consider a best arm identification (BAI) problem for stochastic bandits with adversarial corruptions in the fixed-budget setting of T steps. We design a novel randomized algorithm, PROBABILISTIC SEQUENTIAL SHRINKING(u) (PSS(u)), which is agnostic to the amount of corruptions. When the amount of corruptions per step (CPS)

is below a threshold, PSS(u) identifies the best arm or item with probability tending to 1 as T tends to infinity. Otherwise, the optimality gap of the identified item degrades gracefully with the CPS. We argue that such a bifurcation is necessary. In PSS(u), the parameter u serves to balance between the optimality gap and success probability. The injection of randomization is shown to be essential to mitigate the impact of corruptions. To demonstrate this, we design two attack strategies that are applicable to any algorithm. We apply one of them to a deterministic analogue of PSS(u) known as SUCCESSIVE HALVING (SH) by Karnin et al. (2013). The attack strategy results in a high failure probability for SH, but PSS(u) remains robust. In the absence of corruptions, PSS(2)'s performance guarantee matches SH's. We show that when the CPS is sufficiently large, no algorithm can achieve a BAI probability tending to 1 even as T grows. Numerical experiments corroborate our theoretical findings.

4 - Distributionally robust risk minimization in machine learning: models and algorithms
Anthony So, Jiajin Li, Sen Huang

Distributionally robust optimization (DRO) is a paradigm for optimal decision-making under uncertainty. It postulates that the data of the optimization problem at hand follow an unknown probability distribution from a certain known family and aims to find a decision that has the best performance with respect to the worst distribution in the family. DRO has attracted much attention in the machine learning community lately, as it offers interesting interpretations of regularization and motivates new approaches to various learning tasks. Although many DRO problems arising in the learning context admit convex reformulations, there is currently a lack of fast iterative methods for solving them. This severely limits the applicability of the DRO approach in machine learning. In this talk, we will first survey some recently discovered connections between DRO and machine learning. Then, we will present a new first-order algorithmic framework for Wasserstein distributionally robust regression problems. Lastly, we will discuss some future research directions.

■ HB-03

Thursday, 10:00-11:40 - Room 3

Behavioral finance

Stream: Financial Mathematics and OR
Invited session
Chair: *Jing Yao*
Chair: *Yun Shi*

1 - Work More Tomorrow: Resolving Present Bias in Project Management
Yun Shi

Project management is responsible for almost 30% of the world's economic activity, with a value of $27 trillion annually. Traditionally, the frequent late delivery of projects is attributed to Parkinson's Law, which incorporates laziness, procrastination, and self-protection against reduced deadlines in future. Incentive schemes are widely designed and implemented to eliminate Parkinson's Law, yet many projects are nonetheless delivered late. We therefore propose a new incentive scheme that addresses project workers' time-inconsistent preferences, i.e. present bias, as discussed in behavioral economics. Our work is among the first to develop a multi-period model of time-inconsistent preferences for general projects. Using concepts from savings theory, we design a Work More Tomorrow (WMT) incentive scheme to mitigate present bias in project execution. The WMT scheme extends the underlying economic theory to consider network effects in projects. We show, both theoretically and computationally, that the WMT contract outperforms a widely used benchmark incentive scheme by delivering significant improvements in on-time frequency and expected project tardiness. Moreover, these improvements increase with project complexity. An extensive sensitivity analysis reveals the characteristics of projects that respond best to the WMT scheme.

2 - The Risk-Return Tradeoff in China: A Feedback Approach to Expected Government Actions
Jing Yao

It is often difficult to find a positive intertemporal risk-return relation. We propose a feedback explanation for this phenomenon in China, whereby investors use prior price information to adjust their expectations about future government actions. This feedback effect has three main implications for the risk-return tradeoff faced by investors who seek to take advantage of government's attempt to maintain market stability: 1) it weakens (strengthens) the risk-return tradeoff in bad (boom) times; 2) it links the risk-return relation with return autocorrelations; 3) it is weak (strong) at the firm (market) level. Our empirical tests confirm these predictions by examining whether the market's mean-variance relation, in conjunction with the serial correlation of market returns and the idiosyncratic volatility effect, varies with market instability features in the direction indicated by the market stability objective of government intervention.

3 - Profit-driven selection of optimal segment churn prevention actions for a financial institution: A multi-action and shared-segment budget optimization approach
Alejandro Mac Cawley, Abraham Fuentealba

Customer churn is a problem for a large number of industries and most of the customer churn research has mainly focused its attention on predicting the churn action through classification methods. In this research, we will present an optimization model which helps managers to select the optimal segment churn prevention actions, from a multi-action set with different retention capabilities, with a shared-segment budget constraint. To achieve this we segment the probable churners segments according to their customer lifetime value and probability of churn, also we define a set of actions with different retention capabilities and cost which can be applied to each segment. Using an optimization approach we maximize the customer lifetime value of the portfolio of churners and determine an optimal match between segment and actions, subject to a budget constraint. We applied the model in a financial institution and compared our results with different heuristics. Results show that the model is able to improve in over 100% the value of retention compared to heuristics.

■ HB-04

Thursday, 10:00-11:40 - Room 4

Scheduling under Uncertainty

Stream: Scheduling, Timetabling and Project Management
Invited session
Chair: *Rodrigo A. Carrasco*

1 - Salvage Logging Under Uncertainty
Constanza Lorca, Rodrigo A. Carrasco

The rise of temperatures and droughts caused by climate change has led to an increased spread of wildfires worldwide. This issue represents a severe threat to diverse ecosystems and a significant strain for the forestry sector since their primary income source becomes severely damaged. The Salvage Logging problem stems from this scenario. Forestry companies must decide between claiming certain forest areas to insurance companies or harvesting the burnt timber. In the latter case, there is a limited timeframe before the wood loses its value. The post-fire course of action aims towards optimizing some financial metrics. However, given that scheduling is based on estimations of the wood available in each forest stand, an error might place the organization in a disadvantageous financial situation at the end of the harvesting

period. Our research study explores the impact of uncertainty in wood availability regarding the strategic and operational decisions made before harvesting and sawmilling. To tackle this challenge, we developed novel chance constraints to construct a stochastic optimization model that will guide the workforce's planning, providing a suitable solution for the forestry to turn out with an optimal output, considering their operational constraints.

2 - Scheduling storage usage for photovoltaic generation
Helena García-Jaimalis, Rodrigo A. Carrasco

Due to climate change concerns, many governments have pushed for higher penetration of intermittent renewable energy sources. Among these energy sources, photovoltaic (PV) generation is one of the most sought off, in particular by domiciliary users and small industries. The main drawback of this source of energy is its variability and not being available for the whole day. Oneway of canceling or diminishing this drawback is to use energy storage systems, like batteries. Although storage systems are currently expensive, its price has dropped significantly in the last decade and many studies indicate that they will become an economically viable alternative in the coming years. In this work, we present a novel approach to schedule the use of these storage units in a PV generation system, based on stochastic optimization. Using real historical data, we analyze different methods for generating scenarios for our optimization model, showing that the resulting decision support system improves current scheduling policies significantly. We further validate our results by testing the resulting schedules in a real prototype.

3 - A multistage scenario stochastic optimization procedure for capacity planning in TV production final assembly lines
Alpaslan Garip, Ihsan Yanikoglu, Gorkem Yilmaz

In this paper, we study multistage capacity planning problem of Vestel Electronics TV production assembly lines. We consider production planning of a multiple product family using capacitated unrelated parallel machines over a multi-period time horizon. The demand uncertainty is modeled via a scenario tree structure. Each node of the tree corresponds to a scenario of demand realization with an associated probability. The proposed model includes worker group assignment for different assembly lines. The problem has two main decision groups: period based and scenario-based decisions. Product based decisions consist of production planning, worker assignment and shift selection; while scenario-based decisions extra ordering and overtime decisions. Developed algorithms are solved with both Gurobi and CPLEX optimization libraries. The results provide a robust solution for these kinds of capacity planning problem including demand uncertainties while minimizing the total of inventory cost, backlogging cost, normal production cost, extra order production cost and workers' cost depending on shift type.

■ HB-05

Thursday, 10:00-11:40 - Room 5

Applications of OR 1

Stream: Applications of OR (contributed)
Contributed session
Chair: *Byung-Keun Kim*

1 - Malapportionment and Evaluating the Inequality for Degressive Proportionment with Representativeness Index
Akiko Tanimoto, Lyu Wenruo, Liang Zhao

After James Madison concluded that "no political problem is less susceptible of a precise solution than that which relates to the number most convenient for a representative legislature" (The Federalist, 1788), numerous studies have been contributed to the "most convenient" number of representatives including the common proportionality and the less common but more convincing degressive proportionality. The latter includes Penrose square root law (1946) - which was adopted by IFORS, Taagepera's cube root law (1972), Zhao et al.'s 2/5 power law (2020) etc. This study, assuming the existence of such a convenient number, proposes an index of representativeness for electoral districts and uses it to provide a novel point of view on the so-called malapportionment issue which has been studied for over two centuries with no consideration on the convenient number of representatives before. As a result, it was found that allocating seats proportionally to the population may increase the inequality of the representativeness among districts, i.e., only proportionality may give more representativeness to a district with larger population, as illustrated by the case of Japan. As a conclusion, it is shown that allocation of electoral districts by equalizing the populations is better than the proportionality since it solves both the (traditional) malapportionment issue and the inequality problem of representativeness, whereas the proportionality rule only solves the former.

2 - Application of Operations Research in China's Real Estate Development Companies
Yin Yu Wong

Operations Research is a subject that helps people make the optimal decision by mathematical models and algorithms in their works or their everyday life. However, Operations Research is not very popular in China, not only in real estate development, but also in other industries. So the purpose of the paper is to analyze how Operations Research can be applied in China's real estate development companies by a real and specific example in order to emphasize the importance of Operations Research. The paper would introduce 6 kinds of common and basic methods of Operations Research, which can be adapted in real estate development: Posterior Probability of Risk Decision(PPRD) can be used to decide whether a project deserve to be invested or not; Fuzzy Analytic Hierarchy Process(FAHP) is used to evaluate which project is the best by experts through giving the score for the components of 2 or 3 projects; Program Evaluation and Review Technique(PERT) is used for scheduling in order to decrease the duration of the whole project; Integer Programming(IP) could be used to decide how to purchase a plot of land under the limited funds and some other constraints with the least cost; Transportation Problem(TP) is often used to calculate the minimum cost of materials delivering in civil engineering and from the theory of TP, Hungarian Algorithm(HA) is developed for choosing the materials corresponding to the suppliers with the minimum cost.

3 - Decomposition optimization and multi-modal Golden Section algorithm applied in the short term hydro power planning
Pedro Campos, Lais Schiavo, Igor Querino, Israel Amaral, Matheus Mendonça, Gustavo Lacerda, Douglas Vieira

The proposed approach aims to split the problem of hydro power planning into two: a secondary problem (simulation) that solves the unit commitment and considers the physical problem restrictions, and a primary problem (optimization) that evaluates the simulation in an iterative loop, until the optimal power is found. The evaluation of the secondary problem results in a multi-modal objective function, due to this fact, a golden section multi-modal algorithm is used. This work focuses on the explanation of the primary problem algorithm, its objective function is to maximize the total produced energy, with a penalty parameter to consider possible simulation's unfeasibilities. Additionally, a volume goal to be achieved in the end of the day is received as input, and modeled as restriction. Furthermore, load intervals are also considered, establishing a production with low, medium or high load, thus allowing the plant to produce more power in some instants, and less power in others, which is a useful feature considering that the energy price changes throughout the day. Tests using real cascades of hydroelectric plants in the Brazilian electric grid show that the proposed approach can achieve a feasible final result that also produces more power in comparison to other strategies. Additionally, the execution of the entire process takes around one minute, allowing it to be used as a tool to aid the decision taking process for the operation agents. Support: ANEEL and Cemig.

4 - A Study on the Drivers and Processes of Business Model Innovation
Byung-Keun Kim

This research explored the drivers and processes of business model innovation in a particular industrial ecosystem. With the emergence of new technologies and changes in the environment, such as customer needs and competition bases, companies must modify, improve, and reinvent their business models. Extant research emphasizes changes in business models due to changes in the external environment but lacks a theoretical framework and empirical research on what drivers and processes lead to a business model. A case study was conducted on four different types of start-ups within the delivery service industry in Korea. The results show that various types of business models coexist and compete according to the value proposition content, value creation structure, and value capture method. It also found that the shift in the competition base in the delivery service industry enables the change in the value creation structure from an integrated structure to a modular structure, and the modularization of the value creation structure enables companies with expertise in specific areas of the value creation structure to create opportunities for business model innovation through unbundling.

■ HB-06

Thursday, 10:00-11:40 - Room 6

Applications of DEA 4

Stream: Data Envelopment Analysis and Performance Measurement
Invited session
Chair: Tatiana Kodama

1 - Good Governance in Asia using the DEA Measure
Mary Caroline Castaño, Emilyn Cabanda, Viverita Viverita, Ali Emrouznejad

This research attempts to provide a different approach by means of the data envelopment measure for ranking the countries using existing aggregate governance indicators for a comparative country's governance performance. This study will also assess whether a country's good governance performance is linked to a country's economic development. This research uses the six dimensions of the World Bank's Worldwide Governance Indicators for 31 Asian countries. The new DEA-governance index is developed to measure a cross-country comparison of governance quality in Asia. The research also found a positive and statistically significant linkage that good governance matters for a country's economic development.

2 - A Full Dimensional Efficient Facets DEA Frontier applied to Public Bidding in Government Procurement
Marcos Estellita Lins, Nilson Trevisan, Luiz Fernando Nascimento, José Dulá, Angela Estellita Lins

This work proposes a methodology to find appropriate weights to be assigned to criteria to assess bids for government contracts. It complies with the European Union procurement directives, and contributes to providing transparency regarding criteria tradeoff weights in government procurement. It is illustrated with an example from the Brazilian Navy to process bids evaluated using the Most Economically Advantageous Tender (MEAT). The objective is to produce a DEA frontier composed of all full dimensional efficient facets as a framework for measuring performance and ranking the proposals. It intends to contribute to reduce the discretion of experts' judgments inherent to weight restrictions, since there will be no null weights assigned to criteria. It also requires a non-radial non-oriented approach for performance measurement, suppressing non-Pareto efficient regions. We propose a method to find all faces of maximum dimension in two stages, the first one based on known applying of mixed integer linear programming and the second through pivoting for changing bases. We applied the method to a three-dimensional subproblem with visualizations of the pivoting path along the production possibility set and then to the complete database with one input and seven outputs. We also suggest alternative solutions whenever there is no full dimensional efficient facets.

3 - Energy Efficiency & Sustainability-A behavioural OR approach
Jinal Parikh

According to a recent report published by International Energy Agency(IEA)* , India's achievements in its energy sector in recent years have been outstanding. The Government of India is implementing reforms aimed at achieving a secure, affordable and sustainable energy system that can power robust economic growth. These reforms particularly aim at providing access to electricity and clean cooking, deploying renewable energy on a major scale and significantly improving energy efficiency. The country has made huge strides to ensure full access to electricity, bringing power to more than 700 million people since 2000. It is pursuing a very ambitious deployment of renewable energy, notably solar, and has boosted energy efficiency through innovative programs. As one of the world's fastest-growing major economies, India will be vital for the future of the global energy markets. Looking ahead, the Government has laid out an ambitious vision to bring secure, affordable and sustainable energy to all its citizens. In this context, this paper aims to: 1) to understand and categorize the input and output behavioural variables influencing energy efficiency and 3) to apply a behavioural operations research approach using Data Envelopment Analysis to evaluate behavioural energy efficiency.

*Source: https://www.iea.org/commentaries/indias-rise-on-the-global-energy-scene

4 - How did COVID-19 affect retailing companies in Brazil? - A novel benchmarking approach through Data Envelopment Analysis (DEA) and Optimal Control Theory (OCT)
Tatiana Kodama, Isotilia Costa Melo, Paulo Alves Junior, Daisy Rebelatto, Marcelo Nagano

Because of the COVID-19 global pandemic, traditional retailers increased online sales. Though retailing companies were not able to respond to this urgent necessity with the same efficiency level as their competitors, especially in developing markets. We aimed to propose a dynamic model - integrating Data Envelopment Analysis (DEA) and Optimal Control Theory (OCT) - for benchmarking retailing companies' cost efficiency. We also aimed to contribute through the application, by investigating the impact of the pandemic in companies from a developing market (Brazil). We investigated 21 companies publicly traded in the São Paulo Stock Exchanges between the third quarter of 2018 (3Q2018) and the third quarter of 2020 (3Q2020) (i.e, a period encompassing before and during the pandemic). We considered 189 financial observations of each of the six model's measures: initial inventory cost (IIC), final inventory cost (FIC), net operating income (NOI), cost of goods sold (COGS), cost of the purchased product (CPP), and plant, property, and equipment (PPE). In this way, our findings have implications for researchers, as well as for practitioners. Because practitioners can know exactly which competitor is a benchmark regarding the best practices of each operational aspect (for example, inventory cost during the pandemic). Additionally, the proposed method can be replicated in other markets (developing or not) and for other categories of retailing companies (small and middle).

■ HB-07

Thursday, 10:00-11:40 - Room 7

Graphs and Networks 3

Stream: Graphs, Networks and Combinatorial Optimiza-

tion with Applications (contributed)
Contributed session
Chair: Om Damani

1 - Community-based Nonsubmodular Constrained Profit Maximization in Attributed Networks from Increment Perspective
Liman Du, Wenguo Yang

The growing importance of online social networks leads to the emergence of viral marketing, a new way to promote the sales of products. A derivation of classical Influence Maximization (IM) problem is the Profit Maximization (PM) problem. In this paper we propose the PM problem with a cardinality constraint in attributed network. The attributed network, in which every node contains a variety of features, is closer to the real-word social networks than the pure network focused by many existing works. Different from the IM problem, the profit spread metric of PM calculates the total benefit and cost, leading to the lack of both monotonicity and submodularity in general. We design a new algorithm to solve Community-based Constrained Profit Maximization Problem in Attributed Networks, containing four steps as community detection, influence strength calculation, pruning and searching. Base on the result of community detection, a model to predict influence strength between nodes in attributed network is proposed, making best of topology structure similarity and attribute similarity between nodes. Then, from the perspective of marginal increment, the searching phase deals with a decreasing search space gained after the third step and takes advantage of the natural form of the profit spread metric as the difference between two submodular functions. Extensive experiments demonstrate the effectiveness and outperformance of our algorithm.

2 - Integrated Ship Loading and Berth Allocation Planning for a Cargo Assembly Coal Port
Lanbo Zheng, Xin Tang

This paper studies an integrated ship loading and berth allocation planning problem faced daily by one of the largest cargo assembly coal ports in China. The decisions are to be made based on demands and priorities of vessels, types and amount of different coal stocked on stockyards, blending recipes, vessel and berth compatibilities, to list just a few. The problem has a large impact on port throughput, and mostly relies on rule-based decision systems or human experience to get a solution due to its high complexity. We present a optimal flow model for this problem such that decisions of sequential operating procedures, i.e., rail dumping, stockyard planning, ship loading and berthing are integrated in one model and are optimized together. In this production scenario, raw materials are stored as designated stockpiles on stock yards and blended when loading onto vessels. The stock yards are divided into 6 regions and only coal components from the same region can be blended together. We present an optimal flow model for this problem where blending recipe are specified in the way that some arc flows must satisfy proportional constraints, and must be confluent at a specified node. Moreover, priority of vessels are modeled as lexicographical ordering on flows. We report a dynamic programming algorithm to solve the problem. Computational results based on real data sets are reported by comparing with current approach used by the industry.

3 - Adding Relations between the Top and K Members of the Same Level in a Pyramid Organization Structure of a Complete K-ary Tree
Kiyoshi Sawada

This study proposes a model of adding relations between the top and K members of the same level in a pyramid organization structure of a complete K-ary tree. When edges are added between the root and K nodes with depth N in a complete K-ary tree of height H, the total shortening distance which is the sum of shortening lengths of shortest paths between every pair of all nodes by adding edges is formulated for obtaining an optimal depth N.

4 - Piping Cost Optimisation of Water Distribution Networks
Saumya Goyal, Om Damani, Ashutosh Mahajan

We study the problem of pipe cost optimisation for water distribution networks that contain cycles. These networks contain a single source node and multiple demand nodes with residual pressure constraints. The cost minimisation problem entails selection of pipe diameters for all links while meeting these pressure constraints. The problem is convex in case of acylic networks since flow values are easy to determine for each link in the network. However, indeterminism of flow values and even directions through most links in a cyclic network lead to nonlinearity in constraint formulations making the problem non-convex. In this work, instead of focussing on optimisation techniques like genetic algorithms, we exploit recent advances in generic NLP solvers to develop three optimisation formulations for finding least capital cost design configurations of water networks. We note that despite the presence of link cycles in the network, flow through the network is necessarily acyclic and that very few of these acyclic orientations are actually optimal, or even feasible. We thus explore the feasibility and benefit of enforcing such orientations explicitly as a constraint. Finally, we propose a parallel link formulation that models flow in each link as two separate flows with opposing directions that allows the model to tackle numerical difficulties in optimisation near origin. This makes the model more tractable for use with bigger networks and results in the best known technique for so

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■ HB-08

Thursday, 10:00-11:40 - Room 8

Metaheuristics 2

Stream: Metaheuristics
Invited session
Chair: Haichao Liu

1 - An adaptive large neighborhood search for solving the multi-depot fleet size and mix open vehicle routing problem
Rahma Lahyani

This paper introduces a new variant of the vehicle routing problem named the multi-depot fleet size and mix open vehicle routing problem (MDFSMOVRP). In the MDFSMOVRP, the vehicle fleet is composed of vehicles having different capacities and different fixed and variable costs starting from different depots and ending at the last customer served. The objective of the MDFSMOVRP is to minimize the routing costs. Some works in the literature studied some reductions of the MDFSMOVRP such as the multi-depot fleet size and mix vehicle routing problem (MDFSMVRP) and the multi-depot open vehicle routing problem (MDOVRP) with homogeneous fleet. In this research paper, we formally present a mixed-integer linear program of the MDFSMOVRP and we propose a an hybridized Adaptive Large Neighborhood Search metaheuristic to solve large size instances of the problem. We carry out a computational study to assess the performance of the proposed matheuristic on a set of instances from the MDFSMOVRP variants, i.e., OVRP,MDOVRP and MDFSMVRP. The computational results show that the proposed matheuristic is competitive compared with the state-of-the-art methods. To better evaluate its performance, we generate a new testbed for the MDFSMOVRP and we compare the results to exact solutions provided by a commercial solver. Computational experiments substantiate the excellent performance of the proposed method.

2 - The convex hull heuristic (CHH) for nonlinear mixed-integer optimization problems with linear constraints
Monique Guignard-Spielberg, Aykut Ahlatcioglu

The convex hull heuristic (or CHH) is a heuristic for mixed-integer programming problems with a nonlinear differentiable objective function, possibly nonconvex, and linear constraints. It is a matheuristic

based on the mathematical programming algorithm called simplicial decomposition, or SD (von Hohenbalken 1977). At each iteration, one solves a mixed-integer programming problem with a linear objective function and the original constraints, and a continuous problem with a nonlinear objective function and a single linear constraint. Its purpose is to produce quickly feasible and often near optimal or optimal solutions for convex and nonconvex problems. It is usually multi-start, and as such may lend itself to parallel implementations. Each restart requires a new starting point, which may come from using a sample of representative points of the feasible region or from a different heuristic, such as for instance a genetic algorithm. We present numerical results for the GQAP (generalized quadratic assignment problem), the CDAP (cross-dock door assignment problem), the QAP (quadratic assignment problem) and the QKP (quadratic 0-1 knapsack problem). We compare solution quality and solution times with results from the literature, when possible.

3 - Comparing two population-based metaheuristics designed to solve a bilevel location-inventory problem.
Dámaris Arizhay Dávila Soria, José-Fernando Camacho-Vallejo, Leopoldo Cárdenas-Barrón

The situation here addressed is modeled as a bilevel programming problem with one objective in the upper level and multiple independent non-linear problems in the lower level. In this work, a company (hereafter the leader) needs to locate a set of warehouses and then associate customers to each opened warehouse. Once all the customers are associated with a warehouse, the decision maker at each warehouse (hereafter the follower) chooses his own inventory decision. The leader has the objective of minimize the total cost for locating warehouses, for allocating the customers to warehouses, and for placing and order at each warehouse. On the other hand, each one of the followers has the objective of minimize the total inventory cost according to the customers' demands. For this problem, the demand of the customers is known and backorders are allowed in the inventory policy. This bilevel problem is very difficult to solve to optimality. Thus, we propose two different population-based metaheuristics for obtaining good quality solutions. The first one is a novel discrete Brain Storm Optimization algorithm; while the second one is a standard nested Genetic Algorithm. For the two proposed metaheuristics, the lower level is solved to optimality by using a Lagrange multipliers method. Extensive computational experiments are conducted to compare the performance of both proposed metaheuristics. Statistical analysis is done to assess the effectiveness of the algorithms.

4 - A hybrid metaheuristic for the daily elective surgery scheduling problem under surgeon resource constraints
Haichao Liu, Yang Wang, Jin-Kao Hao

This paper deals with such a daily elective surgery scheduling problem that assigns a number of patients to multiple operating rooms over one day and sequences the patients of each operating room subject to the available time of surgeons. The objective is to simultaneously maximize the number of scheduled patients and minimize the overtime of operating rooms. This problem is equivalent to the parallel machine scheduling problem with additional resource constraints. To solve this hard combinatorial optimization problem, we propose a hybrid metaheuristic that integrates discrete particle swarm optimization and path relinking. In particular, we divide the search space into different regions based on the structures of surgery sequences and design an innovative fitness evaluation function that considers both the quality of the surgery sequence and its distance to the region center. Experimental results on different datasets disclose that our algorithm is favorably competitive with the high-performance Gurobi MIP solver with respect to the solution quality while the computational time is reduced by at least an order of magnitude.

■ HB-09

Thursday, 10:00-11:40 - Room 9

Optimization and Multi-agent Reinforcement Learning

Stream: Statistical learning, stochastic optimization and applications
Invited session
Chair: *Xiangfeng Wang*
Chair: *Tsung-Hui Chang*

1 - A Proximal Dual Consensus Method for Linearly Coupled Multi-Agent Non-Convex Optimization
Tsung-Hui Chang

Motivated by large-scale signal processing and machine learning applications, this talk considers the distributed multi-agent optimization problem for a linearly constrained non-convex problem. Each of the agents owns a local cost function and local variable but is coupled with each other due to the linear constraint. Most of the existing methods are either applicable for convex problems only or are developed under the non-convex setting subject to a specific type of linear constraint. There still lacks a distributed method for solving the linearly constrained problem under the general and non-convex setting. In this paper, we propose such a method, called the proximal dual consensus (PDC) method, that combines a proximal technique and the dual consensus method. Theoretical analysis shows that the proposed PDC method can yield a Karush-Kuhn-Tucker solution of the linearly constrained non-convex problem with a sbulinear iteration complexity. The practical behavior of the proposed method is examined by numerical results.

2 - F2A2: Flexible Fully-decentralized Approximate Actor-critic for Cooperative Multi-agent Reinforcement Learning
Xiangfeng Wang

Non-interactivity between agents, defense demand and computation complexity tend to make traditional centralized multi-agent reinforcement learning (MARL) algorithms unpractical in many complicated applications. Hence several decentralized MARL algorithms are motivated. However, existing decentralized methods only partially address the decentralization, i.e. only focusing on policy evaluation stage in fully observable small-scale problem, or only handling the fully cooperative setting where massive information needs to be transmitted in training. In this paper, we propose a fully decentralized actor-critic MARL framework, which can flexibly combine any actor-critic methods and handle large-scale general multi-agent setting (i.e. collaborative, competitive and mixed scenarios). % with less information transmit. Specifically, a primal-dual algorithm framework is designed to learn individual agents separately for decentralization. From the perspective of each agent, policy improvement and value evaluation are jointly optimized, which can stabilize multi-agent policy learning. Furthermore, our framework can achieve scalability for large-scale environment and reduce information transmission, by the parameter sharing mechanism and a novel modeling-other-agents methods based on theory-of-mind and online supervised learning.

3 - A Peaceman-Rachford splitting method with monotone plus skew-symmetric splitting for nonlinear saddle point problems
Wenxing Zhang

This talk is devoted to solving the linearly constrained convex optimization problems by PRSM with monotone plus skew-symmetric splitting on KKT operators. This approach generalizes the HSS method, an unconditionally convergent algorithm for non-Hermitian positive definite linear systems, to the nonlinear scenario. The convergence of the proposed algorithm is guaranteed under some mild assumptions, e.g., the strict convexity on objective functions and the

consistency on constraints, even though the Lions-Mercier property is not fulfilled.

■ HB-10

Thursday, 10:00-11:40 - Room 10

Multiobjective Optimization

Stream: Multicriteria Decision-Making and Multiobjective Optimization (contributed)
Contributed session
Chair: Nikolai Krivulin

1 - Explicit Multi-objective Model Predictive Control for Nonlinear Systems Under Uncertainty
Carlos Ignacio Hernández Castellanos, Sina Ober-Blöbaum, Sebastian Peitz

In this work, we consider nonlinear multi-objective optimal control problems with uncertainty on the initial conditions, and in particular their incorporation into a feedback loop via model predictive control (MPC). For such problems, not much has been reported in terms of uncertainties. We focus on the set-based robustness which allows the decision maker to analyze a given solution from the worst-case perspective. In this kind of problems, each solution in decision space maps to a set that represents the trade-offs of the worst possible scenarios.

To address this problem class, we design an offline/online framework to compute an approximation of efficient control strategies. To reduce the numerical cost of the offline phase –which grows exponentially with the parameter dimension– we exploit symmetries in the control problems. Furthermore, to ensure optimality of the solutions, we include an additional online optimization step, which is considerably cheaper than the original multi-objective optimization problem.

We test our framework on a car maneuvering problem where safety and speed are the objectives. The multi-objective framework allows for online adaptations of the desired objective. Our results show that the method can design driving strategies that deal better with uncertainties in the initial conditions, which translates into potentially safer and faster driving strategies.

2 - A modified NSGA-II for the multiobjective problem of support unit location for multi-stage road traffic surveys
Marcus Camara, Glaydston Ribeiro, Thayse Ferrari

The Multiobjective Problem of Support Unit Location for Road Traffic Surveys (MPSULRTS) aims to determine, from a set of roadside traffic survey stations and a set of candidate facilities (support units) that will provide needed survey appliers and resources to these stations, which support units must be selected to serve each station and in which time period. This decision considers the minimization of costs with travels of the survey teams and minimization of the number of support units used. The NSGA-II has been successfully used in several multiobjective applications, but in large scale real-world problems, the algorithm can show results with low diversity and distant of the Pareto optimality. Concerning the MPSULRTS, as the instance size increases, the structure of chromosomes expands significantly, increasing computational time and decreasing the algorithm efficiency. Thus, this paper proposes a modified NSGA-II which uses new strategies for the MPSULRTS. A new chromosome representation is proposed as well as new strategies for generating the initial population and new crossover and mutation operators. The computational experiments were conducted using 38 instances and the algorithm was implemented using Python. The results show that our new strategies generate good solutions when they are compared against the exact ϵ-Constraint method. Considering the hypervolume metric, our algorithm shows a hypervolume of 94% on average

3 - Application of tropical algebra techniques in bi-objective optimization problems
Nikolai Krivulin

We consider constrained bi-objective optimization problems in the framework of tropical mathematics, which focuses on the theory and applications of semirings and semifields with idempotent operations. The problems are to minimize two objectives, given as functions on vectors over an idempotent semifield (a semiring with idempotent addition and invertible multiplication), subject to constraints on the feasible solution in the form of vector inequalities. We apply a solution technique that reduces the bi-objective problems to a system of parametrized inequalities, where the parameters represent the values of the objective functions. The necessary and sufficient conditions for solutions of the system serve for evaluation of parameters to specify the Pareto frontier for the optimization problem. Given the optimal values of parameters, the solution vectors of the system are obtained to form all Pareto-optimal solutions. With this approach, we derive a complete Pareto-optimal solution of the problem in an explicit analytical form, ready for formal analysis and numerical calculations. As real-world applications, we present solutions to constrained bi-criteria problems in time-constrained project scheduling, decision making with pairwise comparisons and minimax single-facility location.

Thursday, 12:00-13:40

■ HC-02

Thursday, 12:00-13:40 - Room 2

Logistics, Transportation and Traffic 6

Stream: Logistics, Transportation and Traffic (contributed)
Contributed session
Chair: Nuno Ribeiro

1 - A simulation analysis of yard storage management in a container terminal
Bonggwon Kang, Soondo Hong, Annika Marbach, Hans-Dietrich Haasis

A yard storage policy determines an assignment of certain storage areas in a yard for vessels. According to past and recent researches on the yard storage policy, they promise a significant improvement in port operations and can reduce truck service time, yard crane (YC) movement cost, turnaround time of vessels, and overall port performances. This study proposes a storage policy for handling large numbers of vessels and containers in a port. The storage policy considers the estimated workload at a yard block; the partition of a yard block into subblocks; the segregation among different groups of containers; the proximities among containers in a group; and the stack heights of containers. A sophisticated and realistic simulation is developed to investigate the effectiveness of the storage policy and evaluate the truck service time, the number of repositioning, and the vessel turnaround time. Computational experiments are conducted to show the effectiveness of the storage policy in container terminal operations. The simulation result shows that defining a bay as a subblock reduces the need to reposition the YC and vessel turnaround time.

2 - The Aircraft Landing Problem with a U-shape cost function
Allen Zhou, Yao-Huei Huang, Feng-Jang Hwang

The aircraft landing problem (ALP) is a well-known and prominently studied problem in the field of air traffic control since the runways are a meagre resource at airports. The ALP is to assign the landing times to the approaching aircraft at the considered airport such that early and late arrivals are minimised. There are time separation constraints between consecutive aircraft landings, where the separation time depends on the type and size of the landing aircraft. Each aircraft landing is required to be within the time interval between its predefined earliest and latest landing times. In the existing studies, each aircraft landing is associated with a target landing time, any deviation from which will incur a penalty cost of earliness or lateness. To the best of our knowledge, there is no published research investigating the relatively reasonable and practical generalised case in which a target landing time window is considered. Any aircraft landing within the target time window incurs no cost. In this study, new mixed integer linear programs (MILP) are developed to solve the ALP for the minimisation of total weighted earliness and lateness considering target time windows. The computational results will be reported and discussed. The preliminary experimental results indicate the proposed MILPs could be used to produce competitive solutions.

3 - A Passenger-centric Approach to Airport Slot Allocation
Nuno Ribeiro, Phillip Schmedeman, Sebastian Birolini, Alexandre Jacquillat

Slot Allocation is the most dominant demand management mechanism used at the busiest airports worldwide. At these airports, airlines need to be assigned slots by a slot coordinator to schedule their flights. Slot allocation is driven by a set of rules and priorities specified in the IATA Worldwide Slot Guidelines. These rules introduce coupling constraints across the allocation of slots, resulting in a highly complex combinatorial problem. While previous models have explored a wide range of approaches to account for the complexity of the problem, they commonly assume a flight-centric approach, which minimizes flight displacement metrics. Nevertheless, minimizing flight displacement does not necessarily translate into the most attractive itineraries for passengers. This paper develops an original passenger-centric approach to airport slot allocation that optimizes slot allocation decisions while maintaining the feasibility of important historical passenger connections. We integrate two primary analytics models: a passenger flow prediction model that uses historical data and machine learning models to predict passenger flows at Changi Airport, and a slot allocation optimization model that optimizes slot allocation decisions accordingly. Computational results yield two main findings: (i) the passenger-centric model can be solved in reasonable runtimes. (ii) the passenger-centric model can vastly increase the number of feasible connections, as compared to the existing models.

■ HC-03

Thursday, 12:00-13:40 - Room 3

Advanced scheduling in theory and applications

Stream: Scheduling, Timetabling and Project Management
Invited session
Chair: Kangbok Lee

1 - Rescheduling production and outbound deliveries when transportation service is disrupted
Chung-Lun Li, Feng Li

Unexpected service disruptions in transportation systems caused by accidents, system breakdowns, poor weather conditions, etc., are quite common. When disruptions occur, rescheduling of vehicles is often needed in order to mitigate the damage caused by the disruptions. In integrated production and outbound distribution systems, a disruption in outbound distribution operation affects not only the delivery plan but also the production schedule. In this paper, we consider a simple integrated scheduling model of production and outbound deliveries with a minimum headway constraint between vehicle departures, and study the situation where an optimal solution of the integrated scheduling model has been obtained but the delivery service is suddenly unavailable for a certain time period due to some unexpected incidents. We would like to determine a new production and delivery schedule in which no delivery takes place during the unavailable period. The objective is to simultaneously maintain a low cost schedule and control the magnitude of changes in the delivery times of the finished goods. We consider three different ways to control the time disruption, and develop polynomial-time algorithms for the corresponding problems.

2 - The LPT rule for identical machines with small jobs
Myungho Lee, Kangbok Lee

The Longest Processing Time (LPT) rule is a well-known approximation algorithm for identical parallel machine scheduling problems to minimize makespan. In the worst-case example, the longest processing time of the jobs is almost two-thirds of the optimal makespan. We expect that shorter processing times will better the performance of the LPT rule. Thus, we consider a problem where the processing times of the jobs are no more than one-k th of optimal makespan. With m identical machines, we consider three cases according to the relationship of m and k. For each of the three cases, we find the worst-case performance ratio as a function of m and k, and analyze its tightness.

3 - Approximation algorithms for bi-criteria scheduling problems
Xiaojuan Jiang, Kangbok Lee

A bi-criteria scheduling problem is a problem to minimize two scheduling objectives. Since a schedule with both minimums cannot be achieved in most cases, a compromised schedule is necessary. The approximation ratio of a bi-criteria scheduling problem is defined as the pair of approximation ratios for both objectives. We consider problems of simultaneously minimizing the makespan and the total completion time on different machine environments. For each bi-criteria scheduling problem, we find a lower bound curve consisting of the approximation ratios that cannot be improved upon and present an approximation algorithm along with its worst-case analysis.

4 - On Polynomial Time Solvable Cases of Interval Selection with Machine-Dependent Intervals
Kenta Nakano, Shao-Chin Sung

We are concerned with an interval scheduling problem, where there are n jobs to be scheduled on m machines, such that each job has a time interval associated with each machine. Each job can be processed on at most one machine within the corresponding time interval, and each machine can process at most one job at a time. The objective is to maximize the weighted sum of scheduled jobs. This problem is called interval selection with machine-dependent intervals. It is shown that the problem is NP-hard even when all jobs have unit weights and unit intervals, and the number of machines is 2. In this study, we show that any instance, with a constant number of machines and the set of jobs which is intervallically visible, can be solved in polynomial time by proposing a dynamic programming based algorithm.

■ HC-04

Thursday, 12:00-13:40 - Room 4

Stochastic optimization via simulation

Stream: Simulation, Stochastic Programming and Modeling
Invited session
Chair: Jun Luo
Chair: *Zhaolin Hu*

1 - Robust Simulation with Likelihood-ratio Constrained Input Uncertainty
Zhaolin Hu

To use simulation models to study the behaviors of stochastic systems, one needs to specify the distribution of the input random variables. However, specifying this distribution precisely is typically difficult and even impossible in practice. The issue is known as input uncertainty in the simulation literature, and it has been considered and studied extensively in recent years. In this paper we model the uncertainty by an ambiguity set that is defined based on the likelihood ratio functions between the true (unknown) distribution and the nominal distribution (i.e., the best estimate), and develop a robust simulation (RS) approach that estimates the worst-case values of performance measures of the random simulation output when the true distribution varies in the ambiguity set. We show that the RS approach is computationally tractable and the corresponding results reveal important information of the stochastic systems and help decision makers make better decisions.

2 - Sequential Ranking-and-Selection Procedures with Adaptive Sampling Rules
Jun Luo

Selecting the best system design from a finite set of alternatives is known as ranking- and-selection (R&S) in the simulation literature. Many procedures, from either frequentist or Bayesian approaches, have been designed in order to solve R&S problems more effectively or efficiently. Typically, frequentist procedures emphasize more on the effectiveness by ensuring a statistical guarantee while Bayesian procedures focus more on the efficiency of using a small number of total samples. In this paper, we aim to take both the effectiveness and efficiency into consideration, from the frequentist approach under the indifference-zone (IZ) formulation. In particular, we explain the barrier of designing adaptive sample allocation rules for many existing frequentist IZ procedures. Then, we propose a fully sequential selection framework which is suitable for various adaptive sampling rules while still pre- serving a predetermined probability of correct selection. Last, we demonstrate both the effectiveness and efficiency of our proposed procedure by comparing with KN and OCBA, two classical procedures in frequentist and Bayesian approaches, through extensive numerical experiments.

3 - How the first-stage sample size affects the efficiency of R&S procedures
Weiwei Fan, Xuewen Li, Jun Luo

Many procedures have been proposed to select the best alternative from a finite set of alternatives, where the best alternative is defined to have the best mean performance. Among these procedures, the frequentist sequential procedures often take a common first-stage sampling to estimate the unknown variances, and then continue sampling and eliminating the inferior alternatives until only one alternative is left. In particular, the elimination is made based on the first-exit direction of the partial-sum difference processes from a given continuation region. Intuitively, the efficiency of these procedures, which hinges on the continuation region, should depend on the number of samples taken in the first stage. However, this issue is often ignored in most of the existing procedures, thus yielding an undesired inefficiency. To address this drawback, we modify the existing procedures by determining their continuation regions based on the first-stage sample size. As a comparison, our new procedures possess much narrower continuation region and thus a higher efficiency. Moreover, to further improve the efficiency, users are allowed to shrink the continuation region at multiple times.

■ HC-05

Thursday, 12:00-13:40 - Room 5

Energy, Environment and Climate 4

Stream: Energy, Environment and Climate (contributed)
Contributed session
Chair: Geun-Cheol Lee

1 - Customized Nonparametric Hedging Model for Electric Utilities: Suitable Basis Selection to Ensure Robustness
Takuji Matsumoto, Yuji Yamada

Triggered by the recent expansion of renewable energy, the issue of hedging risks of profit/loss fluctuations is becoming more important for electric utilities. In this context, previous studies have demonstrated that hedge models using temperature derivatives estimated by the generalized additive model have high hedge effects. Aiming for the practical applications of these models, this study performs extensive empirical analyses and makes methodological customizations. First, we consider three types of electric utilities exposed to risks of "demand," "price," and their "product (multiplication)," and examine the design of an appropriate derivative for each utility. Our empirical results show that the derivatives priced by tensor-product spline function can maximize the hedge effect when a hedger bears a "price risk" with high nonlinearity. In contrast, standard derivatives are more useful for utilities with only "demand risk" in having a comparable hedge effect and in being liquidly traded. In addition, the squared prediction error derivative on temperature has a significantly high hedge effect on both price and product risks, which illustrates its potential as a new standard derivative. Furthermore, spline basis selection can considerably improve hedge effects especially when the model has strong nonlinearities. Interestingly, the hedge effect of temperature derivatives in the previous study is improved by 13-53% by using the new basis with periodic constraints.

2 - Efficient Distribution of Compressed Natural Gas for Sabarmati Gas Limited Fueling Stations in Gujarat, India, with Simulation
Goutam Dutta, Ramesh Kumar, , Sumeetha Natesan, Debjit Roy

Rapid urbanization in Gujarat has led to increased number of vehicles and demand for compressed natural gas (CNG). Given that CNG is economical and environment-friendly, Gujarat has chosen CNG as conventional fuel instead of gasoline for cars and three-wheeler passenger vehicles (autorickshaws). The increased demand for CNG increased the need to develop a city-based gas distribution network. To cater to this need, Sabarmati Gas Limited (SGL) was incorporated at Gandhinagar, Gujarat, which increased the number of CNG refilling stations to supply CNG to cars and autorickshaws. These gas-refilling stations need a proper distribution network to work more efficiently. This study develops a simulation model for efficient distribution of CNG from mother stations to daughter booster (DB) stations to reduce the dry out (no supply) time and increase the efficiency of the CNG distribution network. The mother station supplies CNG to its DB stations using light commercial vehicles (LCVs) or heavy commercial vehicles (HCVs) or both for transportation of CNG. The focus is on reducing the dry out (no supply) time by a simulation model to analyze transportation and resource allocation scenarios of the CNG distribution network, such as pooling or replacing LCVs/HCVs among DB stations, adding more LCVs/HCVs, increasing storage capacity at DB stations, and adding new DB stations. Implementing this model has an estimated savings of about INR 1.3 million per year for SGL.

3 - Seasonally adaptive methods for the short-term load forecasting in South Korea
Geun-Cheol Lee

In this study, the short-term load forecasting (STLF) problem in South Korea is considered. Due to its importance and ever-changing energy environments, the STLF problem has been studied by many researchers for decades. South Korea is located in a region where the four seasons are clear, and such seasonal changes are one of the major factors affecting the short-term electricity demand. Moreover, in a large manufacturing country like South Korea, much of electricity consumption is driven by the industry rather than the residential side. Taking into account such features of South Korea's electricity demand, in this study, we combine several season-specific load forecasting methods, such as, summer, winter, and all-season regression models, and explore the best mix of the models which is appropriate for the demand patterns at the time. In additions, the work schedules of the manufacturing industry, which has a significant impact on the electricity demand are reflected on the models. The performance of the proposed model is evaluated through the extensive computational experiments. Forecasts obtained by the proposed model are compared with those obtained by the various existing forecasting methods, which will show the superiority of the proposed model. Additionally, the effects of the particular features of the proposed model are analyzed, which will reveal the basis for excellence of the proposed model.

4 - Development of strategic deployment methodology for hydrogen charging stations
Hyunjoon Kim, Myungeun Eom, Byung-In Kim

The Republic of Korea plans to expand the use of hydrogen vehicles and has set yearly targets for distribution by 2040. Hydrogen charging stations are very important for expanding the use of hydrogen vehicles. This study attempts to solve the hydrogen charging stations location problem. Due to the high installation cost of hydrogen charging stations, it is difficult to install enough number of hydrogen charging stations that cover all the planned hydrogen vehicles simultaneously. Korea plans to install a limited number of hydrogen charging stations yearly. Because a limited number of hydrogen charging stations with certain capacity cannot accommodate all hydrogen vehicles within a certain distance, it is important to strategically determine where to install the stations. In this study, we aim to locate the hydrogen charging stations to maximize the number of covered hydrogen vehicles as well as to minimize the sum of the travel time between the hydrogen vehicles and the hydrogen charging stations. We will describe how the estimated number and location of hydrogen vehicles are determined in residential areas and express highways. To solve the location problem, we propose two-stage sequential mixed integer programming models and an improvement heuristic algorithm. The results for 2022 to 2040 will be presented.

■ HC-06

Thursday, 12:00-13:40 - Room 6

Quantitative methods in finance and risk management 1

Stream: Computational and Simulation Methods in Finance
Invited session
Chair: *Dohyun Ahn*

1 - Liquidity, investment, and debt overhang
Nan Chen, Yuan Tian, Jiahui Ji

We develop a theoretical model of dynamic investments, dividend payouts, debt borrowing, external equity financing, and bankruptcy for financially constrained firms. The model characterizes the central importance of liquidity management in corporate decision making in the presence of external financing costs. Mathematically, to solve the recursive equilibrium of the problem to determine the equity and bond values, we formulate it as a variational inequality with a fixed-point structure embedded. Our model generate rich implications. Particularly, we find that the debt may yield two opposing effects. Debt issuance provides an alternative way of financing the firm's investments when it has limited liquidity, but excessive debts will lead to severe underinvestment.

2 - Large-scale financial planning via an extended stochastic dual dynamic programming framework
Yongjae Lee, Jinkyu Lee, Do-Gyun Kwon, Jang Ho Kim, Woo Chang Kim

A multi-stage stochastic programming (MSP) approach has been widely used in financial planning problems thanks to its flexibility. However, the size of MSP problems grows exponentially with the number of stages, making it easily intractable. Because financial planning problems tend to consider several decades of planning horizon, the curse-of-dimensionality issue of MSP is a critical limitation. In this regard, stochastic dual dynamic programming (SDDP), a sampling-based decomposition algorithm, has attracted researchers' attention in resolving the curse of dimensionality issue of MSP. The SDDP has been actively implemented in energy domain, whereas a limited number of applications of SDDP can be found in finance domain. In this paper, we identify major obstacles of the classical SDDP for solving financial planning problems. We then extend the algorithm using some recent advancements in SDDP to overcome the limitations. By modeling uncertainties using discrete Markov states and introducing feasibility cuts, we argue that SDDP can properly address large-scale financial planning problems.

3 - Asymptotic optimal impulse control of interest rate under slowly varying stochastic volatility models
Chi Seng Pun

In this paper, we study the optimal central bank intervention of interest rate problem, where the interest rate process is modelled by an Ornstein—Uhlenbeck (mean-reverting) process with a slowly varying stochastic volatility. The objective of the central bank is to maintain the interest rate close to a target level, subject to fixed and proportional costs of interventions. The problem is formulated as an impulse control problem, which is being converted to a free boundary problem by adopting an ansatz of a band policy. Due to the complexity introduced by the stochastic volatility, there is no analytical solution to the free boundary value problem in the literature. This paper apply a regular perturbation approach to derive an asymptotic solution to the value function and the optimal impulse control (intervention).

We rigorously proved that the zeroth-order approximation of the optimal impulse control is associated with the first-order approximation of the value function. Moreover, we show that this zeroth-order suboptimal impulse control is asymptotically optimal in a specific family of impulse controls.

4 - Negative Income Shocks and Asset Pricing
Seyoung Park, *Steven Kou*

Rare but large negative income shocks can occur due to pandemics, technological disruption, etc. We study the impact of these shocks on asset pricing by adding them to the classic Friedman's permanent income hypothesis. Our model yields analytical solutions for the equilibrium interest rate and state price density. The income shocks can lead to interesting phenomenon that the equilibrium interest rate is a decreasing function of the risk aversion, helping to disentangle the risk-free rate and equity premium. As a result, the model can fit both low risk-free rate and high equity premium by using a small number of parameters.

Thursday, 14:00-15:40

■ HD-01

Thursday, 14:00-15:40 - Room 1

OR for development and developing countries

Stream: OR for Development and Developing Countries
Invited session
Chair: *Youssef Masmoudi*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Elise del Rosario*

1 - Optimisation of road construction alternatives to improve accessibility and economic development in rural Nepal
Andries Heyns, *Robert Banick*

The remoteness of mountainous areas of Nepal limits accessibility to essential services and constrains their economic development potential. The Karnali Province government's Provincial Transport Master Plan has identified a large number of roads to construct across the province, with the aim of improving accessibility to critical services, while also benefitting economic sectors like tourism and agricultural production. The budget available for construction is not large enough for every proposed road to be built and the challenge is therefore to construct a subset of roads which maximises the predicted benefits to rural communities. Since there are multiple objectives with respect to which a combination of selected roads may be evaluated, a number of superior road-combination alternatives may be sought and their trade-offs in objective function values compared to each other before a final decision is made. In this talk we present a novel variable chromosome-length genetic algorithm solution approach which may, in future, be used to determine superior road-combinations. We present examples of solution alternatives determined for the Karnali Province, evaluated using accessibility values to various services determined by a newly-developed cost-time model. When compared to the actual set of roads that were already selected for construction, the results obtained by the new solution approach showed significant accessibility improvements, even at half the budget spend.

2 - Teaching Efficiency in Higher Education: A Non-parametric Analysis for Indian Institutions
Aishna Sharma, *Simanti Bandyopadhyay*, *Tushar Bhageria*

We address following questions: a) How efficiently do Higher Educational Institutions (HEIs) perform in teaching? b) Are they more capable in utilizing resources to produce a targeted level of output or in expanding the output with a given level of resources? c) How efficiency of HEIs varies according to their locations, ownerships, specialisations in courses and age? We estimate the teaching efficiencies of top 101 Indian Higher Educational Institutions (HEIs) using Data Envelopment Analysis (DEA) according to their location, ownership, specialisation of courses and age. We find that Indian HEIs on an average can expand their output by 32 per cent. But when we look at the input efficiency results we find that on average Indian HEIs can save their resources by 21 per cent and produce the same level of output. The input efficiency is consistently higher than the output efficiency. The HEIs located in Southern region perform the best, whereas HEIs located in the Western region perform the worst. The private HEIs perform better than the public HEIs. The HEIs specialising in non-professional courses perform better than those specialising in professional courses. The old HEIs perform better than the young. The young public HEIs have their efficiency barely at 50 per cent. Young private HEIs specialising in non-professional courses perform better than the old public HEIs specialising in professional courses. Overall teaching efficiency of the HEIs in India is low.

3 - System for evacuation and intermodal relief logistics during disasters
Oscar Rodriguez-Espindola, Pavel Albores, Hossein Ahmadi, Diego Alonso Gastelum Chavira, Omar Ahumada

The inflow of relief to the affected areas after disasters can create challenges such as congestion in entry points and delays in delivery. Decision-making support systems need to account for the possibility of intermodality in disaster relief operations given the different potential sources of relief and the potential of overflow, especially at the initial stages. At the same time, although the urgency in relief operations precedes environmental considerations, optimising evacuation allocation and the flow of relief whilst minimising carbon emissions can be achieved through the coordination of activities and resources. This research aims to introduce the design of a system to optimise the selection of shelters, allocation of human resources, and fair distribution of relief considering CO2 emissions. The system is based on interviews with civil protection authorities in Mexico and their continuous involvement. This presentation introduces a novel two-stage bi-objective stochastic formulation for disaster preparedness and immediate response aiming to minimize operational and environmental cost and maximize the number of people served. A case study in Mexico is undertaken to test the system and share the results with stakeholders and users. The analysis shows the advantages of introducing intermodality in the formulation and the potential reduction of CO2 emissions that can be achieved in humanitarian operations.

4 - An arc routing model for mosquito control
Matheus Andrade, Fábio Usberti, Rafael Kendy Arakaki

Between the epidemiological weeks 2 and 21 of the year 2020, more than 1,6 million cases were reported of arboviral diseases in the Americas. Among those, 97.3% were dengue cases (164.18 cases per 100,000 population). Between those same weeks, more than one million cases of dengue were reported in Brazil. In areas affected by or at risk of dengue, a form of control of both the disease and the biological vector proliferation is to reduce the mosquito breeding sites. The first step is to locate, within the city blocks, the hotspots of breeding sites. With this information, coordinated actions can target these hotspots for intensive vector control. Among the techniques used in the vector control stands out the application of insecticides in ultra-low volume by employing nebulizers attached to vehicles. This technique is very effective for the control of outbreaks because it eliminates the adult mosquito population and it has high widespread, reaching 80 to 160 blocks per day. This work combines operations research and dengue vector control by proposing an arc routing model for insecticide nebulization of mosquito breeding sites. The proposed methodology is tested with real-life networks from the city of Campinas, Brazil. The experimental results show optimal solutions for all considered scenarios, indicating the methodology's effectiveness in reducing the operational costs.

■ HD-02

Thursday, 14:00-15:40 - Room 2

New Product Development in Supply Chains

Stream: Supply Chain Management
Invited session
Chair: Tobias Potoczki

1 - Supply chains of mobile apps: Competition, private labels and bypassing when the app's quality is co-created
Tatyana Chernonog

This work deals with issues characterizing the mobile app industry. In particular, we focus on an app developer who competes against either a rival app developer or a private label of the distribution platform, and who can bypass the platform's distribution and billing systems. The innovation of this work lies in considering the co-creation of app quality by the app developer and the distribution platform while using a revenue-sharing contract, which is popular in the mobile app industry. We investigate both tactical equilibrium (the parties' operational decisions for a given market structure) and strategic equilibrium (for the developer — whether or not to bypass; for the platform — whether or not to discourage bypassing by improving the contract terms). Our research provides answers to the following strategic questions: Is it beneficial for the app developer to bypass the distribution platform and offer the app to users directly in a competitive environment? Is it beneficial for the distribution platform to introduce a private label to compete with the app developer? Can bypassing also be beneficial for the platform and/or the rival developer? In response to these questions, several counter-intuitive results are revealed.

2 - Co-creation of mobile app quality in a bi-platform supply chain
Priel Levy, Tatyana Chernonog

Mobile apps development is a fast growing industry nowadays, with Google Play and App Store being the two largest distribution platforms, providing app developers a global coverage of audience. While each platform has its own captive app users, developers have the freedom to distribute their app via either one single platform or both of them. In the latter case, developers should create two versions of the app, differing in their conformance quality (dictated by the platform) but coinciding their design quality (defined by the developer). The innovation of this work lies in considering the co-creation of app quality by the platform and the developer using a revenue-sharing contract, which is popular in the mobile app industry. We analyze a supply chain of mobile apps, where a strategic developer chooses how to distribute his app—via both platforms or via one of them, so each platform might lose the contract and has a priori to strategize accordingly. Equilibrium analysis is given for two market power structures: horizontal power balance (both platforms simultaneously offer their contract) and horizontal power imbalance (the platform-leader has the right to offer the contract terms first). Several counterintuitive properties of the equilibrium are obtained, in particular regarding the first-move advantage, the mutual effect of the platforms market conditions on the app quality and the conditions under which the developer prefers to distribute his app via a single platform.

3 - New product development with technology uncertainty and the effect of upstream supplier competition
Minxin Wu

This study investigates the problem of new product development with technology uncertainty in a supply chain comprising two competing suppliers and a single manufacturer. In this supply chain, the manufacturer playing the role of stackelberg leader determines the design quality of the product. The two suppliers are in charge of developing the product the manufacturer need and determine the conformance quality to design specification. Using the principal-agent model and taking R&D uncertainty into account, we propose an analytical framework that investigates the effect of upstream competition in new product development. Rich managerial insights into supply chain innovation are provided by analyzing the equilibrium behaviors of decision variables (design quality, the suppliers conformance quality) with respect to three aspects: market and market share, customer preference and cost.

4 - Design of distribution systems in grocery retailing
Tobias Potoczki, Andreas Holzapfel, Heinrich Kuhn

We examine a retail distribution network design problem that considers the strategic decision of determining the number of distribution centers (DC) as well as their type (e.g. central, regional, local) and anticipates the tactical decision of allocating products to different types of DC. The resulting distribution structure is typical for grocery retailers that choose to operate several types of DC storing a distinct set of products each. We propose a novel model considering the decision-relevant costs along the retail supply chain and present a case study of a major European retailer.

■ HD-03

Thursday, 14:00-15:40 - Room 3

Logistics, Transportation and Traffic 2

Stream: Logistics, Transportation and Traffic (contributed)
Contributed session
Chair: Ying Lian

1 - Aggregate probabilistic modelling framework to evaluate business resiliency in transport sector
Aristi Karagkouni, Dimitrios Dimitriou

The ability to absorb and adapt in a changing environment of both incremental changes and sudden disruptions is widely mentioned as business resiliency, which is the cornerstone of dynamic risk management. Hence, the quantification of business risks is an essential counterpart of the decision process, especially, for capital intensive investments in transportation where financing long-term payback period may rise high provisions in the business plans. This paper objective deals with the development of a business resiliency evaluation framework for the transportation sector. The modelling approach is based on discrete modelling, where the aggregate value of resiliency is driven by three state variables determined as continues functions over time. The continues in time state functions adjust the outputs in terms of the demand variations probabilities; the supply chain services conditional probabilities (including contingency) to adapt changes and mitigate risks; and the impact severity dealing with the socioeconomic effects. The assessment framework provides results regarding the impact in terms of cost and business contingency for unpredict events (e.g. climate change) and times over high uncertainty (e.g. COVID-19 pandemic period). The numerical application will illustrate essential messages to planners, managers and decision makers in transportation sector business ecosystem, providing results for economies with high seasonal travel demand such as the south Europe region.

2 - Stochastic modelling for assessing business attractiveness in the shipping sector.
Dimitrios Dimitriou, Georgios Sklias

Shipping business environment is maybe the most deregulated in transportation sector, where business performance impacts the commodity prices and business attractiveness related to stock market prices.For the shipping companies, the volatile business environment and the capital-intensity nature of the industry can create liquidity and cash flow problems, especially, in times of unpredicted market changes.The purpose of this paper is to present a dynamic performance evaluation tool based on stochastic modelling approach that can enhance decision making capabilities.Performance assessment modelling framework based on Markov Chains formulation,where the key input states will include the variation of three categories of impact:(a)price of commodities,including crude oil,coal,and LNG;(b)economic development indicators such as GDP, purchasing power and socioeconomic indicators; and(c)shipping industry conditional performance issues, such as existing and orderbook fleets.The performance objective function will provide aggregate results for each shipping category, by extrapolating results over time in three dimensions:revenues and profit maximization, opportunity cost minimization and fleet usage optimization. The numerical example will highlight key results for shipping industry performance due pandemic Covid-19 time window.Conventional wisdom is to provide an easy-to-handle business intelligence tool to support decision making in the frame of risk management and funding allocation.

3 - The multi-port berth allocation problem with speed optimization: Exact methods and a cooperative game analysis
Bernardo Martin-Iradi, Dario Pacino, Stefan Ropke

In this study, we focus on a variant of the Berth Allocation Problem (BAP), which aims at assigning berthing times and positions to vessels in container terminals. The problem, known as the multi-port berth allocation problem (MPBAP) extends the BAP to cover multiple ports where vessel traveling speeds are optimized between ports, thus exploiting the potentials of a collaboration between carriers and terminal operators. Exploiting a graph representation of the problem, we reformulate an existing mixed-integer problem formulation into a generalized set partitioning problem where each variable refers to a sequence of feasible berths in the ports visited by the vessel. Integrating column generation and cut separation in a branch-and-cut-and-price procedure, the method is able to outperform commercial solvers in a set of benchmark instances and adapts better to larger instances. In addition, we apply methods of cooperative game theory for distributing efficiently the savings of a potential collaboration and show that both carriers and terminal operators would benefit from such collaboration.

4 - Static on-demand bus routing problem with consideration of potential requests
Ying Lian, Kenneth Sörensen

The On-Demand Bus Routing Problem (ODBRP) is defined as large-scale dial-a-ride problem with bus stop selection, where the route is completely determined by the passengers, and each passenger may have alternative stops to get on/off. The static case assumes requests are known before routing and scheduling. In this case, as the objective is to maximize the total number of served passengers, there is a possibility to lose the potential passengers that can be easily integrated into the solution. One way to make this model more realistic is, we also take into consideration potential requests along or nearby the bus routes, when routing and scheduling according to the current requests list, while the known requests have priority. The potential requests are expressed by time-variant probability. Thus the objective function also includes the expected value of incoming passengers that will be served upon arriving those stops. The problem is solved by large neighborhood search. Experimental results with artificial data show the effectiveness of this proactive method.

■ HD-04

Thursday, 14:00-15:40 - Room 4

Stochastic modeling and simulation in engineering, management and science

Stream: Simulation, Stochastic Programming and Modeling
Invited session
Chair: Felix Grumbach

1 - A Quantum Algorithm for optimising venture capital portfolios
Sanjeev Naguleswaran

A typical Venture Capital investment strategy relies on picking at least one company that will provide a return high enough to offset losses even if all other companies in the portfolio fail to provide returns. Therefore, the optimal portfolio requires identifying companies with a high probability of achieving large returns. We propose that by simulating the startup eco-system as a Brownian motion model with data driven drift and diffusion parameters, we can provide more rigour and insight in this challenging decision-making scenario. The company attributes corresponding to explanatory variables, such as Industry sector, Product-Market Fit, Founding Team etc. can be used to determine the drift and diffusion parameters. Time varying coefficients are used in the model to accommodate change in the magnitude of drift and diffusion through the evolution of a company. The level of diffusion would correspond to startup energy (or returns) and a successful winning investment such as an exit would be represented and predicted by the crossing of a pre-defined energy level. These levels are determined by analysing previous data and back-testing through simulation. Given that the model is based on a well understood physical system that has quantum effects, we will also show that this method is amenable to using more computationally competitive quantum algorithms that have the potential to solve larger scale and currently intractable scenarios.

2 - Digital twin optimises container terminal handling
Holger Schuett, Hoon Lee

Container terminals are under pressure forced by all stakeholders to serve bigger and bigger vessels with more cargo per arrival in shorter times. Digitisation and automation are providing some opportunities to optimise the handling processes, but still the strategies built in the terminal operating system (TOS) are the kernel for high efficiency. The paper will present a solution, which is based on a simulation model directly connected to a TOS. The current state of all processes, the equipment and the container inventory within the model is updated in real time. Using this digital twin to forecast the future operation based on the planned strategies allows the combined system (TOS + digital twin) to detect bottlenecks before they occur. In this way warnings about potential delays in vessel departures may be shown to the planner and he or (in the future) AI-based algorithms may (automatically) optimise the strategies to avoid them. The approach has been funded in several Korean-German research projects between research organisations (universities from Busan and Bremen) and industrial partners of both countries.

3 - Problem-oriented initialization of discrete simulation models for a socio-technical shopfloor scheduling
Felix Grumbach, Pascal Reusch

Job Shop Scheduling Problems (JSP) are becoming more extensive to depict real planning situations. A current research trend is, to interlink the physical shopfloor with a digital twin for more realistic analytics. It can be assumed, that simulation-based optimization will gain importance in context of predictive and reactive scheduling. It is fueled by the fact, that AI research has achieved great success in recent years. E.g., reinforcement learning agents (RLA) can explore environments in a self-learning manner. However, it is a complex matter to develop precise simulation models. A key challenge is to reduce the real-world situations to its essential components. Our research is focussed on dual resource JSP in manufacturing. Based on current literature and case studies, we mapped identified parameters and dependencies into a object model (OM). First, the OM represents a live interface to the shopfloor (enables reactive scheduling). Second, the OM is used to generate a simulation environment automatically. Third, the OM can be used for forecastings (enables predictive scheduling). We have found that it is effective to integrate even complex scenarios in this way. We have developed a generic, expandable and adaptable framework for a problem-oriented simulation, which can be initialized with live data. In detail we describe the OM, a generic simulation routine and a constraint module. Followed by an outlook on how RLA can be implemented on identified decision nodes.

■ HD-05

Thursday, 14:00-15:40 - Room 5

Individual behavior and implications to operations management

Stream: Behavioral OR
Invited session
Chair: *Yang Zhang*

1 - Product Variety and Quality Perception for Innovative Products
Haoyu Liu

Technology companies frequently face the problem of product variety decisions for their innovative products. The quality of innovative products consists of two parts, the part familiar to the consumers and the part not. The existence of the unfamiliar part makes results in previous studies on product variety unsuitable. In this paper, we build an analytical model to answer this problem. Consumers whose attentional resources are costly, make purchase decisions by evaluating both the design and quality of the product, and the technology company decides how great the product variety should be. Our analytical model is accompanied by experimental evidence, which provides strong support for our model. The contribution of our paper is threefold. First, the model fills a vacuum in the literature on product variety decisions by considering both horizontal and vertical dimensions. We reveal a tradeoff between product fit and perceived quality. Second, the experiment helps with understanding how consumers choose innovative products from a consumer behavioral viewpoint. We suggest that the impact of product variety on quality perception is not merely a result of signaling. Third, we also provide practical guidelines and important implications for marketing managers. We present a novel incentive for firms to limit product variety.

2 - Supplier Bottleneck and Information Dissemination
Yue Li, Yang Zhang, Meng Li

This paper investigates the capacity decisions of complementary suppliers who produce different components of a product. The suppliers solicit private forecast information from a retailer who has more precise information as compared to the suppliers regarding the market. In this context, the lowest capacity built among suppliers—termed as effective capacity—represents the bottleneck of a supply chain, which in turn determines the supply capacity of the entire channel. Standard analysis posits that the capacity decisions of suppliers are based on their prior belief of demand, with no consideration of the retailer's information dissemination or the number of peer suppliers. We test the predictions experimentally, and our laboratory observations reject the prediction of standard analysis. We then develop a behavioral model based on suppliers' heterogeneous updating process regarding the market demand, given the retailer's information dissemination. We analytically indicate that suppliers lower their capacities as the number of suppliers increases, thereby exacerbating the supplier bottleneck. While the retailer may exaggerate the market demand to ensure abundant supply, the inflation can interestingly benefit suppliers by increasing their capacity levels. In this manner, the inflation of the retailer can serve to mitigate the supplier bottleneck, thereby resulting in a win-win outcome for both the suppliers and the retailer.

3 - Predicting the production quality risk of individuals in manufacturing: from empirical experiments to a predictive model
Clint Steed, Namhun Kim

Purpose - In this study we conduct experiments to quantitatively compare the relationship between human fatigue and quality in manufacturing assembly tasks. Our ultimate goal is to construct a model to predict the production quality risk of a human individual. Design/methodology/approach - We developed a VR simulation in which subjects perform common assembly tasks. We measure the tasks dimensional error as the quality indicator and time-of-day, task complexity, task duration, previous workload, etc. as fatigue factors. Findings - We observe known phenomena such as (1) learning reduces the task time for untrained subjects, and (2) poor ergonomic placement increased risk to quality. Moreover we observed a strong correlation between quality risk and time-of-day. The effects of task complexity are not so obvious and we are yet to decipher them. Research limitations/implications - The model developed can be used to optimize job schedules to maximize quality. Particularly in the case of jobs with varying duration, complexity, and quality requirements. This model is limited to individual human operators, and should be integrated in a simulation predict system wide behavior. Due to the nature of the virtual reality we cannot investigate the effects of physical fatigue effectively.

■ HD-06

Thursday, 14:00-15:40 - Room 6

Freight logistics

Stream: Logistics in new economies
Invited session
Chair: *Yuyang Zhou*
Chair: *Qu Wei*

1 - Branch and price for the time-dependent green vehicle routing problem with time windows in real road network
Qu Wei, *Guido Perboli*, *Mariangela Rosano*

The ever-growing concern over environmental issues has led many logistics companies to reduce fuel consumption and CO2 emission in their freight transportation operations. This paper investigates a time-dependent green vehicle routing problem based on real traffic speed data in the real road network. We propose a branch and price algorithm to solve this problem and demonstrate the potential benefits for different path selection decisions with respect to the temporal and spatial differences of congestion in real road network. Extensive experiments show that the proposed branch and price algorithm is efficient to solve the investigated problem up to 40 customers in a real road network of Chengdu, a megacity in Western of China. Besides, incorporating the time-dependent lowest consumption path into vehicle routing has several benefits in terms of fuel consumption, CO2 emission and travel time savings comparing to the traditional shortest distance and quickest time path selection decision. The saving of CO2 emission and travel time is up to 4.79% and 6.91% for investigated instances. It is also demonstrated that the benefits would be more significant in the larger size of real road network.

2 - Joint distribution optimization problem for small and medium-sized restaurants
Yuyang Zhou, *Congying Zhao*, *Yuchen Jia*, *Zhenlin Xu*, *Jie Yu*, *Xiping Cong*, *Yang Wang*

3 - Two-Echelon Open Vehicle Routing Problem with Autonomous Mobile Lockers
Jun Li, *Hamidreza Ensafian*, *Abdollah Zare Andaryan*, *Michael Bell*, *Glenn Geers*

In this study, Autonomous Mobile Lockers (AMLs) are deployed in a parcel pickup and delivery network to increase efficiency and save cost. AMLs transfer parcels between depots and couriers in the field, so that couriers can continue their tours without having to return to the depot repeatedly. We propose a mixed integer programming model and a hybrid heuristic algorithm to deal with the AML-Courier 2-Echelon Open Routing Problem (AC-2E-ORP), which is a two-echelon variant of the open routing problem (ORP). This problem seeks to determine the tours of AMLs and couriers such that the AML does not have to return to the same depot from which it starts a tour. Likewise, couriers do not have to rejoin the AMLs at the same rendezvous point in the second echelon. We finally carry out sensitivity analysis on key parameters to derive business insights through several numerical experiments.

■ HD-07

Thursday, 14:00-15:40 - Room 7

Emerging applications in data science and optimization

Stream: Data Science meets Optimization
Invited session
Chair: *Kevin Tierney*
Chair: *Xing Xiong*

1 - Forecasting of number of international immigrants in Turkey's sea lane
BaŞak Gever, *Fatma Çarman Çevik*, *Nihat Tak*, *Tahir Khaniyev*

Forecasting of the number of immigrants on the sea lane in Turkey, is examined in this study for the first time. The cost of using several types of vehicles to catch illegal immigrants can be extremely high. For both minimizing the expenditure problem and providing a proper scan, the route of the assigned vehicles as well as their types should be optimized. To do so, the volume of the immigrants over the sea line of Turkey is forecasted. Thus, the cost regarding control over maritime lines can be optimized accordingly. In order to obtain predictions for 2020, the daily dataset of the number of located international immigrants and their corresponding coordinates acquired from "Republic of Turkey Ministry of The Interior Coast Guard Command" for the last five years. To make precise predictions, the coordinates are clustered as latitude based into four regions. Seven distinguished forecasting methods from simple to complex, are implemented to reach out the most accurate results. Then, the Forecast Combination Approach with Meta Fuzzy Functions is proposed, which combines all methods. Consequently, the results are acquired and evaluated by using R. Evaluation of the results are made by using widely considered measurement accuracy metric Root Mean Square of Errors. According to the final assessments, the proposed approach gives the most accurate forecasts for the number of immigrants on Turkey's maritime line.

2 - A failure-based data-driven approach for advancing preventive maintenance
Heletje van Staden, *Laurens Deprez*, *Robert Boute*

We investigate whether observed machine failures may be used to prescribe advancements of scheduled preventive maintenance interventions. By estimating future failures, we supplement and improve on current periodic maintenance practices, based on the estimates. We model the problem as a finite horizon Markov decision process with a variable order Markov chain that captures the dependency of a machine's failures on both recent failures and preventive maintenance actions. We validate our model using an original equipment manufacturer data set and obtain policies that prescribe when to deviate from the planned periodic maintenance schedule. To improve our predictions for machine failure behavior with limited to no past data, we pool our data set over different machine classes by means of a Poisson generalized linear model. We find that our obtained policies can improve on those currently applied by the OEM by 5%, on average.

3 - Guiding AI and machine learning models through the economic cycle
Joseph Breeden, *Eugenia Leonova*

Data volume has two dimensions. How many accounts / transactions / do we have, and how much time history do we have? Few Big Data sets cover one full economic cycle. Therefore, ML algorithms will be unable to distinguish between long-term macroeconomic drivers and point-in-time account-level variations. We present a solution to the long-range forecasting problem in ML. We first build a long-range forecasting model on long thin data sets. Then we incorporate this as a fixed input to an ML model. Examples are shown for neural networks and gradient boosted trees as applied to consumer loans.

4 - Data-Driven Robust Dual-Sourcing Inventory Management Under Purchase Price and Demand Uncertainties
Xing Xiong, *Yanzhi Li*, *Wenguo Yang*, *Huaxiao Shen*

We develop an actionable data-driven approach to a periodic-review dual-sourcing inventory management system in the presence of purchase price and demand uncertainties. The two supply sources differ in their lead times and prices due to, e.g., different transportation modes. We adopt robust optimization because the limited historical data is insufficient to construct meaningful distributions to characterize purchase price and demand fluctuations. Specifically, we build a robust rolling-horizon model and, in particular, the uncertainty sets, with data and business insights. Using a four-year data set from a real firm, we show that our approach can yield significant cost savings compared to the other popular methods. Our experiments echoes the

earlier theoretical finding that a firm may incur a lower total cost under a more volatile purchase price process. However, we find that under data-driven decision making, many counter-intuitive results may arise. For example, first, considering a longer planning horizon may backfire. Second, some feasible region-reducing business constraints such as limited inventory capacity may lead to unintended benefits. Third, dual sourcing may not dominate single sourcing. These findings are largely driven by the sampling error and our practically limited ability, as almost always, to characterize uncertainties. Our research therefore calls for prudence in extending theoretical insights to data-driven decision-making scenarios.

■ HD-08

Thursday, 14:00-15:40 - Room 8

Developments in multistage stochastic programming

Stream: OR in Electricity Sector
Invited session
Chair: *Anthony Papavasiliou*
Chair: *Jehum Cho*

1 - SDDP for multistage stochastic MINLP and applications in electricity
Andy Sun, Shixuan Zhang

In this talk we will present a new algorithmic framework that extends stochastic dual dynamic programming (SDDP) to multistage stochastic mixed-integer nonlinear programming (MINLP). We answer an open question regarding the iteration complexity of SDDP in this broad setting. In particular, we show the iterations of the new algorithms are bounded above by a polynomial function of the number of stages of the multistage MINLP, and further we show this upper bound is essentially tight by providing a lower complexity bound. We also demonstrate computational results on applications in the electricity sector.

2 - Envelope Theorems for Multi-Stage Linear Stochastic Optimization
David Wozabal, Goncalo Terca

We propose a method to compute derivatives of multi-stage linear stochastic optimization problems with respect to parameters that influence the problem's data. Our results are based on classical envelope theorems and can be used in problems directly solved via their deterministic equivalents as well as in stochastic dual dynamic programming for which the derivatives of the optimal value are sampled. We derive smoothness properties for optimal values of linear optimization problems, which we use to show that the computed derivatives are valid almost everywhere under mild assumptions. We discuss two numerical case studies, demonstrating that our approach is superior, both in terms of accuracy as well as computationally, to naive methods of computing derivatives that are based on difference quotients.

3 - StoOpt - Comparison of deterministic and stochastic optimization approaches in the German electricity and reserve markets
Christian Furtwängler, Christopher Jahns, Philip Beran, Arne Vogler, Christoph Weber

The profitable exploitation of asset portfolios in the Central European electricity market has become more challenging in recent years. This is particularly true for combined heat and power (CHP) generation units that are often facing must-run conditions due to heat demands that need to be satisfied. Including the use of flexibility from storage technologies is key to optimize power plant operation margins and therefore it is crucial to adequately account for price uncertainties in the European market design. Stochastic optimization is thus frequently suggested for an optimal bidding and dispatch of said portfolios. In our contribution, we program a chain of one weekly and five daily two-stage stochastic optimizations with recourse to identify the optimal bidding strategies for CHP portfolios to all relevant markets, including the Central European electricity markets, i.e. hourly day-ahead and quarter-hourly intraday opening auctions, and control reserve markets, i.e. primary, secondary and tertiary reserve auctions. We test our model by means of a rolling-horizon approach on historical data of the year 2016 and contrast our model's performance with regards to objective function improvement and computation time for various numbers of scenarios. We furthermore benchmark the model against its deterministic representation with and without perfect information.

4 - An application of SDDP to SOCP for active distribution network management.
Jehum Cho, Anthony Papavasiliou

Recent research has demonstrated that real-time auctions can generate the need for side payments, even if the market clearing models are convex, due to the rolling nature of real-time market clearing. This observation has inspired proposals for modifying the real-time market clearing model in order to account for binding past decisions. We extend this analysis in order to account for uncertainty by proposing a real-time market clearing model with look-ahead and an endogenous representation of uncertainty. We define two different types of expected lost opportunity cost as performance metrics. Our market clearing model provides the price signal minimizing one of these metrics using the Stochastic Gradient Descent algorithm. We present results from a case study of the ISO New England system under a scenario of significant renewable energy penetration while accounting for ramp rates and storage.

■ HD-09

Thursday, 14:00-15:40 - Room 9

Multiobjective Optimization 2

Stream: Multiobjective Optimization
Invited session
Chair: *Duleabom An*

1 - A new two-phase algorithm for the bi-objective integer minimum cost flow problem
Lavinia Amorosi, Matthias Ehrgott

In this talk we describe a new two-phase algorithm to generate a minimal complete set of efficient solutions for the bi-objective integer minimum cost flow (BIMCF) problem [1]. For the first phase, we propose the adoption of the dual variant of Benson's algorithm [2] taking advantage of the total unimodularity of the coefficient matrix of this problem. The second phase consists in a new enumerative recursive procedure, based on increasing values of reduced costs of variables in associated weighted linear programs [3]. This procedure is able to generate all integer feasible flows on a connected network. Combined with bounds for the costs of efficient flows, the two-phase method finds a minimal or maximal complete set of efficient solutions. The description of this procedure is accompanied by an illustrative example. Preliminary numerical tests show the effectiveness of the method.

[1] Raith, A., Ehrgott, M., A two-phase algorithm for the biobjective integer minimum cost flow problem. Computers & Operations Research, 36 (2009), 1945-1954. [2] Hamel, A. Löhne, A., Rudloff, B., Benson type algorithms for linear vector optimization and applications, Journal of Global Optimization, 59 (2014), 811-836. [3] Amorosi L., Bi-criteria network optimization: problems and algorithms, Ph.D. thesis, University of Rome, Sapienza (2018).

2 - Multi objective combinatorial optimization FICO Xpress Optimization
Sebastien Lannez, Vincent T'kindt

FICO Xpress Optimization Suite is a set of software that can be used to build decisioning application based on mathematical optimization. It comprises solvers, a modelling language and a modern rapid application development environment. It has recently been extended with a module integrated with the modelling language that can be used to solve multi-objective combinatorial optimization problems. These problems often arise when several nonhierarchical objectives must be taken into consideration (revenue, risk, conversion rate, ...). When the relative priorities between multiple objectives cannot be determined, using algorithms like goal programming does not usually provide satisfactory answers because the user is not offered the ability to compare various solutions. Our approach is based on an algorithm that leverages the epsilon constraint method proposed by Kirlik and Sayin in [1] and can be used to generate complete sets of non-dominated solutions for multi objective combinatorial optimization problems, giving the user the ability to compare multiple nondominated solutions.

[1] Kirlik G, Sayin S, "A New Algorithm for Generating All Nondominated Solutions for Multiobjective Discrete Optimization Problems." European Journal of Operational Research, Vol. 232, pp. 479—488, 2014

3 - A modified sandwich algorithm for nonconvex multi-objective mixed-integer nonlinear programming
Ye Seol Lauren Lee, Amparo Galindo, George Jackson, Claire Adjiman

The application of multiobjective optimization (MOO) is increasingly recognized across a range of engineering fields that identify trade-offs between multiple conflicting objectives. Many engineering applications often need to incorporate discrete decision variables and nonlinear model equations in their mathematical formulation. Such problems are characterized as the class of multiobjective mixed-inter nonlinear programming (MOMINLP). The most common approach to solve MOO problems is the scalarization method that includes the weighted sum method and sandwich algorithm [1]. However, previous research has shown that it is challenging to use such methods for producing reliable solutions along the disconnected and nonconvex regions of a Pareto front. In this work, we present a modified sandwich algorithm to address the numerical challenges associated with the nonconvextiy of the MOMINLP. The main improvement of the algorithm focuses on exploring the nonconvex regions of the Pareto front by combining a sandwich algorithm with a revised Pascoletti-Serafini scalarization method. The performance of the algorithm in its ability to construct an accurate approximation of the Pareto front is compared with the weighted sum method and the sandwich algorithm. The features of the MOMINLP algorithms are evaluated using published benchmark models and it is also applied to a molecular design problem. [1] Rennen, Van Dam, Den Hertog (2011) INFORMS J. Comput, 23, 493

4 - A LP relaxation based heuristic for multi-objective integer programming
Duleabom An, Sophie Parragh, Markus Sinnl, Fabien Tricoire

We investigate multi-objective integer programming problems where there is, in the general case, no solution which optimises all objectives simultaneously. As the number of such solutions usually significantly increases in higher dimensions, it is often not possible to obtain all Pareto optimal solutions within a reasonable time limit. We thus develop a matheuristic based on LP relaxations, which efficiently explores both the decision and objective space and provides a diverse representative set of solutions. We first leverage the multi-objective linear programming solver, BENSOLVE to obtain LP solutions. These solutions are then iteratively processed with a Path-relinking (PR) approach. To find an integer solution, the proposed PR variant chooses two solutions that represent the starting and ending points of the path from the lower bound set (LP solutions). Then, we build intermediate paths that link the pair of solutions in a neighbourhood space. At this stage, the fractional value of the lower bound is rounded down and up to be converted into an integer number, and the adapted solution becomes one of the paths. While exploring paths, the algorithm collects integer feasible solutions. An extensive computational study on standard benchmark instances, three-objective facility location problems and general three-objective binary integer programming based on MIPLIB instances is done to compare the performance of our method to the benchmark, feasibility pump based heuristic.

■ HD-10

Thursday, 14:00-15:40 - Room 10

Telecommunications

Stream: Applications of OR
Invited session
Chair: Banu Kabakulak

1 - The optimal sub-array division in antenna array by genetic algorithm
Xiaoxin Wang, Suixiang Gao

As the frequency of wireless communication increases and the wavelength decreases, the antenna size decreases accordingly. If we want to maintain the antenna array size and keep the antenna spacing not greater than half-wavelength, the number of antennas will inevitably increase, and the number of phase modulators that adjust the antennas' phases will also increase. However, due to limitations of technology, modulators can't be made small enough. So, it needs to reduce the number of modulators, with maintaining the performance of the radiation pattern. Now we have two choices. Method 1 is to reduce the number of antennas directly. We can encode antennas and phases, then use genetic algorithm to solve it. This is very intuitive and already has some related studies. Method 2 divides the array into subarrays of same shape, antennas in same subarray are controlled by one modulator and have same phases. The difficulty is hard to formulate "what is a division". However, when a division is decided, it's easy to use genetic algorithm to find the optimal phases for every subarray. Therefore, we can combine those two methods to get a better result. We assume that the sparse array from the method 1 has more potential to become a division, and design a backtracking algorithm to transform sparse array into a sub-array division, then put it into method 2. By using this new method, we can get a better result then than the other two in the case of reduce half of phase modulators.

2 - A Multi-Dimensional QoS on Acceptance of OTT Service: Moderating Role of Switching Barriers
Su Jin Kim

This study establishes a research model based on to understand the effects of mobile OTT-related service quality and customization on mobile OTT service acceptance. We analyze the effects of service quality components and customization on user satisfaction. Service quality consists of six factors in three sub-dimensions (interaction quality, service environment quality, outcome quality). Then, we verify how user satisfaction affects continuous usage intention, and how switching barriers as moderator variable affect between user satisfaction and continuous usage intention. This study derived 11 hypotheses from previous studies and performs statistical analysis on users of mobile OTT service. And the reliability and validity of the measurement model were verified. The hypothesis was tested using SPSS-AMOS to analyze the relationship of variables. System connectivity and informativeness significantly affected user satisfaction. Customization significantly influenced satisfaction and continuous usage intention. User satisfaction significantly affected continuous usage intention. Transaction cost (switching barrier) as moderator variables significantly influenced between user satisfaction and continuous usage intention. This study is meaningful in that it identifies the relationship between variables and suggests future research directions for the acceptance of mobile OTT services.

3 - An Optimal Area Exploration Algorithm for the Swarm of Unmanned Aerial Vehicles
Banu Kabakulak

Unmanned aerial vehicle (UAV) is an autonomous device which has the ability of sensing events in a region and communicating with other UAVs or a base station. A UAV has limited battery energy and fuel which limits the maximum operational time. Moreover, the technical capabilities of a UAV apply upper and lower bounds on the speed, diving/climbing angle, turning angle and flying altitude. In this study, we consider a swarm consisting of multiple UAVs of different types. We aim to scan a predetermined convex area in order to detect the events within the shortest time via swarm of UAVs. During the mission, each UAV should stay connected to the swarm and there should be a data transmission route from each UAV to the base station. We model the problem as an integer programming formulation and develop a heuristic method for the solution. We test the efficiency of our method on various test instances.

■ HD-11

Thursday, 14:00-15:40 - Room 11

Ethics, fairness and governance

Stream: OR and Ethics
Invited session
Chair: *Cathal MacSwiney Brugha*

1 - Panocracy: People Driving Governance Globally
Cathal MacSwiney Brugha

Governance has always been constraint-driven, shaped by the subjectors of resources, whether corporate or autocratic, who subject and obtain resources for their own ends. Then agencies, whether educational or democratic, project and develop what subjectors have obtained. Next institutions, whether state or bureaucratic, connect and advance what agencies have developed: hospitals, schools, housing, industry. The intention, then, is that communities, whether voluntary or panocratic, would reflect and integrate what institutions have advanced, to benefit the people. Except this doesn't happen. There is no panocracy, no reflecting governance of, by, and for all the people. The alternative is where the goals of the people shape governance. It starts with communities, whether voluntary or panocratic, that reflect people's intentions and integrates them into systems. Then institutions, whether state or bureaucratic, connect and advance what communities have integrated. Next agencies, whether educational or democratic, project and develop what institutions have advanced. Finally, subjectors, whether corporate or autocratic, subject and obtain the resources needed for what the agencies have developed. Except none of this happens. Constraint-driven governance by autocrats and bureaucrats has depleted the planet's air, energy, cannot cope with pandemics. Goal-driven governance needs both democrats and panocrats, and we as governance experts should develop this future.

2 - Preferential sampling method for classifying without discriminating: large one way of addressing the fairness metric
Thais de Bessa, Leonardo Vieira, Bárbara Bianca Alves Cardoso, Gustavo Lacerda, Douglas Vieira

Organizations that automate decisions are being called upon to consider the broader impact the application could have on society, including any possible negative effect. To deal with possible discriminatory outcomes is to address the recently called fairness metrics, and may be part of the company's environmental, social and corporate governance (ESG) sustainability assessment. Rather than being 'hand-written' in a decision-making structure, the discriminatory bias may emerge unexpectedly from decisional rules developed by the algorithm using a biased dataset. This may happen when the algorithm is trained with historic dataset: if the dataset is biased towards certain groups or classes of objects (say, there is racial discrimination towards black people), then the learned model will also show discriminatory behavior towards said group or class. To mitigate bias and promote fairness, there are several approaches. We tested a pre-processing method called preferential sampling (PS), which changes the distribution of different data objects. Since data objects close to the decision boundaries are more prone to be discriminated against, PS changes the distribution of these borderline objects. For this reason, PS is considered less intrusive than data-massaging approaches. Also, PS does not negatively affect performance. Whatever the case, automated decisions should be evaluated not only under performance metrics, but also under fairness metrics. Support: Brazilian CNPQ.

3 - Handling multidimensional efficiency and fairness concerns in public service provision
Damla Akoluk, Ozlem Karsu

We develop two mathematical modelling-based approaches that incorporate multidimensional efficiency and fairness concerns for problems, in which decisions lead to distributions of multiple benefits to multiple users. The first formulation aggregates multidimensional efficiency concerns and multidimensional fairness concerns in a biobjective model. The second one defines the objective functions based on the type of benefit as the total social welfare obtained from a specific benefit distribution. We illustrate and compare these approaches using examples of public service provision problems.

4 - Reconceptualizing "best practices" in public sector
Eftychia Kessopoulou, Styliani Xanthopoulou, Ypatia Theodorakioglou, George Tsiotras, Katerina Gotzamani

Public sector managers frequently herald that implementing best practices as a set of standards, may lead to superior organisational performance. Research though highlights the inability of public sector organisations to develop innovative administrative practices, as well as the adoption of stereotypical practices inculcated in the public sector by international governance bodies. The process through which organisations construe what a best practice is, still remains a black box that is yet to be investigated. This study aims to describe and understand how organisational best practices are constructed by public sector performance management teams during the benchmarking-mediated performance improvement process and what mechanisms enable this construction. A critical realist action research methodology is employed, starting from a description of various approaches on best practice nature when a benchmarking-mediated performance improvement initiative, is applied. Then the different perspectives emerged were reflected on the design and implementation of an interview protocol. Thirty semi-structured interviews were conducted with "best practice" process owners, in order to examine their experiences and performance needs.Findings of this work include a causal account of the nature of best administrative practices in the Greek public sector that shed light on explaining their management and a description of the various contexts affecting best practice conceptualisation.

Thursday, 16:30-17:45

■ HE-01

Thursday, 16:30-17:45 - Room 1

Plenary: Max Shen

Stream: Plenaries
Plenary session
Chair: *Janny Leung*

1 - Honors & Awards: ITOR Best Paper Awards
M. Grazia Speranza

2 - Analytics for Wildfire Management
Max Shen

With climate change, the already serious problem of forest fires is clearly becoming increasingly troublesome. This is happening in vast forest areas as well as in the transitional zone between urban and rural areas, with grave consequences to the population living in or near forests. Analytic tools have been developed to determine what resources need to be in place, such as airplanes, helicopters, crews, and equipment, to help suppress fire. Once a fire has started, simulation models of fire spread have been quite successful in predicting the direction of fire to support decisions on how to deploy such resources. Less emphasis has been given to preventive Landscape Design or Fuel Management, which leads to decisions on how to manage forests to minimize the impact of fires once they start. These decisions include harvesting, prescribed burnings, and others. This talk will present the different tools we have developed in this problem area. Our main effort is on the integration of prediction analysis of fire ignition and spread, and the decisions on landscape design. The techniques used include stochastic simulation, derivative-free optimization, machine learning, optimization, heuristics, and deep learning. We have applied these techniques in a preliminary way in Chile, Spain, and Canada with the aim of translating research efforts into practical applications.

Thursday, 18:00-19:40

■ HF-01

Thursday, 18:00-19:40 - Room 1

Keynote: Prashant Yadav

Stream: Keynotes
Keynote session
Chair: *Matthias Ehrgott*

1 - COVID-19 and the Global Supply Chain for Medical Products
Prashant Yadav

The COVID-19 pandemic has exposed the vulnerabilities of supply chains across many industries, but nowhere has it caused more suffering than in the supply chain for medical products including PPE, vaccines, testing supplies and therapeutics. Enhanced public scrutiny of the medical supply chain is resulting in policy makers taking drastic steps to require onshore production, engage in export controls, and vaccine nationalism. This talk will share with how flexibility in the vaccine and health product manufacturing and distribution network and better information tools can help us get to a better equilibrium. I will highlight the types of OR models which can inform such efforts. I will also share some early ideas on research questions arising from the global planning for pandemic preparedness.

■ HF-02

Thursday, 18:00-19:40 - Room 2

Financial econometrics of cryptocurrency markets

Stream: Contemporary Issues in Cryptocurrency Markets
Invited session
Chair: *Thong Dao*

1 - External Uncertainties and Cross-Market Convergence in Bitcoin Markets
Jeremy Cheah, Ming-Chien Sung, Johnnie Johnson, Jinqiang Ye

This paper proposes an innovative process, which captures and explain dynamics in Bitcoin cross-market convergence behaviour. We scrutinize the existence of linkages between convergence behaviours and external uncertainties based on aggregate market and individual markets. We find Fear sentiment originated from conventional markets speeds up consensus formation among bitcoin markets, after controlling for fundamental and technical aspects of bitcoin markets, extreme market conditions (viz., bubbles and crashes), and general attention. Our findings suggest FEAR sentiment given by real economy can explain and predict patterns of consensus among Bitcoin market, which shed lights on the fact that participants in Bitcoin markets are adaptive to information flows from real economy, rather than purely isolated as designed. Our study brings hints for understanding the mechanism of Bitcoin price formation process as well as trading strategies based on cross-market signals.

2 - Herding Intensity and Speed of Adjustment in Virtual Currencies
Thong Dao, Jeremy Cheah, Tapas Mishra, Linzhi Tan

The speed at which disequilibrium errors are corrected, can determine investors' choice of cross-market investment strategy in a virtual currency. A major challenge concerns identification of the hidden driver

of this speed. In this regard, we advance the role of herding intensity as a primary determinant of the speed of adjustment (SA). We dynamically generate SA and employ a hierarchical Probit model to demonstrate that a higher herding intensity improves the likelihood of Bitcoin markets to diverge from their long-run cointegrating relationship. We find that even a small rise in herding intensity enlarges divergence probability by more than 7%.

3 - Speed of Adjustment and a Responsiveness Index in Bitcoin Markets
Linzhi Tan, Jeremy Cheah, Tapas Mishra, Thong Dao

For investors, a temporal deviation of Bitcoin prices from its long-run equilibrium has strong implications for their decision making and trading performance. By modelling time-varying behaviours of speed of price adjustment, we produce a novel relative responsiveness index to demonstrate disproportionate speculative profit opportunities and risks across Bitcoin markets. Importantly, we also investigate potential determinants of price adjustment and reveal the positive impact of trading volume and Google trends on the probability of fast price adjustment.

■ HF-03

Thursday, 18:00-19:40 - Room 3

Project management and scheduling

Stream: Scheduling, Timetabling and Project Management
Invited session
Chair: Harshal Lowalekar

1 - Graph-based representation and state-space reduction for final exam scheduling
Szilvia Erdős, Bence Kovari

Scheduling has been a heavily researched topic in the past decades. Final exam scheduling is a special subtopic of scheduling, which possesses several unique requirements in comparison to production optimization.

In our paper, we present a graph-based representation for the problem and discuss the mapping between the domain-specific elements and the graph representation.

The various resources (like timeslots, instructors, students, rooms, programs of the exams, etc.) are represented by the vertices of the graph. Their connections are defined in different ways at the edges of the graph.

Both hard and soft requirements can be represented by the proposed model. For the former, certain rules are applied, while for the latter, a weight system is introduced for the edges.

Although this representation can directly be mapped to an integer programming task, we can still simplify it by the systematic elimination of unnecessary connections, thereby significantly reducing the state-space.

Our solution is competitive against other IP-based representations, and given the same circumstances, it produces better runtime results.

Acknowledgement The work presented in this paper has been carried out in the frame of project no. 2019-1.1.1-PIACI-KFI-2019-00263, which has been implemented with the support provided from the National Research, Development and Innovation Fund of Hungary, financed under the 2019-1.1. funding scheme.

2 - A predictive - prescriptive approach for Telco's project management applications
Gianmaria Leo, Ruggiero Seccia, Hanadi Wali

Project Scheduling is a crucial business practice that ensures profitability and economic sustainability in companies. We focus on a real-world use-case at a major Middle Eastern Telco Group, where Project Management department is responsible for profitability of strategic projects across the Group. These projects have an important impact on revenue due to the remarkable entity of costs and amount of resources they absorb. The main challenge is to monitor project activities and take prompt corrective actions so as to limit revenue erosion. However, activity durations are affected by highly uncertain factors that might not be captured as structured information.

We focus on a Predictive-Prescriptive approach that supports the entire decision process of Project Management Department. We tested various Machine Learning approaches to predict activity duration; but the accuracy observed does not allow to adopt a purely deterministic scheduling approach. Thus, we introduce a Bi-Level Stochastic Programming model, which better catches the effect of uncertainty at an acceptable computational effort.

We develop two solution approaches: a Monte-Carlo-based heuristic and a Mixed Integer Programming reformulation of the problem. Both approaches improve the current practices adopted in the company and deliver valuable insights to better control and overcome projects' execution risks. Moreover, they proved to be computationally effective leading to either good or optimal solut

3 - Resource-constrained project selection and scheduling problem in multisite context: An integer model
Mauricio Vega-Hidalgo, Lorena Pradenas, Víctor Parada

Project selection and scheduling problems are frequent in different public institutions or private initiatives. In many calls, project selection methods are relevant to maximize the total profit of selection. On the other hand, project scheduling methods are important to use appropriately the limited resources across the time. Sometimes, these resources are distributed in different sites. The state of art shows that is better to consider a joint approach instead of aboard separately the project selection and scheduling. In this work, we can thus formulate a problem as follows: Consider a set of applied projects to be conducted, a set of resources, a set of sites, and a time horizon. Each project has resource requirements, duration, and profits related to timely completion. We can transport some resources between sites, but in certain sites, we cannot use certain resources. Therefore, we consider a transportation time when we need the same resource in different sites. Furthermore, there is a subset of projects included in the schedule. The objective is to select and schedule projects in multiple sites such that they maximize the total profit. In this work, we propose an integer model that represents this problem. We generate random test instances, of different sizes, that simulate real-life situations and solve them with CPLEX. For small instances, we can obtain optimal solutions, but for bigger instances, we can only obtain feasible solutions after 3600s of execution.

4 - Implementing theory of constraints (TOC) in a furniture manufacturing company
Harshal Lowalekar, Shelja Jose Kuruvilla

We demonstrate the application of Theory of Constraints (TOC) in a large furniture manufacturing firm in India. Using the current-reality-tree method the root cause behind the company's major problems was identified. The lead times in delivery were substantially reduced, the on-time-delivery performance was improved and the work-in-process and finished goods inventory levels were drastically reduced using the simplified-drum-buffer-rope method. The raw-material availability also substantially improved due to TOC approach. Critical chain project management technique was implemented for engineered-to-order projects. Using the TOC approach the profitability of the company was improved substantially within a short span of time.

■ HF-04

Thursday, 18:00-19:40 - Room 4

Applications of integer programming

Stream: Combinatorial Optimization
Invited session
Chair: *Jørgen Skålnes*

1 - A new formulation for the inventory routing problem based on customer schedules
Jørgen Skålnes, Magnus Stålhane, Guy Desaulniers, Henrik Andersson

We propose a new formulation for the inventory routing problem with an exact solution method, where each customer has an inventory with a maximum holding capacity and a periodic demand. The decision maker has to make sure the customers have enough products in their inventories to satisfy demand in each time period of the planning horizon. Thus, the decision maker must decide which customers to serve in which time periods, how much to deliver of a product once a customer is visited and how to route the fleet of vehicles in order to minimize transportation cost and inventory holding cost. We propose an improved branch-and-cut algorithm combining the current state-of-the-art valid inequalities with a new concept called customer schedules. Customer schedules contain information about delivery periods for each customer and quantity delivered to a given customer in a given period. Preliminary results show that the new algorithm increases the lower bound compared to existing state-of-the-art branch-and-cut methods. A full computational study on how the different valid inequalities impact the lower bounds and solution times will be presented.

2 - A hybrid metaheuristic for the two-echelon inventory routing problem with lateral transshipments
Edgar E. Córdoba-Sarmiento, Javier Arias-Osorio, Laura Y. Escobar-Rodríguez

Inventory management and vehicle routing are critical elements in today's supply chains. Optimizing these logistics operations improves chain performance, increasing service levels and minimizing associated costs. In a dynamic environment, a multi-period planning horizon is considered. The demand in each period is different, resulting in the need to rethink logistical decisions as the delivery generation, units to deliver, customers to serve, sequence of service, delivery scheduling, inventory policy. In this work, we developed a hybrid metaheuristic for the two-echelon inventory routing problem with lateral transshipments (2EIRPT) integrated with two algorithms: Genetic Algorithm and Tabu Search. In this problem, the demand of the chain's customers is deterministic for each period and can be higher than the fleet's capacity. Customers are served from distributors, where partial deliveries are allowed. Lateral transshipments are only executed between distributors and are carried out with the second echelon's fleet. The proposed metaheuristic is developed and tested using MATLAB R2020a obtaining satisfactory results in its validation.

3 - An MILP model for multi-floor facility layout with elevators
Songsong Liu, Jude Ejeh, Lazaros Papageorgiou

In this work, a mixed-integer linear programming (MILP) model is proposed for the solution of the multi-floor facility layout problem with elevators. As a subclass of the facility layout problem, the multi-floor facility layout problem with elevators aims to simultaneously obtain the optimal spatial arrangement of a set of facilities amongst available floors having elevators for inter-floor material transport. Facilities here refer to physical entities used to perform a task/job, e.g. work centres, departments in an organisation, manufacturing cells, etc, and their layout configurations are known to have a tremendous short and long-term impact on the performance of a system.

The proposed model determines the floor location and position of facilities and elevators, the number of floors and elevators required, the amount of material flow handled by each elevator, the floors each selected elevator services, as well as the minimum material handling cost, fixed and area dependent floor construction cost, area dependent land purchase cost, base and floor dependent elevator installation costs. The model builds on existing works in literature by further determining the elevator footprint per floor and allowing for elevator change along inter-facilities routes if deemed optimal. The performance of the proposed model is tested on a set of examples with a varying number of facilities, inter-facility connectivity and available elevators for installation.

4 - A Lot Sizing Problem in a Co-production Environment
Semra Agrali, Bahadir Pamuk, Z. Caner Taşkın, Banu Kabakulak

We consider a lot sizing problem in a co-production system where it is possible to produce multiple items simultaneously in a single production run. Each product has a deterministic demand which needs to be satisfied on time. We need to decide on which items to co-produce and associated production amounts over a planning horizon. We show that the lot sizing problem with co-production is strongly NP-Hard. We develop a separation algorithm based on a set of valid inequalities, lower bounds based on a dynamic lot-sizing relaxation of our problem and a constructive heuristic that is used to obtain an initial solution for the solver, which form the basis of our proposed Branch & Cut algorithm for the problem.

■ HF-05

Thursday, 18:00-19:40 - Room 5

Learning optimization of production systems

Stream: Metaheuristics
Invited session
Chair: *Stefan Wagner*
Chair: *Roland Braune*

1 - Explainable surrogate models for automated box-type boom design
David Joedicke, Philipp Fleck, Michael Kommenda, Gabriel Kronberger

We have employed explainable machine learning techniques to build surrogate models for the structural analysis of box-type booms. A box-type boom is described by several variables (e.g., plate thickness, number of stiffener elements, or stiffener types). The objective is to find a configuration of the box-type boom so that the material and welding costs are minimized while respecting constraints regarding its structural integrity. A simulation model that takes approximately five minutes to execute for a given configuration analyzes the structural integrity. Hence, evaluating 10,000 different configurations results in an execution time of over a month, which is a major obstacle for automated design methods. Therefore, we have built explainable surrogate models with much faster evaluation speed to avoid this bottleneck and only use the simulation model for evaluating promising configurations. The surrogate models have been created by symbolic regression, which is a nonlinear machine learning method. Symbolic regression builds models in the form of mathematical expressions that are open for inspection and interpretation. We can accurately estimate the structural integrity with symbolic regression models and utilize these models for automated design optimization. Using the described workflow (mathematical problem formulation, surrogate modeling, automated design) we have been able to generate high quality box-type boom designs that only need minor adaptions before deployment.

2 - Open-ended and adaptive optimization of dynamic production and logistics systems
Stefan Wagner, Andreas Beham, Viktoria Hauder, Johannes Karder, Sebastian Raggl

Metaheuristics are well suited for solving hard optimization problems in production and logistics processes. They provide a reasonable trade-off between computation time and solution quality and are therefore frequently applied. In order to guide the search to high-quality solutions effectively and to balance exploitation and exploration of the search space, metaheuristics rely on static quality functions. Therefore, they are usually not able to deal with dynamically arising events, which might occur in production and logistics systems while an optimization algorithm is executed. In order to react on such dynamic events, optimization has to be rerun again. Thus, computation time needs to be limited drastically, which in turn reduces the quality of found solutions.

In the recently founded Josef Ressel Center for Adaptive Optimization in Dynamic Environments, we research on open-ended metaheuristics in order to overcome this drawback. By continuously observing the optimized system, these algorithms can take dynamic changes into account and adapt the search process accordingly by increasing or decreasing exploration of the search space. In this regard, we also integrate machine learning in order to foresee upcoming changes and to control adaption accordingly. In this contribution we will present a generic system architecture for adaptive optimization of dynamic production and logistics processes as well as first results on dynamic benchmark problems.

3 - Classification-based algorithm selection for a multiprocessor scheduling problem
Roland Braune

The subject of this contribution is a multiprocessor scheduling problem with unit time tasks and precedence constraints associated with minimum and maximum time lags. The objective is to minimize the total weighted completion time, where the weight of a task is equal to its size (width). This kind of objective function leads to a resource allocation profile that is "left-shifted" and hence avoids idle time to occur in earlier time periods. In the extreme case, the multiprocessor resource is maximally occupied in all time periods except for the last one, where just some residual load remains. This kind of allocation profile is referred to as an "ideal" schedule.

The goal of this contribution is to predict the existence of an ideal schedule for a given problem instance and, consequently, to choose the appropriate algorithm for exact optimization. An instance that actually has a feasible solution in the form of an ideal schedule could be solved by generating maximal feasible sets of tasks only. Otherwise, a conventional branch-and-bound algorithm has to be used which also enumerates incomplete feasible sets, leading to a higher degree of combinatorics. Promising features are identified based on the problem definition, extracted and used for training various different binary classifiers known from machine learning. First computational experiments show prediction accuracies of around 90% and considerable time savings compared to exact optimization without algorithm selection.

■ HF-06

Thursday, 18:00-19:40 - Room 6

MCDA Methods 1

Stream: Multiple Criteria Decision Aiding
Invited session
Chair: Milosz Kadzinski

1 - Contingent preference disaggregation model for multiple criteria sorting problem
Milosz Kadzinski, Mohammad Ghaderi, Maciej Dabrowski

We propose a new approach for handling inconsistency in the context of a threshold-based value-driven sorting procedure. Specifically, we introduce preference disaggregation methods for reconstructing all assignment examples with a set of complementary preference models. The proposed approach builds on the assumption that the importance of particular criteria or, more generally, the shape of marginal value functions and their maximal shares in the comprehensive value are contingent (i.e., dependent) on the performance profile of a given alternative. Therefore, in case of inconsistency, the set of assignment examples is divided into subsets, each of which is reconstructed by a unique model to be used only if certain circumstances are valid. We present three methods for learning a set of contingent models, allowing different degrees of variation in the contingent models along two dimensions: the shape of marginal value functions and interrelations between the models. To apply such a set for classification of non-reference alternatives, we learn a decision tree which makes the application of a given model dependent on the alternatives' profiles represented by the performances on particular criteria, hence allowing to select an appropriate model among the competing models to evaluate a non-reference alternative. The method's applicability is demonstrated on a problem of evaluating research units representing different fields of science.

2 - A decision support system for MCDA method recommendation
Grzegorz Miebs, Milosz Kadzinski, Marco Cinelli, Michael Gonzalez, Roman Slowinski

We present a Decision Support System (DSS) for selecting a Multiple Criteria Decision Analysis (MCDA) method, which is relevant for a particular case study. The selection is based on the user-specified values of features referring to the particular MCDA process. A few tens of accounted characteristics concern the problem formulation, preference elicitation and types of admitted preference information, desired features of a preference model, and construction of the decision recommendation. The questions asked to a user are split into manageable and justifiable steps. The provided answers are used to filter out the non-relevant methods, hence leading to a subset of MCDA methods suitable for the type of decision-making problem at hand. In case such a subset is empty, the DSS identifies the approaches which are as close as possible to the user's preferences. The proposed DSS outperforms the existing tools in terms of completeness of both accounted features and already considered methods.

3 - A decision model for a recruitment process of Special Forces
Ana Sara Costa, José Rui Figueira, José Borbinha

This study is related to the military recruitment process of the Portuguese Army Special Forces. It aims to assign soldiers that completed the initial military training to an adequate category (or categories) of Special Forces. To address that, we use CAT-SD (CATegorization by Similarity Dissimilarity), a multiple criteria decision aiding (MCDA) method for nominal classification, to construct a decision model. In this method, there is no preference order among the categories and each category is defined by reference profiles. The assignment of the soldiers to the categories depends on their comparison to those reference profiles in terms of similarity-dissimilarity. The model was constructed with military experts in collaboration with the Portuguese Army through the Centro de Psicologia Aplicada do Exército. We apply interaction protocols for eliciting the values of the preference parameters used in CAT-SD. A set of candidates to become Special Forces soldiers are assessed and assigned, considering multiple criteria, interactions between criteria, and similarity-dissimilarity judgments. We get the assignment results from DECSPACE, a web-based platform for MCDA methods. The decision model and the results of this study are a relevant contribution to the research on the recruitment process of the Portuguese Army Special Forces.

Acknowledgments: This work was supported by national funds through Fundação para a Ciência e a Tecnologia (FCT) with reference UIDB/00097/2020.

■ HF-07

Thursday, 18:00-19:40 - Room 7

Meta-Analytics in Innovative Applications of OR

Stream: Meta-Analytics: A Marriage of Metaheuristics and Analytics
Invited session
Chair: *Yang Wang*

1 - Multiple operators driven iterated local search for collaborative operating room scheduling
Daiqiang Yin, Juanru Wang, Yang Wang

The operating theatre is one of the most important sources of revenues and costs of hospitals. In the realistic situation of China, patients often prefer to perform surgeries in superior hospitals, which causes overcrowding of these hospitals and low patient access of ordinary hospitals. With the implementation of the Hospitals Alliance Policy in China, multi-hospital collaborative operating room scheduling is considered as an effective way to alleviate the imbalance of resource utilization. In this work, we propose a new operating room scheduling problem underlying a superior-ordinary hospital union conceptual model. To solve this problem, we design an iterated local search algorithm that consists of a greedy initial constructive phase to quickly construct a feasible solution, a multiple operators driven local search phase to reach high-quality local optima, and a perturbation phase to explore more promising regions. Experimental results on instances of different characteristics demonstrate that our proposed algorithm is able to find approximate optimal solutions in much shorter time compared to the general-purpose Gurobi solver.

2 - Finance-based scheduling of construction projects with resource constraints
Wanlin Liu, Jingwen Zhang

Almost 80 percent of construction projects failed because of the lack of funds in the process of their implementations. It is a serious challenge for many contractors to keep the cash availability when they execute construction operations. They need borrow money from bank, but the funds from bank overdrafts cannot exceed a specific credit line during the execution of a project. Meanwhile, the contractors are also suffered from the shortage of labors, materials, equipment and so on. It's very universal that the execution of a construction project is doubly constrained by capital and certain resources. Therefore, we propose finance-based scheduling of construction projects with resource constraints (FBSCP-RC) problem. Firstly, we extend the existing calculating method for cash flows of construction projects to two new models, and then a nonlinear integer programming (NIP) model with minimized total costs is constructed. Secondly, we design a method to transform the NIP model of FBSCP-RC into its integer programing (IP) model. Then some instances with small scales (the amount of activities) can be optimally solved by CPLEX. More generally, a heuristic algorithm is developed to solve the NIP model for the instances with large scales. In summary, the investigation of FBSCP-RC not only contribute to the cash flow management of construction projects in theory, but also help project managers gain an optimum schedule scheme for a construction project in practice.

3 - Multi-hospitals collaborative operating room scheduling with uncertain surgery duration
Yang Wang, Haichao Liu, Abraham Punnen

China has been vigorously promoting the hospital alliance policy to alleviate the unbalanced utilization of medical resources in superior and ordinary hospitals. The fact that operating rooms consume the most medical resources and yield high revenues determines the importance of an effective management of operating rooms for hospitals. In this work, we study a multi-hospitals collaborative operating room scheduling problem with uncertain surgery duration, which simultaneously considers the advance scheduling and allocation scheduling. Due to many variables and constraints, we build a bi-level stochastic optimization model and design a simulation optimization approach to handle this hard optimization problem. We perform extensive experimental analysis to demonstrate the effectiveness of the proposed approach and provide general management insights based on our findings.

4 - A Hybrid Mat-Heuristic Algorithm for the Capacitated Location-Routing Problem
Theocharis Metzidakis, Panagiotis Repoussis, Manolis Kritikos, George Ioannou

This work presents a Mat-Heuristic framework for the Capacitated Location Routing Problem (CLRP). The CLRP is a np-hard combinatorial optimization problem, arising in a large variety of practical contexts. In this problem a set of candidate depot locations is given along with a set of geographically scattered customers with known demands. We need to optimally locate a number of facilities and design least cost vehicle routes in order to service the customers using a fixed fleet of homogeneous capacitated vehicles. We propose a two-phase Matheuristic algorithm, which alternates between a depot location phase and a routing phase. In the first phase a facility location problem is solved and then the assignment solution is used to produce a starting solution by a greedy heuristic. In the second phase, the resulting routes are used to produce reduced Multi-Depot routing problems, which are solved exactly. At the end of each global iteration, information about the assignments used is recorded to be used in the following phases. Based on benchmark datasets taken from the literature, various promising computational results are reported.

■ HF-08

Thursday, 18:00-19:40 - Room 8

Decision Analysis and Decision Support Systems 2

Stream: Decision Analysis and Decision Support Systems (contributed)
Contributed session
Chair: *Sang-Hoon Lee*

1 - Analytic Hierarchy Process for citizen consensus building
Yoichi Iida

In recent years, evidence-based policymaking has been attracting attention in Japanese administrative activities. On the other hand, it is important to collect the voices of the residents in the policymaking process. The purpose of this presentation is to show an easy and useful way of collecting them by the Analytic Hierarchy Process. The voice here means the importance of the program. This case shows that the Analytic Hierarchy Process can get some kind of objective evidence by collecting individual subjective voices. In 2019, the committee was set up to make a commercial revitalization plan in Okaya City in Japan. The committee consisted of thirteen citizens, most of whom were representatives of commercial groups. They created three basic strategies and eleven key programs in eight committees. Finally, the members made a relative evaluation of these programs with respect to importance. This importance was to be referenced at the time of budget application and was actually referenced. There I suggested an easy way for the ordinary citizens to obtain comparison tables of the Analytic Hierarchy Process. In 2021, the members of the committee reweighed these programs using this way and agreed on the result by comparing it with the previous result. This shows that this way is useful for ordinary citizens, although we lose some accuracy of the Analytic Hierarchy Process. From now on, I need to show that this method is mathematically valid.

2 - Methods for eliciting preference systems with applications to decision making under severe uncertainty
Christoph Jansen, Georg Schollmeyer, Thomas Augustin

Jansen, Schollmeyer & Augustin (2018, Int. J. Approx. Reason) introduced a framework for decision making under imprecise probabilities and weakly structured preferences. There, the decision maker's preferences are modelled by a pair of relations encoding their ordinal and their cardinal part, respectively. The talk will briefly review this framework and then develop efficient elicitation procedures. These procedures aim at enabling decision makers to reveal their preferences while having to answer as few as possible simple ranking questions. Two different approaches will be presented. The first approach directly utilizes the collected ranking data to build up the ordinal part of the preferences, while the cardinal part is derived implicitly by collecting meta data on the decision maker's consideration times. The second approach directly elicits also the cardinal part of the decision maker's preferences, however, only an approximate. Specifically, this approximate is obtained by eliciting, besides the rankings of the alternatives, also categories of preference strength. For both approaches, we investigate how efficiency can be improved by incorporating ranking data from previous elicitation rounds and/or expert knowledge. Finally, we show how our elicitation methods can be utilized to solve decision problems under severe uncertainty, while demanding the decision maker to specify exactly as much information as is needed for the specific decision problem under consideration.

3 - New predictive approach for the modal choice: the case of Moroccan travelers
Mohamed EL Hadraoui, Fouzia Ghaiti

The transport sector is a pillar and a driving force for all countries. Thus, the development of any economy, in this case the emerging one, can only be achieved with the improvement and adaptation of its various transport services. Morocco, and since the 2000s, an emerging economy in the Middle East and North Africa (MENA) region, has adopted a proactive policy for the development of the transport sector. However, the different modes of transport competed based on single-modal approaches. Thus, a kind of cannibalization was unleashed between the different transport sectors while crushing any vision of optimization, multi-modality and intermodality in the country. It is for this reason that several research projects on the theme of modal choice in the Moroccan transport sector have been undertaken recently to allow decision-makers a better visibility on the choice of the Moroccan traveler as a mode of transport to move around from point A to another B. This research work is part of this dynamic and proposes a new approach based on the concept of machine learning to predict the choice of the mode of transport of a Moroccan traveler to move between two areas A and B. Unlike other classical approaches (statistical modeling Probit, Logit, etc.) which often use utility functions or the method based on artificial neural networks, the present method based on support vector machines (SVM), as a predictive model, gives better results for the case of a database of Moroccan travelers.

4 - Interactive Digital Directory for Mobile-based Smart Transportation Applications
Sang-Hoon Lee, Tae-Sung Kim, Taehun Yang, Soochang Park

Informative directories have always responded to a fundamental need of humanity: providing available information to people. Recently, digital displays which could interact with service users is becoming an essential interface since the escalating amount of content to be visualized on a directory makes relevant information search extremely time-consuming. However, it is still left as one of crucial challenging issues to support smarter and differentiated service provisioning to multiple users at once due to different situations and requirements. Hence, this paper proposes a novel directory visualization framework based on optimization between preferences of multi-users, denoted by Proximity-Relevance Driven Visualization on digital directory (PRDV). PRDV understands user state via smartphone-based interaction and optimizes visualization by game theory analytics in terms of preferences of users.

■ HF-09

Thursday, 18:00-19:40 - Room 9

Production Management, Supply Chain Management and Location 1

Stream: Production Management, Supply Chain Management and Location (contributed)
Contributed session
Chair: Anastasios Gialos

1 - Integrated capacity and appointment scheduling for access time management
Ka Yuk Carrie Lin

This paper examines a simultaneous scheduling strategy of service capacity and patient appointments in a multi-server appointment system over a multi-day planning horizon. Demand is characterized by priority classes with seasonal variation. Short-term capacity is allowed to vary within limits while the total capacity is maintained constant, or within certain deviation, to comply with prior agreement. System performances are measured by the (weighted) sum of access times to an appointment, capacity utilization and completion time. The integrated problem, first formulated by an integer program, is relaxed and solved. The optimal capacity schedule provides input to improve appointment scheduling by a simple scheduling procedure, yielding an alternative optimal schedule but with the smallest range of access times for each priority class. Data on annual demand, capacity of public out-patient clinics and seasonality data in literature are used in designing the experiments. Results indicate better capacity utilization and significant reduction in non-urgent patient access times.

2 - An Improved Collision Decision Method in a Series-Parallel Machines Model
Taiki Otsuka, Eishi Chiba

In designing manufacturing lines, collision probability is one of the most important factors relating to their performance. There are two areas of collision probability study, theoretical studies, which focus on the analysis of collision probability, and algorithmic studies, which focus on the computation of collision probability using simulation. The results of theoretical studies so far have been somewhat limited in comparison to the results of their algorithmic counterparts. Recently, a computation method for collision probability in a series-parallel machines model was presented. This method for computing collision probability utilizes a subroutine for deciding whether a collision occurs or not. This subroutine is referred to as 'Collision Decision Method'. The time complexity of the previous collision decision method is dominated by a sorting algorithm. We offer a new collision decision method which does not require a sorting algorithm. Analysis of the time complexity of this new method shows it to be more efficient than the previous method. Moreover, we carry out computational experimentation in order to show that this new method is actually faster.

3 - Digital transformation in the supply chain sector: Insights from the Greek market
Anastasios Gialos, Vasileios Zeimpekis

Research of Digital Transformation (DT) in supply chains is at the nascent stage in many aspects. Despite extensive research in the recent past, research of DT in supply chains lacks solid data that come from the industry. This paper presents the results from a survey that was conducted in Greece in 2020 with the participation of 283 companies that operate in the manufacturing, wholesale, retail as well as in the logistics service provision sectors. The results show that currently manufacturing and wholesale/retail companies have invested mainly in supply chain planning systems (e.g. ERP, CRM) whereas the logistics service provides in supply chain execution solutions (e.g. WMS, TMS). All companies clearly understand the need for their DT in the following years in order to provide better customer service, increase productivity and minimize operational cost, but on the other hand they face various barriers such as the investment cost, the lack of staff skills as well as the culture that currently exists in many companies. Furthermore, the results show that large companies have the manpower

and the economic ability to create a solid strategy for their DT whereas SMEs are struggling with day-to-day operation. In the future, the focus of the companies will be the automation of warehouse and transport operations, as well as on demand forecasting and customer service operations in order to cope with big data and the need for fast response.

■ HF-10

Thursday, 18:00-19:40 - Room 10

OR in Natural Resources 1

Stream: OR in Natural Resources (contributed)
Contributed session
Chair: Islem Kaabachi

1 - The structure of optimal solutions for harvesting a renewable resource

Thorsten Upmann, Dmitry Gromov

In this contribution we consider the problem of optimal harvesting a renewable resource, whose dynamics are governed by a logistic differential equation and the payoff is proportional to the amount of the harvested resource. We consider both the finite and infinite horizon cases and analyse the structure of the optimal solutions depending on the values of system parameters. It is shown that the optimal control profile can have one of three shapes: 1) maximal harvesting effort until the resource depletes, 2) zero harvesting during the initial interval (whose duration is determined by the system parameters and the initial amount of the resource) and a subsequent switch to maximal harvesting effort, and 3) a so-called singular solution that corresponds to an intermediate value of the harvesting effort. The latter scenario realizes only for the infinite horizon case and corresponds to a particular combination of system parameters. In contrast to the former two scenarios, the singular solution corresponds to a sustainable harvesting strategy as it does not lead to complete depletion of the resource. We characterize the conditions under which the singular solution is optimal and present suggestions for designing optimal and sustainable harvesting strategy.

2 - Building a Performance Indicator to Investigate the Robustness of Water Supply Utilities in Japan

Tatsuo Oyama

We build a work performance indicator (WPI) for quantitatively measuring the performances of water supply utilities in Japan. The WPI is defined from three different perspectives: management, facility/equipment, and operations. It can be used to measure the robustness of a water supply network system. Based on actual data expressing the work performances of Japanese water supply utilities from 1980 to 2018, we illustrate the numerical results of the WPIs, so as to determine their regional characteristics. We apply statistical data analysis techniques (such as a cluster analysis and principal component analysis) to calculate the WPIs, and investigate the historical and regional characteristics and trends of water supply utilities in Japan during the investigated period. These approaches can be applied to design and improve natural disaster mitigation policies, such as those focusing on earthquakes in Japan.

3 - Optimizing the ramp design in an open pit mine

Islem Kaabachi, Frédéric Meunier, Nelson Morales

In open pit mining, material (mineral and waste) is hauled outside of the excavation by trucks that move along a ramp. The design of this ramp must be carefully addressed because it must provide access to the different levels, but also maximize the value of the material extracted, which means to allow the extraction of the valuable material, and to reduce the extraction of waste. Since an optimization approach able to deal with the problem in its full generality seems to be out of reach at the moment, we consider two slightly simplified versions of the problem, which are still completely relevant from a practical point of view, and correspond to finding the best ramp to provide access in one given potential volume to be excavated, by discretization of the volume and the ramp into blocks. In this setting, our contribution is three-fold. We first discuss the intrinsic complexity of the two versions and show in particular that they are NP-hard. Second, we propose integer programs modeling the two versions. The computational experiments performed on real instances with an off-the-shelf solver show the relevance of the modeling and allow a discussion of the respective advantages of the two versions, between them and also over other approaches of the literature. Third, exploiting a natural decomposition of the problem, we design an efficient genetic algorithm able to cope with the largest instances.

Thursday, 21:30-24:00

■ HG-01

Thursday, 21:30-24:00 - Room 1

IFORS AC Meeting 2

Stream: IFORS Sessions
Invited session

Friday, 8:00-9:00

■ FA-01

Friday, 8:00-9:00 - Room 1

OR in Natural Resources 2

Stream: OR in Natural Resources (contributed)
Contributed session
Chair: Kumudumali Piyasena

1 - Influence of Crude Oil Prices on Food Insecurity Problem: the Nexus of Crude Oil and Food Prices
Andre Assis de Salles, Marta Novo, Natalia Leite dos Reis

Food cost is a fundamental factor to reduce world hunger minimizing the food insecurity problem. Agricultural commodities prices, especially grains, are determinant for food cost therefore studying the commodity prices behavior that are responsible for food security on the planet is important for economic agents, especially for those involved in macroeconomic policy decision making. Food production and prices are related to energy prices, mainly through biofuels and fertilizers production. Among energy sources, crude oil is one of the main in the world energy matrix. Many studies and researches on crude oil and food prices have been carried out relating energy and food or more specifically crude oil and agricultural commodity prices. This work aims to examine the dynamic relationship between oil price and grain commodity prices, namely rice, wheat, corn and soybeans. It also verifies the causality and cointegration between each grain and crude oil price return time series. Autoregressive vector models were estimated to infer the impulse response function and the variance decomposition. The sample period corresponds to the interval between the two biggest crises of the century, the subprime financial crisis and the Covid-19 pandemic sanitary crisis. Thus, the data is not impacted by significant abnormal variations caused by these crises. The inferences show an interaction between crude oil prices practiced in the international market and each of the food commodity prices.

2 - Optimal Schedules for Corn Planting and Storage
Reena Kapoor, Rodolfo Garcia-Flores

Corn (or maize) is, with rice and wheat, one of the most consumed cereals in the world, together accounting for 94% of all cereal consumption. It is estimated that, in 2012, the total world production of corn was 875.23 million tonnes. The development of seeds with desirable traits typically requires many years of in-field testing before new products can be delivered to market. Recently, innovative genomic technologies have shortened the time required to develop new corn hybrids, that is, new products that can deliver higher-yielding, better-adapted seed options for growers at a faster pace. However, higher yields and increased rates of produced parental lines introduce many new challenges. In this presentation, we address one such challenge, namely, the problem of managing the demands on storage facilities to cope with increasing output. The problem was proposed by Syngenta Seeds to improve their year-round breeding process by optimizing planting schedules to achieve a consistent output, which translates into a weekly harvest quantity. Erratic weekly harvest quantities create logistical and productivity issues. The research question we address is: How can we optimally schedule the planting of our seeds to ensure that when ears are harvested, facilities are not over capacity, and that there is a consistent number of ears each week? The solution we present considers climate uncertainty and is the winner of the INFORMS 2021 Syngenta Crop Challenge in Analytics.

3 - Measuring Robustness of Water Supply Utilities in Japan
Kumudumali Piyasena, Yuji Kawase, Tatsuo Oyama

We build a work performance indicator (WPI) for quantitatively measuring the performance of water supply utilities in Japan. The WPI can be defined from three different perspectives: management, facility/equipment, and operation. It can also be used to measure the robustness of the water supply network system. Using actual data expressing the work performance of Japanese water supply utilities during the period from 1980 to 2018, we illustrate the numerical results for the WPIs to determine the regional characteristics of the WPI. We apply statistical data analysis techniques such as cluster analysis and principal component analysis to calculate the WPIs and investigate the historical and regional characteristics and trends of Japan's water supply utilities during the above period. These approaches can be applied to design and improve natural disaster mitigation policies focussing on earthquakes in Japan.

■ FA-02

Friday, 8:00-9:00 - Room 2

Advances in Interior points methods

Stream: Continuous Optimization
Invited session
Chair: Julio C. Góez
Chair: Daniel Stilck Franca

1 - Parametric Analysis of Semidefinite and Second Order Conic Optimization
Tamás Terlaky, Ali Mohammad-Nezhad

Parametric analysis of optimization problems is crucial in understanding fundamental theoretical properties of optimization problems, and also for their application in engineering and business. While parametric analysis is well developed and understood for linear linearly constrained convex quadratic optimization problems, it is less developed for conic optimization, and the computation of the relevant quantities is considerably more challenging.

In this talk we study parametric analysis of SDO and SOCO problems with respect to the perturbation of the objective function. We study the behavior of the optimal partition and optimal set mapping in a so-called nonlinearity interval, and investigate the sensitivity of the approximation of the optimal partition in a nonlinearity interval. The approximation of the optimal partition is obtained from a bounded sequence of interior solutions on, or in a neighborhood of the central path. An upper bound on the distance between the approximations of the optimal partitions of the original and perturbed problems is presented.

Joint work with Ali Mohammad-Nezhad, Department of Mathematics, Purdue University, Lafayette, IN, USA; and Jonatha Hauenstein and Tingting Tang, Department of Applied and Computational Mathematics and Statistics, University of Notre Dame, IN, USA.

2 - A Limiting Analysis on Regularization of Singular Semidefinite Programs and its Implication to Infeasible Interior-point Algorithms
Takashi Tsuchiya, Bruno Lourenco, Masakazu Muramatsu, Takayuki Okuno

We consider primal-dual pairs of semidefinite programs and assume that they are ill-posed, i.e., both primal and dual are either weakly feasible or weakly infeasible. Under such circumstances, strong duality may break down and the primal and dual might have a nonzero duality gap. Nevertheless, there are arbitrary small perturbations to the problem data which makes the perturbed primal-dual pair strongly feasible thus zeroing the duality gap. In this talk, we conduct an asymptotic analysis of the optimal value as the perturbation is driven to zero. Specifically, we fix two positive definite matrices (typically the identity matrices), and shift the associated affine spaces of the primal and dual slightly in the direction of the two positive definite matrices possibly in a different proportion so that the perturbed problems have interior feasible solutions, and analyze the behavior of the optimal value of the perturbed problem when the perturbation is reduced to zero keeping

the proportion. We do not make any further assumptions such as compactness or constraint qualifications. It will be shown that the optimal value of the perturbed problem converges to a value between the primal and dual optimal values of the original problem. Finally, we show that the infeasible interior-point algorithms for SDP generates a sequence converging to a number between the primal and dual optimal values in the presence of nonzero duality gap.

3 - A class of primal-dual interior-point relaxation methods for nonlinear and linear optimization
Yu-Hong Dai, Xinwei Liu

We present a class of primal-dual interior-point relaxation method for nonlinear and linear optimization problems. The methods are of the interior-point variety, but do not require any primal or dual iterates to be interior-points, thus providing a new approach for improving interior-point methods. Some topics on the system for search directions, the selection of step size and the update of barrie parameter are discussed. Global and local convergence are analyzed. Some preliminary numerical results on CUTE and NetLib test problems are reported.

4 - Faster quantum and classical SDP approximations for quadratic binary optimization
Daniel Stilck Franca, Fernando Brandão, Richard Küng

We give a quantum speedup for solving the canonical semidefinite programming relaxation for binary quadratic optimization. The class of relaxations for combinatorial optimization has so far eluded quantum speedups. Our methods combine ideas from quantum Gibbs sampling and matrix exponent updates. A de-quantization of the algorithm also leads to a faster classical solver. For generic instances, our quantum solver gives a nearly quadratic speedup over state-of-the-art algorithms. We also provide an efficient randomized rounding procedure that converts approximately optimal SDP solutions into constant factor approximations of the original quadratic optimization problem.

■ FA-03

Friday, 8:00-9:00 - Room 3

Data analytics and learning for health

Stream: OR in Health, Medicine and Life Sciences
Invited session
Chair: Gerhard-Wilhelm Weber
Chair: *Suryati Sitepu*
Chair: *Herman Mawengkang*

1 - Machine Learning and Applied Multivariate Research in Parkinson's Disease (PD): An Exploratory Approach in PD Data Analysis and Interpretation
Robert Koo, Suzanne Tsukenjo, Charles Crain

Parkinson's Disease (PD) is a progressive neurodegenerative disorder that is defined by both motor and non-motor symptoms. Clinicians use a broad range of biospecimen and assessments to characterize the subtype and severity of PD. While there is currently no cure for PD, early identification and diagnosis offer patients timely treatment and coping options. Parkinson's Progression Markers Initiative (PPMI) is a landmark observational clinical study that aims to identify potential biomarkers of PD progression through collaborative research. This study surveys various exploratory data analysis techniques when applied to PPMI big data. Clinical assessment and biospecimen data from over 600 PD and Healthy Control subjects are analyzed through classical multivariate and modern machine learning techniques. Using a novel composite scoring and regression approach, PD progressions are characterized against biospecimen. Additionally, latent features from motor/non-motor assessments are extracted and transformed for algorithmic classifications. Factor analysis is also used to examine any underlying data structures, themes, and correlations. This presentation will focus in the following areas: 1) approach and data mining methodology; 2) results and findings; 3) main challenges with analyzing PPMI data; 4) future analytic efforts.

2 - Reinforcement Learning Based Optimal Treatment Recommendations for Diabetes Patient using Electronic Health Record
Sang-ho Oh, Jeonghoon Mo

In recent years, electronic health records have become more available for increasing interests to discover personalized healthcare suggestions to optimize clinical decision making and patient management. Thus the study on treatment recommendation moves from knowledge-driven into data-driven. The sharing of electronic health records by the national health insurance services of Korea has made it possible to analyze electronic health records which include medical treatments, prescriptions, lab tests and more for Koreans. Considering the merits and effectiveness of such data, this study analyzes the medical information of patients and recommends the optimal pharmaceutical prescription for diabetes, which is known as the most burden disease to Koreans. For treatment recommendation model, reinforcement learning techniques have been introduced, namely, Markov decision process, Q - Learning, and contextual bandits are used. We compared the three methods by matching percentage with real life doctors' prescriptions and delay period of diabetes complication occurrence then concluded which model is best for treatment recommendation.

3 - Data analytics and simulation modeling of emergency department operations in Hong Kong
Yong-Hong Kuo, Janny Leung, Colin Graham

In this talk, we will present our work of utilizing data analytics and simulation modeling for analyzing operations at a hospital emergency department in Hong Kong. We developed a calibration procedure to improve the performance of our simulation model. This simulation model can be used to assess the outcomes of different scenarios and strategies for enhancing system efficiency. Simulation-optimization approaches were also developed to determine resource allocation decisions.

4 - Identifying Changes in Demand for Perishable Products Using Statistical Process Control and Machine Learning Forecasting
Linden Smith, John Blake

Fast and accurate identification of demand shifts is crucial in the management of blood products. Canadian Blood Services (CBS) manages the collection and distribution of blood products in the Ottawa region of Ontario, Canada. CBS is planning a pilot project to apply pathogen reduction technology (PRT) to platelet production. The introduction of PRT is expected to shift hospital demand for platelets; however, the form of this shift is unknown. A lag time exists between the identification of a supply-demand imbalance and the ability to address it. The objective of this research is to determine how quickly and accurately demand shifts can be detected, to minimize lag time and thus provide better patient health outcomes. A discrete-event simulation was used to model platelet inventory and generate data for possible demand shift scenarios. Process control methods were used to detect and quantify shifts in demand. Forecasting methods were applied to the inventory data to reduce detection time. We found that statistical process control methods were effective in detecting demand shifts of all types and that forecasting decreased the time to detection. When the magnitude of the demand shift increased, the detection rate increased and the time to detection decreased. The consequences of a hidden demand shift are substantially less for shifts of smaller magnitude, mitigating the risk due to increased detection time. These results will be useful in minimizing the patient impact of PRT.

■ FA-04

Friday, 8:00-9:00 - Room 4

Applications in optimization under uncertainty

Stream: Simulation, Stochastic Programming and Modeling
Invited session
Chair: *Kibaek Kim*
Chair: *Florian Mitjana*

1 - A Scalable Global Optimization Algorithm for Stochastic Nonlinear Programs
Yankai Cao

We present a reduced-space spatial branch and bound (BB) strategy for two-stage stochastic nonlinear programs. At each node, a lower bound is constructed by relaxing the non-anticipativity constraints and an upper bound is constructed by fixing the first-stage variables. Both lower and upper bounds can be computed by solving individual scenario subproblems. Another key property is that we only need to perform branching on the first-stage variables to guarantee convergence. We present an implementation of the algorithm called SNGO. The implementation is interfaced with the structured modeling language Plasmo.jl, which facilitates benchmarking and model processing. Our implementation incorporates typical features that help accelerate the BB search such as LP-based lower bounding techniques, local search-based upper bounding techniques, and relaxation-based bounds tightening techniques. We also present different heuristics to significantly accelerate the solution process. Numerical experiments are performed for a set of optimal control problems and stochastic programs.

2 - A Two-Stage Stochastic Model For Enhancing Seismic Resilience of Water Pipe Networks
Azam Boskabadi, Jay Rosenberger, Seyed Mohsen Shahandashti

Earthquakes are sudden and inevitable disasters that can cause enormous losses and suffering, and having accessible water is critically important for earthquake victims. To address this challenge, utility managers do preventive procedures on water pipes periodically to withstand future earthquake damage. The existing seismic vulnerability models usually consider simple methods to find the pipes to rehabilitate with highest priority. In this research, we develop an optimization approach to determine which water pipes to rehabilitate subject to a limited budget.

3 - Building Load Control using Distributionally Robust Binary Chance-Constrained Programs with Right-Hand Side Uncertainty and the Adjustable Risk Variants
Yiling Zhang

Aggregation of heating, ventilation, and air conditioning (HVAC) loads can provide reserves to absorb volatile renewable energy, especially solar photo-voltaic (PV) generation. However, the time-varying PV generation is not perfectly known when the system operator decides the HVAC control schedules. In this talk, we consider a distributionally robust binary chance-constrained (DBCC) building load control problem under two typical ambiguity sets: moment-based and Wasserstein ambiguity sets. We derive mixed integer linear programming (MILP) reformulations for DBCC problems under both sets. Especially for the DBCC problem under the Wasserstein ambiguity set, we utilize the right-hand side (RHS) uncertainty to derive a more compact MILP reformulation than the commonly known big-M MILP reformulations. All the results also apply to general individual chance constraint binary programs with RHS uncertainty. Furthermore, we propose an adjustable chance-constrained formulation to achieve a reasonable trade-off between operational risk and costs. We derive MILP reformulations under both ambiguity sets. Using real-world data, we conduct computational studies to demonstrate the efficiency of the solution approaches and the effectiveness of the solutions.

4 - Reinforcement learning for hydropower optimization under chance constraints
Florian Mitjana, Michel Denault, Kenjy Demeester, Dominique Orban

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" to maximize the generated electricity with respect to the chance constraints. These backoffs aims to tighten the feasible set and are simple to ajust with a bisection method. Stochastic dynamic programming (SDP) is used as a benchmark. Applications of SDP are limited as the computational effort increases exponentially with the number of reservoirs considered in the hydropower system. Through the RL approach, the computational effort remains constant regardless of the number of reservoirs. RL numerical results highlight similar electrical productions with a drastic reduction of the quantity of water which does not satisfy the constraints in comparison to the SDP method.

■ FA-05

Friday, 8:00-9:00 - Room 5

Revenue Management, Pricing, and Consumer Behaviours

Stream: Revenue Management and Pricing
Invited session
Chair: *Changseung (Chang) Yoo*
Chair: *Hyun Seok Lee*

1 - Variations of the Bullwhip Effect Across Foreign Subsidiaries
Seung Jae Park, Seungrae Lee, Sridhar Seshadri

We investigate the variations of the bullwhip effect across foreign subsidiaries of Korean multinational firms in over 100 countries. Measuring the bullwhip effect by estimating the ratio of the volatility of purchase to the volatility of demand, our measure is significantly different from the traditional measure of the ratio of the volatility of production to the volatility of demand, and better reflects the prevalence of the bullwhip effect across foreign subsidiaries. Using our alternative measure, we find that the strength of the bullwhip effect is strongly associated with country-specific factors where subsidiaries are located, which support the analytical findings from the existing literature that include the impacts of replenishment lead time, price volatility, ordering and production costs, and supply chain integration on the bullwhip effect. These associations are also found to be different across industry sectors and regions where subsidiaries operate.

2 - Impeding Behavior in Shopping and Product Trial
Hyun Seok Lee, Ryann Reynolds-McIlnay

Prior study found impeding behavior, i.e., behavior that disrupts others' (1) information search, (2) evaluation of alternatives, or both during high-traffic periods. We observe the impeding behavior in shopping and product trial from a field study. We further explore (a) its motivation via online experiment and (b) its behavioral underpinnings via in-lab experiment.

3 - The Impact Of Strategic Consumer Behavior On Shipping And Return Policies Of Omnichannel Retailers
Abhishek Roy

By the virtue of its operations, an omnichannel retailer can select from a wider set of shipping and return options. These shipping and returns policies impact consumer behavior, and therefore the supply chain decisions. Overall, how these consumer-facing policies are chosen greatly impacts the overall supply chain, and these interactions are of increasing importance to academics and practitioners alike. However, to the best of our knowledge, the literature in marketing and supply chain management has not studied the joint impact of an omnichannel retailer's shipping and returns policies on its supply chain decisions. We address the following main research questions. First, how do different consumers change their purchasing behavior, based on an omnichannel retailer's shipping and returns policies? Secondly, how does an omnichannel retailer's choice of shipping and return policies affect supply chain and financial performance? We develop an analytical modeling framework to study the interaction between different shipping and returns policies of the retailer with the consumers' purchasing and returns behaviors, and their implications on supply chain decisions within the retailer's firm and across the supply chain.

4 - Crowd-starting a Service with Customer Engagement
Long He, Tu Ni

The emerging development of smart-city operations not only improves social efficiency and welfare, but also creates new business models and services, especially those with customer engagement. In the domain of urban transportation, the shared shuttle service is being deployed in many cities, which is an intermediate mode between the traditional public transport and the modern ride-hailing service. In particular, the service can be offered by a platform based on customer suggestions in a crowd-starting manner. This new interaction reveals some information about the customer side, but at the same time, poses a great challenge in the service design for the platform side. Motivated by this example, we study how to crowd-start a service with customer engagement. We propose a service design optimization model to maximize the expected adoption of a service. We first employ the non-parametric preference list model to characterize how customers will respond given different service attributes and how customer suggestions are related to the response. We then quantify and investigate the value of information from customer suggestions. Moreover, we estimate adoption probabilities using modern data-pooling techniques for implementation.

■ FA-06

Friday, 8:00-9:00 - Room 6

MCDA Applications 2

Stream: Multiple Criteria Decision Aiding
Invited session
Chair: Vivien Y.C. Chen

1 - Assessment and management of satisfaction development for wetland ecotourism
Vivien Y.C. Chen, Con-Rong Wang, Gwo-Hshiung Tzeng

Ecotourism is currently an actively developing tourism sector. Wetland itself has many ecological functions and values, thus having great potential in developing ecotourism. In terms of the sustainable development of wetland ecotourism, the general public view is usually focussed on the impact on human enjoyment. The sustainable development of wetland ecotourism is affected by many interrelated factors, such as land use, human welfare, property safety, convenient transportation, management and operation, ecological maintenance, manmade structure, and climate control. The purpose of this paper is to probe how to use qualitative and quantitative measurements of Wetland Ecotourism to create plan indexes in criteria/attributes, as well as how to use these indexes towards achieving the aspiration levels for each criterion/attribute. Previous efforts to measure Wetland Ecotourism evaluations and plans have assumed that the criteria are independent, but this assumption does not always hold in real-world applications. Therefore, in this study, a novel hybrid Multiple Attribute Decision-Making model is used to address dependent relationships among various attributes. The DEMATEL (decision-making trial and evaluation laboratory) technique is used to construct the influential network relationship map (INRM), and along with a basic concept of ANP (Analytical Network Process) to determine the influential weights of criteria (called DANP).

2 - Exploring essential sustainable indicators among food corporates: Taiwan perspective
Tsung Yen Wang

Food production and retention are always an essential issue for sustainable development, and the influence of food corporates among economic, environmental, and social resources is significant. Recent years in Taiwan, food corporates have followed the international footsteps and are committed to promoting the concept of sustainable development; planning to create a healthy, peaceful, and stable living environment for the future. However, even if the business operators hope to achieve the goal of sustainable management, there is lack of research result to provide reference and precise guideline. The implementation of the management and application of sustainable development will be of substantial help to enhance industrial competitiveness. This study integrated fuzzy set theory and DEMATEL method to identifying the causal relationship and the influence among the sustainable indicators. The empirical result of this study proposed the essential sustainable indicators as a guideline of sustainable development for food corporates.

3 - Sustainable third-party reverse logistics partner selection using MCDM techniques: A case study in Indian electronics industry
Meenu Singh, Deepanshu Nayak, Sunil Jauhar, Millie Pant

Reverse logistics (RL) refers to the backflow of used end products from customers to producers and manufacturers. The operations and management of RL is a challenging task involving various complicated processes and procedures, making it critical for industries like electronics and automotive, where products have harmful effects on the environment and humans. Thus, to ensure that such products are handled efficiently, the companies tend to outsource the RL to the third-party reverse logistics partners (3PRLPs) with satisfying infrastructure, advanced technology and potential experience. Hence, the evaluation and selection of efficient as well as sustainable 3PRLPs have become a complex issue among company managers and researchers. To handle such situation, Multi-Criteria Decision Making (MCDM) techniques may be utilized due to their capability of handling the quantitative as well as qualitative data. In this research, the authors have tried to build a hybrid model for selecting the 3PRLP for e-waste products by applying the weights determined by AHP to the comparative performance of six popular MCDM techniques like TOPSIS, COPRAS, SAW, VIKOR, PROMETHEE, MOORA to reach the final outcome. A real-life case study of the Indian electronic industry is demonstrated to present the practicality and effectiveness of approaches used in this study.

4 - Economic and edafoclimatic evaluation of Brazilian regions for african mahogany planting: An approach by the COPELAND, SAPEVO-M-NC and REGIME methods
Sérgio Mitihiro do Nascimento Maêda, Igor Pinheiro de Araujo Costa, Carlos Francisco Simoes Gomes, Marcos dos Santos, Ivan Mota, Isaque Almeida, Luiz Teixeira, Arthur Pinheiro de Araújo Costa

In 2019, deforestation in Brazil consumed about 1,218,708 hectares of native vegetation. Among the measures adopted to reduce the exploitation of wood considered noble, the planting of commercial forests is an important alternative, increasing the supply of wood in the market, thus decreasing the exploitation of the native forest. Each species has peculiarities and needs in relation to cultivation regarding rainfall, average temperature of place, type of soil, resistance to pests and diseases, etc. In addition to these factors, the producer must consider the initial investment costs, such as the purchase of land and seedlings. Another important point is related to the logistical facilities existing in the region that can contribute to the flow of its production, reducing the associated costs. Given the above, the area to be chosen for the plantation must be carefully evaluated before the farmer decides and begins his cultivation. In view of the above, this article proposes the

use of three ordinal methods of multicriteria decision assistance, to select, among seven regions of different states, those most suitable for planting African mahogany of the ivorensis species. The alternatives were evaluated by professionals in the agricultural sector, considering climatic and economic criteria using the methods: COPELAND, REGIME and a new ordinal, non-compensatory methodology, with support for multiple decision makers, called SAPEVO-M-NC. This new method provides information on the partial weights, indicating the relative importance of the criteria for each of the decision makers, the relative dominance values and two evaluations on the performance of the alternatives: a partial one, which considers the absolute dominance indices, being used to assess existing dominance relationships; and a global one, which provides the performance rates of the alternatives, making it possible to order them as well as to carry out a sensitivity analysis on the observed performances, reflecting in greater transparency in the decision-making process. The results obtained by the methods, point to the same direction in the ordering of preferences of the best regions for planting and, due to the robustness and relative ease of application, associated with a low cognitive effort on the part of the evaluators, it appears that this new methodology it can provide great gains, not only for the academic community, but also for the entire society.

■ FA-07

Friday, 8:00-9:00 - Room 7

Shared mobility and transport

Stream: Innovative & Shared Mobility and Transportation
Invited session
Chair: *Shadi Sharif Azadeh*
Chair: *Hai Wang*

1 - A dynamic many-to-one ride-matching algorithm for shared mobility services on congested networks
Seyed Mehdi Meshkani, *Bilal Farooq*

We propose a novel Graph-based Many-to-One ride-Matching (GMOMatch) algorithm in the presence of other vehicles for the dynamic many-to-one matching problem in which one vehicle can serve multiple riders. The proposed algorithm, which is an iterative two-step method, is efficient in terms of computational complexity while providing high service quality. The GMOMatch starts with a one-to-one matching in Step 1 to match the ride requests with vehicles. It is then followed by solving a maximum weight matching problem in Step 2 to combine the ride requests. To evaluate the performance of the GMOMatch, it is compared with a ride-matching algorithm developed by IBM. We implemented both algorithms in a micro-traffic simulator to assess their performance as well as their impact on the traffic congestion. Downtown Toronto road network was chosen as the study area because it usually faces high-level of recurrent congestion during the peak periods. The simulation results showed that the GMOMatch improved the service rate and traffic travel time by 32% and 4%, respectively, compared to the IBM algorithm. Also, the sensitivity analysis revealed that in downtown Toronto, utilizing vehicles with a capacity of 10 can accomplish 25% service rate improvement compared to a capacity of 4, which also meant a lower fleet size on the network.

2 - Battery Swapping and Inventory Rebalancing in Electric Micro-mobility Sharing Systems
Gaeun Lee, *Kun Soo Park*

We consider a battery charging and vehicle inventory rebalancing problem arising in free-floating electric micro-mobility sharing systems. To successfully meet user demand, operators have to redistribute the vehicles with the right number in the right place and swap batteries with insufficient levels into fully charged ones. With the free-floating property of the system, vehicle locations are randomly scattered, which increases the difficulty to visit and collect every single vehicle. Therefore, it is essential that operators take battery charging(swapping), staff routing, vehicle rebalancing problems all together into consideration. We aim to satisfy demand as much as possible and at the same time minimize routing and swapping costs. We formulate this problem in a mixed integer linear programming. Target levels for rebalancing is suggested by analyzing a stochastic process that incorporates demand changes. To alleviate the difficulty and complexity in practically large size, we develop a Cluster-first Route-second heuristic where a set partitioning problem clusters the regions into multiple sets to adjust inventory imbalances. We benchmark our heuristic approach on the pure MLIP formulation in settings with various demand patterns. The experimental result demonstrates that the heuristic is good at decomposing a large problem and gives efficient solutions in large-sized instances.

3 - Short-term repositioning for empty vehicles on ride-sourcing platforms
Hai Wang, *Zhengli Wang*

Due to stochastic demand, supply, and their imbalance on shared transportation platforms, the repositioning guidance for empty vehicles (idle drivers) is very important to improve passenger service level, driver income, and platform revenues. In this paper, we study the short term empty vehicles repositioning guidance problem using a two-stage model. First, we propose a general idealized relocation policy and its theoretical guarantee assuming that all travel times between regions are equal within a time unit; second, we study the specific repositioning optimization considering practical general travel times among regions and provide performance bounds both theoretically and numerically.

■ FA-08

Friday, 8:00-9:00 - Room 8

Continuous Optimization 1

Stream: Continuous Optimization (contributed)
Contributed session
Chair: *Tongli Zhang*

1 - Extension of SQP methods to constrained optimization problems on Riemannian manifolds
Mitsuaki Obara, *Takayuki Okuno*, *Akiko Takeda*

We consider optimization problems on Riemannian manifolds with equality and inequality constraints, which we call Riemannian nonlinear optimization (RNLO) problems. Although they have numerous applications, the existing studies on them are limited especially in terms of algorithms. In this paper, we propose Riemannian sequential quadratic optimization (RSQO) that uses a line-search technique with an l_1 penalty function as an extension of the standard SQO algorithm for constrained nonlinear optimization problems in Euclidean spaces to Riemannian manifolds. We prove its global convergence to a Karush-Kuhn-Tucker point of the RNLO problem by means of parallel transport and exponential mapping. Furthermore, we establish its local quadratic convergence by analyzing the relationship between sequences generated by RSQO and the Riemannian Newton method. Ours is the first algorithm that has both global and local convergence properties for constrained nonlinear optimization on Riemannian manifolds. Empirical results show that RSQO finds solutions more stably and with higher accuracy compared with the existing Riemannian penalty and augmented Lagrangian methods.

2 - The indefinite proximal subgradient-based algorithm for nonsmooth convex problems
Rui Liu, *Deren Han*, *Yong Xia*

This paper is focus on solving nonsmooth convex optimization problems. The well-known Nesterov's dual average method is generalized to a new version, called indefinite proximal subgradient-based (IPS) method, by introducing an indefinite proximal penalty in each iteration. The convergence analysis of IPS is established under some appropriate assumptions. Numerical experiments demonstrate the efficiency of IPS in comparing with the classical dual averaging-type algorithms.

3 - A Feasible-Inexact Quantum Interior Point Method For Semidefinite Optimization
Brandon Augustino, Giacomo Nannicini, Tamás Terlaky, Luis Zuluaga

We present the first provably convergent quantum interior point method (QIPM) for semidefinite optimization problems, building on recent advances in quantum linear system solvers. The quantization of classical interior point methods is the subject of several recent papers in the literature. However, current QIPMs proposed in the literature are simply not correct. We point out several challenges that have been overlooked so far, and propose solutions to these challenges. We compare the theoretical performance of classical and quantum interior point methods with respect to various input parameters, concluding that based on the current state of the art, our algorithm is the first convergent QIPM that provides a speedup in terms of the size of the problem.

4 - On the complexity of optimal simplex covering by spheres
Tongli Zhang, Yong Xia

Simplex covering optimization problem (SCO) is modeled from the application of covering a simplex by m given balls. It contains the maximin dispersion problem as a special case. In this paper, we prove that (SCO) is NPhard. We present an enumeration method (EM) to globally solve (SCO) and show that the complexity is strongly polynomial when m is fixed. Numerical experiments demonstrate that (EM) outperforms CPLEX when m is small. For larger m, we propose an efficient incomplete enumeration method.

■ FA-09

Friday, 8:00-9:00 - Room 9

Decision making in disaster management

Stream: Human Behavior in Disaster and Humanitarian Operations Management
Invited session
Chair: *Hyeong Suk Na*

1 - Understanding departure time choice behavior affected by social influence for hurricane evacuation planning
Hyeong Suk Na

Over the past few decades, human evacuation departure behavior has been described by various departure time choice models (DTCMs). Although this decision is given at the individual level, social media is transforming the communication channels for sharing the evacuation-related information during the evacuation; therefore, through social media evacuees collectively influence their departure time decisions and this causes high correlation among individual decisions. While it is apparent that this high correlation could be one of the main reasons of the simultaneous departures, there are only very few evacuation studies considering the effect of social influence on the human evacuation behavior. This is because it is demanding to build an evacuation plan dealing with the inherent complexity of the evacuation planning and the effect of social influence on human evacuation departure behavior. In this paper, to describe the departure behavior of evacuees interconnected by social influence, we propose a DTCM using a time inhomogeneous, discrete-time Markov chain. In other words, the evacuation decision probability of each evacuee at each stage is not independent of each other, but collectively affecting each other's decision in a social network representing a community of evacuees sharing the evacuation-related information. A numerical case study is provided to understand the effect of the evacuation planning on different social network topologies and the human evacuation behavior.

2 - A framework of multi-stakeholder coordination in humanitarian operations: A case study of Merapi Volcano eruption
Sekar Sakti, Bertha Maya Sopha, Hilya Mudrika Arini

This study aims to build a framework describing stakeholder coordination in humanitarian operations during the eruption of Merapi volcano. The study is motivated by the ambiguous coordination procedures amongst the involved stakeholders, particularly between government institutions and Non-Government Organizations (NGOs). An empirical framework was constructed based on a qualitative approach using a set of semi-structured interviews which was performed to the stakeholders from both government institutions and NGOs. The developed framework was therefore qualitatively validated. The NGOs were engaged in three main functions, i.e., logistics, rescue, and healthcare system, led by the government as a team coordinator. During response phase, NGOs coordinate with the government team to directly monitor the real time condition in the shelters and make daily report submitted to the administrator. Based on the report, the government make decisions which were then followed-up by the teams of each function.

■ FA-10

Friday, 8:00-9:00 - Room 10

Mathematical models in macro- and microeconomics 2

Stream: Mathematical Models in Macro- and Microeconomics
Invited session
Chair: *Milagros Baldemor*
Chair: *José Guadalupe Flores Muñiz*

1 - Retailers' endogenous sequencing game and information acquisition game in imperfect and evolving information
Yongjae Kim

This study explores the equilibrium states of the endogenous timing of order placement in imperfect and evolving information in the supply chain. Competition and information asymmetry in the business environment adversely affect firms across industries, often leading to suboptimal outcomes. We examine the dynamics of two competing retailers due to asymmetric information on their decision-making strategies. Specifically, we analyze a supply chain with one supplier and two competing retailers under demand uncertainty in which the retailers' decisions on the timing of order placement and acquisition of demand information are endogenous. It is natural for firms to have imperfect information in the earlier period, and this imprecision can be resolved in the later period. In this model setting, we could find important equilibria with meaningful managerial implications. One case is where the informed firm still orders early despite a certain degree of noise in the demand information if the imprecision factor of the informed firm is above a threshold value. Indeed, even if the informed firm can obtain better information later, the market leader advantage could still be dominant in the competition model.

2 - Consistent Conjectural Variations Equilibrium for a Financial Model
Nancy Solis Garcia, José Guadalupe Flores Muñiz, Vladik Kreinovich, Nataliya Kalashnykova, Viacheslav Kalashnikov

We consider a financial model in which a group of sectors (e.g., investors) buy, sell or exchange a set of instruments (e.g., stocks). Each sector faces some uncertainty when selecting its assets and liabilities to optimize its portfolio structure. We use the concept of conjectural variations to find the equilibrium in a multi-sector model of financial flows and prices of multiple tools. Each sector's utility function is accepted

as a quadratic function, whereas the constraints satisfy the accounting identity corresponding to the flow-of-funds accounts, as well as the equilibrium conditions that guarantee market clearance. The problem is modeled as a continuous bilevel programming problem. The upper level is a non-cooperative game where the set of strategies for each sector are their possible conjectures about its influence over the instruments' prices. The lower level is the financial model's equilibrium problem where, according to the conjectures selected in the upper level, each sector determines the composition of its portfolio, i.e., its assets and liabilities. In both levels, the sectors try to minimize the risks, whereas at the same time they seek to maximize the value of their assets and minimize the value of their liabilities.

3 - Consistent Conjectural Variations Equilibrium in the Semi-Mixed Oligopoly
José Guadalupe Flores Muñiz, Gabriela Renata Huarachi Benavídez, Nataliya Kalashnykova, Viacheslav Kalashnikov

We study a variant of the mixed oligopoly model with conjectural variations equilibrium, in which one of the producers maximizes not his net profit but the convex combination of the latter with the domestic social surplus. The coefficient of this convex combination is named socialization level. The producers' conjectures concern the price variations depending upon their production outputs variations. In this work we extend the models studied before, considering the case of the producers' cost functions being convex but not necessarily quadratic. The notion of exterior and interior equilibrium is introduced (similarly to previous works), developing a consistency criterion for the conjectures. Existence and uniqueness theorems are formulated and proven. Results concerning the comparison between conjectural variations, perfect competition, and Cournot equilibriums are provided. Based on these results, we formulate an optimality criterion for the election of the socialization level. The existence of the optimal socialization level is proven under the condition that the public company cannot be too weak as compared to the private firms.

■ FA-11

Friday, 8:00-9:00 - Room 11

Simulation, Stochastic Programming and Modeling 2

Stream: Simulation, Stochastic Programming and Modeling (contributed)
Contributed session
Chair: Takashi Hasuike

1 - Characterization and Mitigation of Errors in Quantum Computing via Consistent Bayesian
Muqing Zheng, Ang Li, Tamás Terlaky, Xiu Yang

Various noise models have been developed in quantum computing study to describe the propagation and effect of the noise which is caused by imperfect implementation of hardware. Identifying parameters such as gate and readout error rates are critical to these models. We use a Bayesian inference approach to identity posterior distributions of these parameters, such that they can be characterized more elaborately. By characterising the device errors in this way, we can further improve the accuracy of quantum error mitigation. Experiments conducted on IBM's quantum computing devices suggest that our approach provides better error mitigation performance than existing techniques used by the vendor. Also, our approach outperforms the standard Bayesian inference method in such experiments.

2 - An Integrated Control System Using Deep Q-Network in Battery Swapping Decision Making
YoonShik Park, Chanho Lee, Hyunwoo Lee, Taesu Cheong

This study proposes a reinforcement learning (RL) based central control system to support battery swapping decision-making for electric vehicles (EV) in the delivery business. To maximize the expected profit gained from the service within a whole system, a new architecture is proposed using an integrated single-agent system. This system can avoid the data distribution problem in the Q-value function which often occurs in a multi-agent system with conventional independent Q-learning. In our study, the Deep Q-Network model takes into account multi-agents and environmental information and gives orders to each driver when and which station to go. Numerical experiments are conducted to validate the performance of our model and it is shown that it maximizes the overall profit with the real-world delivery data.

3 - Forecasting gross inland natural gas consumption via regularized ensembles
Erick Meira, Fernando Luiz Cyrino Oliveira, Lilian De Menezes

Natural gas has been regarded as a strategic energy source in several countries. Given the increasing understanding of natural gas as a low carbon and environmentally friendly option, its consumption levels are predicted to rise in the next few decades. Natural gas markets, however, have suffered significant turmoil in recent years. Issues on multiple fronts have led to increased uncertainty for gas utilities and consumers. To underpin the impact of natural gas dependence in such a volatile environment and, at the same time, optimize production, distribution and storage strategies, reliable demand forecasts are arguably called for. In this work we propose a hybrid, ensemble-based approach that provides accurate forecasts of gross inland natural gas consumption across a range of European economies, including both major and minor consumers. The approach combines Bootstrap Aggregation (Bagging) algorithms, time series forecasting methods and regularization routines. A comparative, multi-step ahead, out-of-sample evaluation is conducted using different forecast performance metrics and several robustness checks. Overall, the proposed approach outperforms standard benchmarks and recently proposed ensemble methods, showing to be suitable to support decision making in the gas sector. Moreover, the methodology presented is flexible, in the sense that it can be used to generate reliable forecasts for other types of time series.

4 - The impact and effective distribution methods of Fast Pass and Stand-By Pass systems in a theme park
Nanami Ogata, Takashi Hasuike

Waiting time for attractions in a theme park is one of the big issues for visitors there. They get disappointed when they are made to wait for unacceptably long time. In order not to disappoint visitors, some theme parks have introduced Fast Pass system and Stand-By Pass system. By conducting Multi Agent Simulation, we find out about the impact of those systems, especially focusing on the sum of the time spent and the waiting time of visitors in a modeled theme park. Fast Pass system and Stand-By Pass system create reservation required queues with capacity in some attractions, to reduce visitors waiting time compared to standing in a Stand-By line without these systems. Visitors' behavior differs depending on whether or not they use these systems. If visitors line up in a Stand-By line, on choosing an attraction, they go there. On the other hand, in case that they use Fast Pass or Stand-By Pass, they go to the selected attraction at the time specified on the pass. Although Fast Pass and Stand-By Pass systems reduce visitors waiting time in the attraction rows, they can also make visitors wait longer outside the rows. These systems also have drawbacks like this, so we need to consider methods to make up for them. In this paper, we show that Fast Pass and Stand-By pass systems have positive impact on waiting time of visitors in attraction rows, and consider effective distribution methods that get visitors to wait for shorter time inside or outside the attraction rows.

Friday, 10:00-11:40

■ FB-01

Friday, 10:00-11:40 - Room 1

Keynote: Shmuel S. Oren

Stream: Keynotes
Keynote session
Chair: Eunshin Byon

1 - Mobilizing Grid Flexibility for Renewables Integration through Enhanced Computation
Shmuel Oren

The rapid penetration of renewable resources into the electricity supply mix poses challenges for the efficient dispatch of resources due to the inherent uncertainty and variability of such resources. Hence, in order to accommodate large amounts of renewables in is necessary to account for their output uncertainty and mobilize the flexibility of the system embedded in conventional generation, demand side resources and the transmission grid. In this talk we formulate a stochastic unit commitment optimization in which we expand the traditional recourse actions that are available to mitigate the adverse effect of renewables variability. In particular, we include in these recourse action, topology control through transmission switching and dynamic line ratings that account for the heating and cooling of transmission lines. We will demonstrate the potential gains from such recourse actions through test cases and discuss heuristic approaches for alleviating the computational burden resulting from such a formulation.

■ FB-02

Friday, 10:00-11:40 - Room 2

Continuous Optimization: Methods and softwares

Stream: Continuous Optimization
Invited session
Chair: Luis Felipe Bueno

1 - On sequential optimality conditions for constrained conic programming
Leonardo Makoto Mito, Roberto Andreani, Walter Gómez, Gabriel Haeser, Alberto Ramos

In the past decade, some approximate versions of the Karush-Kuhn-Tucker conditions (the so-called sequential optimality conditions) have been presented for nonlinear programming problems, and later, due to their usability in both theory and practice, extended for other classes of problems as well. In this talk, we introduce strong sequential optimality conditions for nonlinear minimization problems with general conic constraints and describe some of their theoretical and algorithmic properties, that improve some of the existing results even for more specific contexts, such as nonlinear semidefinite programming. Also, new weak constraint qualifications and a detailed localization of the new conditions among classical ones from particular cases of the general conic programming problem are presented.

2 - An Inexact Feasible Quantum Interior Point Method for Linear Optimization
Mohammadhossein Mohammadisiahroudi, Ramin Fakhimi, Tamás Terlaky

Exploring the opportunities offered by quantum computing to speed up the solution of hard optimization problems is a hot research area. To have a quantum speed-up for continuous optimization methods, Quantum Linear System Algorithms (QLSAs) are applied to solve the Newton systems inside the Interior Point Methods (IPMs). Since QLSAs inherently produce inexact solutions, we can only use Inexact variants of IPMs. Existing IPMs with inexact Newton direction are infeasible methods because inexactness leads to infeasibility. In this research, an Inexact-Feasible IPMs is proposed for Linear Optimization problems using QLSAs to solve a novel system that produces inexact but feasible steps. We show that this method has iteration complexity analogous to the best exact IPMs. We also discuss how QLSAs can be used efficiently in an Iterative Refinement scheme to find an exact solution without excessive time of QLSAs. In addition, we present preliminary computational results with our method implemented on a real quantum computer and on a quantum simulator.

3 - Towards an efficient Augmented Lagrangian method for convex quadratic programming
Luis Felipe Bueno, Gabriel Haeser, Luiz Rafael Santos

Interior point methods have attracted most of the attention in the recent decades for solving large scale convex quadratic programming problems. In this paper we take a different route as we present an augmented Lagrangian method for convex quadratic programming based on recent developments for nonlinear programming. In our approach, box constraints are penalized while equality constraints are kept withinthe subproblems. The motivation for this approach is that Newton's method can be efficient for minimizing a piecewise quadratic function. Moreover, since augmented Lagrangian methods do not rely on proximity to the central path, some of the inherent difficulties in interior point methods can be avoided. In addition, a good starting point can be easily exploited, which can be relevant for solving subproblems arising from sequential quadratic programming, in sensitivity analysis and in branch and bound techniques. We prove well-definedness and finite convergence of the method proposed. Numerical experiments on separable strictly convex quadratic problems formulated from the Netlib collection show that our method can be competitive with interior point methods, in particular when a good initial point is available and a second-order Lagrange multiplier update is used.

■ FB-03

Friday, 10:00-11:40 - Room 3

Patient flow optimization

Stream: OR in Health, Medicine and Life Sciences
Invited session
Chair: Nadia Lahrichi

1 - Chemotherapy Appointment Scheduling and Daily Outpatient - Nurse Assignment
Nadia Lahrichi, Menel Benzaid, Louis-Martin Rousseau

Chemotherapy planning and patient–nurse assignment problems are complex multiobjective decision problems. Schedulers must make upstream decisions that affect daily operations. To improve productivity, we propose a two-stage procedure to schedule treatments for new patients, to plan nurse requirements, and to assign the daily patient mix to available nurses. We develop mathematical formulations, and the model uses a waiting list to take advantage of last-minute cancellations. We test the procedure on realistically sized problems to demonstrate the impact on the nurses' productivity ratio. The first stage schedules appointments for new patients, estimates the daily requirement for nurses, and generates the waiting list for the patients. The second stage assigns patients to nurses while minimizing the number of nurses required.

2 - Patient scheduling based on a service-time prediction model: A data-driven study for a radiotherapy center.
Dina Ben Tayeb, Louis-Martin Rousseau, Nadia Lahrichi

With the growth of the population, access to medical care is in high demand, and queues are becoming longer. The situation is more critical when it concerns serious diseases such as cancer. The primary problem can sometimes come from an inefficient management of patients rather than a lack of resources. In this work, we collaborate with the Centre Integre de Cancerologie de Laval (CICL). We present a data-driven study based on a nonblock approach to patient appointment scheduling. We use data mining and regression methods to develop a prediction model for radiotherapy treatment duration. The best model is constructed by a classification and regression tree; its accuracy is 84%. Based on the predicted duration, we design new workday divisions, which are evaluated with various patient sequencing rules. The results show that with our approach, 40 additional patients are treated daily in the cancer center, and a considerable improvement is noticed in patient waiting times and technologist overtime.

3 - The Radiotherapy Scheduling Problem
Tu San Pham, Louis-Martin Rousseau, Patrick De Causmaecker

Radiotherapy treatment is a popular form of cancer treatment where a patient receives a large amount of radiation over a course of several consecutive days. In the most common form of radiotherapy, the radiation is delivered by a linear accelerator (linac). Planning the usage of linacs is essential in reducing the waiting time of patients, which directly affects the treatment outcomes. We study the Radiotherapy Scheduling Problem, which consists of finding the treatment schedule for a set of patients given a set of linacs respecting many side constraints and preferences. We propose a two-phase approach to the problem. The first phase assigns patient treatments to specific linacs and days. The second phase then decides the sequence of patients on each day/linac and the specific appointment times. For the first phase, a Mixed Integer Linear Programming (MIP) model is proposed and solved using CPLEX. For the second phase, a MIP and a Constraint Programming (CP) are proposed. The test data is generated based on real data from the cancer center of CHUM, a large cancer center in Montréal, Canada, with about 3500 new patients and 40.000 treatments a year. The results show that the MIP approach outperforms MIP for this problem and is able to solve real-sized instances. As for future work, we aim to analyse different patient admission strategies to check how they would affect the schedule. It is also interesting to take into account cancellations and changes in the schedule.

4 - Improving patient transportation in hospitals: a case study
Sara Séguin, Yoan Villeneuve, Charles-Hubert Blouin-Delisle

Patient transportation in hospitals is essential in providing care to the patients but is often neglected in terms of logistics and planification. Hospitals have access to huge amounts of data and studying them surely can help them take better decisions in regards to patient transportation. We present a case study of a patient transportation department for a hospital located in the province of Québec, Canada. Historical data of the transports is studied to identify current assignments of transport demands to the patient transportation department employees. The most used routes are identified and a mixed-integer model is used to find the best distribution of the employees throughout the hospital to minimize total costs. Results show that it is possible to diminish costs without disrupting the current schedule of the employees. In order to do so, employees are affected to specific routes instead of taking service calls for the whole hospital.

■ FB-04

Friday, 10:00-11:40 - Room 4

Time tabling and logistics in urban operations research

Stream: Discrete Optimization and Urban Operations Research
Invited session
Chair: *Yong-Hong Kuo*
Chair: *Mari Ito*

1 - Improving network connectivity of compromised digital logistics networks via maximising the second smallest eigenvalue of the graph Laplacian
Kam-Fung Cheung, Michael Bell

Enhancing cybersecurity plays a vital role in the logistics industry as any sabotage of the digital logistics network adversely deteriorates the customer service performance. This paper proposes a novel max-min integer programming model subject to a budget constraint to improve network connectivity of a compromised digital logistics network via maximising the second smallest eigenvalue of the graph Laplacian. Due to the NP-hardness of the model, the optimal solution may not be found in a short time. Thus, several heuristic algorithms, including greedy algorithms, tabu search and relaxed semidefinite programming (SDP) with rounding, are proposed to find promising solutions. Verification of these heuristic algorithms is achieved by applying them, firstly to a hypothetical network, then to a large scale-free network which mimics a digital logistics network.

2 - Scheduling System of the rehabilitation staffs — a case study
Atsuo Suzuki, Runa Mikata

We develop a scheduling system of the rehabilitation staffs in a hospital. In the system, we consider to assign specific rehabilitation staffs to each patient according the effect of the treatment and the preference of the patient. We formulate the problem as 0-1 integer programming problem and implement it on EXCEL using VBA and Python. It generates the schedule for one day in two or three minutes. The system is in a trial use in a hospital, and we are improving the system based on the feedback from the hospital.

3 - Long-term Scheduling of Inspection Process for Evaluating Operability and Maintainability of Fast Reactor Plants
Masaaki Suzuki, Mari Ito, Ryuta Hashidate, Keita Takahashi, Hiroki Yada, Shigeru Takaya

Preventive maintenance has been widely used in many industries, including the power sector. To realize the reasonable and effective maintenance of nuclear power plants, it is essential to optimize the aging management from the viewpoints of both safety and efficiency. However, maintenance scheduling is currently manually handled, which is a time-consuming process because of the large number of components and constraints that must be taken into account when creating a schedule. Besides, there is plenty of room for improvement in the schedules because most of the maintenance requirements are manually checked. Furthermore, to develop next-generation power plants with excellent operability, it is necessary to make it possible to evaluate operability and maintainability in advance at the design stage. Our final objective is to develop and implement an automatic scheduling system using the mathematical technique of Operations Research for addressing the inspection-process-scheduling problem in a sodium-cooled fast reactor plant. A sodium-cooled fast reactor is a nuclear reactor in the research and development stage and has characteristics that are very different from those of light water reactors that have been studied in the past.

4 - The nursery preferences and fairness: A shift scheduling problem
Yoshito Namba, Mari Ito, Ryuta Takashima, Masatake Hirao

In recent years, Japan has faced a shortage of nursery teachers. One of the reasons for this problem includes that nursery teachers are dissatisfied with the schedule because their preferences are not reflected in the schedule. In order to solve the shortage of nursery teachers, it is therefore necessary to create a schedule that improves their satisfaction. In Japan, shift scheduling for nursery teachers is often done

manually. However, it is not easy to manually create a schedule that satisfies the constraints, e.g., shift preferences and fairness. There are very few studies for shift scheduling for nursery teachers, and no studies take preference or fairness into account. Thus, this study proposes two-stage models that solves the shift scheduling problem for nursery teachers possessing shift preference and fairness. One model takes into account only shift preferences, whereas the other embeds both shift preferences and fairness. In the numerical analysis, we compare the proposed models with a previous model and evaluate schedules created by those for shift preference and fairness. As a result, the proposed models can reflect better shift preferences in the schedules than the previous one. In addition, latter model could not only reflect shift preference in the schedule, but also maintain fairness in the long run. The model could be applied in a variety of scheduling where shifts are defined by time period as well as in the field of the nursery.

■ FB-05

Friday, 10:00-11:40 - Room 5

Military OR 2

Stream: Applications of OR (contributed)
Contributed session
Chair: Gustavo Vieira

1 - Combining analytical modelling and simulation techniques to study maritime surveillance operations
Paul Sheehan, Joyanto Mukerjee

In this paper we demonstrate the benefits of combining multiple forms of analysis, including human-in-the-loop (HiTL) simulation, to explore operations research problems. The utility of HiTL simulation to scope a problem and explore uncertainty has previously been demonstrated, however compared to more statistically robust analysis methods, HiTL simulation is often considered to be subjective and therefore less reliable. The integration of HiTL simulation with other forms of analysis techniques in a meaningful way is described using three cases studies. The first case study analysed the utility of employing multiple Unmanned Aerial Vehicles (UAVs) to localise subsurface contacts. Mathematical models of generic search patterns were solved using numerical simulation to determine the number of UAVs required to optimise localisation for two candidate UAV systems. A HiTL simulation was then used to validate these results, and to discover other tactical issues. The second case study utilised both HiTL simulation and probabilistic modelling to understand the impact of cloud cover on a maritime surveillance missions. The third case study combined HiTL simulation and a discrete event simulation to explore different concepts for integrating automation into the human classification process used in maritime surveillance operations. All three case studies demonstrate the benefits of combining HiTL simulation with other forms of analysis, modelling and simulation.

2 - Guidelines for improving Cybersecurity Measures in Brazilian Military Organizations using Strategic Options Development and Analysis (SODA)
Gustavo Vieira, Roberto Gomes, Mischel Carmen N. Belderrain

Strategic Options Development and Analysis (SODA), developed by Colin Eden, is applied to identify some guidelines for improving Cybersecurity within Military Organizations in Brazil. Cybersecurity is the practice of protecting systems, networks, and programs from digital attacks. SODA uses interview and cognitive mapping to capture individual views of an issue. Three different perspectives were considered to identify the possible strategic objectives: Information Technology (IT), Operational (Op) and Research and Development (R&D) perspective regarding a military environment. For each perspective, an individual cognitive map was generated. The three individual maps were aggregated in a single map, with 30 constructs and four clusters. Each cluster was related to strategic information and their relations with other issues in the organization. These clusters were explored in order to identify the possible causes of the issues and to indicate possible actions to reduce its impacts in the strategic objectives achievement. The results highlight many interesting insights and clarify some guidelines which can be adopted in order to improve Cybersecurity. Although the information collected for this work was primarily focused in the Brazilian Air Force context, the mapping effort was conducted carefully to ensure that the results can be possibly adopted in many other public and private organizations.

■ FB-06

Friday, 10:00-11:40 - Room 6

Recent advances in social network and sharing economy

Stream: Revenue Management and Pricing
Invited session
Chair: Zhenzhen Yan
Chair: Liling Lu

1 - Distributionally Robust Influence Maximization
Louis Chen

We propose and study a distributionally robust influence maximization problem. Unlike the classic Independent Cascade model proposed in Kempe, Kleinberg, and Tardos (2003), we consider a model that involves an adversarial response to the selection of seed set. More precisely, rather than the spread of influence being determined by the independent coupling of random arcs, the spread of influence will be determined by an adversarial coupling of random arcs in response to any selection of seed set. Similarly to traditional stochastic models, the optimization problem remains NP-Hard. However, in contrast, with this newly introduced robust model, both the influence function and any node's likelihood of being influenced can now be efficiently computed; furthermore, we show that even with an adversarial coupling, the greedy algorithm still guarantees a (1 - 1/e) - approximation of the optimum, as in the Independent Cascade model. Finally, we consider computational comparisons through experiments.

2 - A Re-solving Heuristic for Online Matching with Capacity Constraints
Hao Wang, Zhenzhen Yan, Xiaohui Bei

We study an online edge-weighted matching problem with capacity constraints. In this problem, the supply vertices are offline with different capacities. Demand vertices arrive online and will each consume a certain amount of resources. The goal is to maximize the total weight of the matching. This framework can capture several real-world applications, such as the online ride hitch problem. We model the offline optimization problem as a deterministic linear program and provide several randomized online algorithms based on the solution to the offline linear program. We analyze the performance guarantee of each algorithm measured by its competitive ratio. Importantly, we introduce a re-solving heuristic that periodically re-computes the offline linear program and uses the updated offline solution to guide the online algorithm. We analyze the effect of incorporating re-solving heuristic and find that the algorithm's competitive ratio can be improved when re-solving at carefully selected time steps.

3 - Re-solving Heuristic in Online Matching with Applications in Ride-sharing
Hao Wang, Zhenzhen Yan, Xiaohui Bei

We investigate an online edge-weighted bipartite matching problem with capacity constraints. In this problem, the resources are offline and non-replenishable with different capacities. Demands arrive online and each requests a certain amount of resources. The goal is to maximize the profit generated by successful matches. This framework can capture several real-world applications, such as the trip-vehicle assignment problem in ride-sharing. We model the offline optimization

problem as a deterministic linear program and present multiple randomized online algorithms based on the solution to the offline linear program. We analyze the performance guarantee of each algorithm in terms of its competitive ratio. Importantly, we introduce a re-solving heuristic that periodically re-computes the offline linear program and uses the updated offline solution to guide the online algorithm decisions. We find that the algorithm's competitive ratio can be significantly improved when re-solving at carefully selected time steps. Finally, we investigate the value of the demand distribution in further improving the algorithm efficiency. Extensive numerical studies on both synthetic and real-world taxi data sets demonstrate the efficiency of the proposed algorithms and the effect of market conditions on the algorithm performance is also investigated.

4 - An On-Demand Ride Hailing Platform for Both Taxis and Private Cars: Should It Be Regulated?
Liling Lu, Guiyun Feng, Xin Fang, Sergei Savin

We consider an on-demand ride hailing platform who can potentially collaborate with taxi companies to gain access to taxi drivers in addition to its own private car drivers. We investigate the government regulation to such collaboration and its implications to riders, drivers, and the platform. In our model, riders are sensitive to service delay. Taxi drivers and private car drivers are different in participation costs and service qualities. The platform sets ride fee for riders requesting ride hailing services and provides wage compensation for participating drivers who serve ride hailing requests. To maximize the driver-rider welfare, the government decides the maximum amount of time that taxi drivers are allowed to serve the requests on the platform. By comparing with the benchmark without the collaboration or regulation, we find that the collaboration between the platform and taxi companies may not always benefit riders or drivers, and the government regulation is needed for higher driver-rider welfare.

■ FB-07

Friday, 10:00-11:40 - Room 7

Graphs and Networks 2

Stream: Graphs, Networks and Combinatorial Optimization with Applications (contributed)
Contributed session
Chair: *Mauricio Cepeda Valero*

1 - In-Tree Based Multi-Commodity Service Network Design
Chungjae Lee, Natashia Boland, Pedro Munari

We present a novel integer programming model and heuristic solution methods for a multi-commodity service network design problem motivated by problems arising in the less-than-truckload (LTL) freight transportation industry. LTL companies solve service network design problems to send shipments from different origins to destinations in a cost-efficient manner. To minimize the transportation cost and simplify handling, LTL companies consolidate freight shipped to the same destination at intermediate hubs and terminals, sending it forward on a single outbound arc. Thus, freight is routed on an in-tree rooted at each destination. We introduce a compact integer programming model that explicitly captures this characteristic using an "in-tree" constraint. The model decides the capacity assigned to each arc, in terms of whole numbers of truckloads, as well as the in-tree to be used for each destination. As compact service network design models are generally weak, we use a column generation scheme. The master problem determines the required capacity on each arc based on in-trees generated from subproblems. We present a diving-based heuristic solution method and analyze its computational performance depending on various strategies used in the heuristic.

2 - Maker-Breaker Resolving Game
Eunjeong Yi

A set of vertices W of a graph G is a metric resolving set if every vertex of G is uniquely determined by its vector of distances to W. The metric dimension of G is the minimum cardinality over all resolving sets of G, and it is known that determining the metric dimension of a general graph is an NP-hard problem. Applications of metric dimension can be found in robot navigation, network, and combinatorial optimization.

In this talk, we introduce the Maker-Breaker resolving game played on a graph G by two players, the Resolver and the Spoiler. The two players alternately select a vertex of G not yet chosen in the course of the game. The Resolver wins the game if, at some point, the vertices chosen by him form a resolving set of G, whereas the Spoiler wins the game if the Resolver cannot form a resolving set of G. We obtain some general results on the outcome of this game. We also determine the outcome of this game played on some classes of graphs, and examine the minimum number of moves for either Resolver or Spoiler to win the game.

This talk is based on joint work with Cong X. Kang, Sandi Klavzar, and Ismael G. Yero.

3 - Identifying Repairable Structures in Graphs with Randomly Changing Topology
Maciej Rysz

We propose a two-stage stochastic programming framework for designing or identifying repairable formations in networks whose topologies may undergo random changes. To this end, a stochastic extension of the problem of finding optimal hereditary and nonhereditary clusters in graphs is introduced. In this work, the repairability of a subgraph is defined in terms of a budget constraint that limits the extent of repairs that can be made to the selected cluster when restoring its original structural properties after observing random changes to the graph's topology. A combinatorial branch-and-bound algorithm is developed, and its effectiveness is illustrated on examples of two-stage stochastic maximum clique and k-club problems.

4 - Transportation network model for infrastructure and demand transportation planning in urban cities
Mauricio Cepeda Valero, Jose Fidel Torres Delgado, Andres Gonzalez

The cities are changing every moment and there are several agents that impact over this dynamic, such as: the citizens that are looking for their places to live or to work, the commerce that is looking for new markets, and the government that is offering the ways of transport. So, this paper shows the Stackelberg's model, to analyze the impact of two agents, in the city disposition. The model has three networks: the first one represents urban and industrial areas; and it is known like the Origin-Destination (OD) network; the second network is the transport and the last one is a full connected network, that allows trips among every node but at a very high cost. For the resolution of the model, two mixed integer linear models were structured, where origin - destination locations were got from the first model, and these locations are fed to second model, which allows to get an optimal transport network. The instances used were three transport infrastructure networks and three networks structures of the cities: the monocentric city, the polycentric city and distributed uniform city. Then, it was possible to identify that regardless of transport network, the monocentric city network didn't change, while transport infrastructure networks increased their edges quantity in the city center. A second finding is that in polycentric cities, most of the people moving to these city centers and periphery locations tend to disappear or decrease their population.

■ FB-08

Friday, 10:00-11:40 - Room 8

Quantitative methods in finance and risk management 2

Stream: Computational and Simulation Methods in Fi-

nance
Invited session
Chair: *Dohyun Ahn*

1 - Efficient Simulation for a Stochastic Linear Program and Its Application to Finance
Dohyun Ahn

Given a linear program with uncertain coefficients, we consider a problem of estimating tail probabilities of its optimal value. Such a problem arises in several applications including systemic risk measurement in financial networks and failure probability estimation in distribution networks. Assuming that the random coefficients follow a multivariate Gaussian distribution, we devise a new importance sampling method based on partitioning the sample space of the coefficients, and we demonstrate its asymptotic optimality. We also provide heuristic approaches to further improve its computational efficiency. Numerical experiments reveal that our method outperforms the existing schemes.

2 - Effects of Ordered Position on Stock Liquidity: New Non-Linear Evidence from Japanese REITs
William Mingyan Cheung

We examine the impact of investor psychology on stock liquidity. Psychology studies suggest that ordered position effects exist extensively in various context of human behavior but less evidence documented in property markets, and often unclear about its functional form. We identify ordered position effects with non-linear functional form using a sample of Japanese real estate investment trusts, J-REITs. Given the relative homogeneity of investment and payout policy, we argue that J-REITs provide a better controlled environment to identify if there are any ordered position effects on stock liquidity. We document a non-linear, two-dimensional ordered position effects of company names on stock liquidity based on the nested linguistic complexity of Japanese. We find that length of a company name is only having marginal impact. Further we find that the ordered position effects has a significant return implication. A portfolio of longing firms with highest syllabary-predicted liquidity and shorting firms with lowest syllabary-predicted liquidity generate an abnormal returns of 5.59 to 7% for a 6-month holding period.. Our results cannot be explained only by rational factors of stock liquidity.

3 - A financial optimization problem applied to Value at Risk and Conditional Value at Risk for a Mexican Index
Maria Rosa Nieto Delfin

When deciding among various alternatives to obtain the highest profitability, an investor must consider three basic factors: the expected returns, the associated liquidity and risk. The first factor will have greater relevance in the decision process, so that the investor will seek to obtain the highest return with a reasonable level of liquidity with the lowest possible risk. In literature, different methods have been proposed to relate the first and third factors. A common method used in finance is the Mean-Variance approach which is based on many assumptions and extremely simplifies reality but has proved been inefficient given the complexity and diversity of current investment alternatives. In 1952 Markowitz develops a model to maximize the return of a portfolio for a given level of risk. This model uses standard deviation as a measure of risk. Contrary, this paper proposes a new model as an alternative solution to Markowitz optimization problem. We propose to use Value at Risk (VaR) and Conditional Value at Risk (CVaR) instead of using Markowitz theory. The VaR can be calculated using different methods, we use Generalized Autoregressive Conditional Heteroskedasticity Models (GARCH) for estimating the volatility factor in VaR and CVaR formulations. The proposed approach uses GARCH to calculate VaR and CVaR measures used to calculate the Markowitz efficient frontier to determine the optimal portfolio. This methodology is applied to the Mexican Consumer Price Index (CPI).

■ FB-09

Friday, 10:00-11:40 - Room 9

Sequential learning in operations research

Stream: Statistical learning, stochastic optimization and applications
Invited session
Chair: *Dongwook Shin*
Chair: *Nandini Seth*

1 - Sparsity-Agnostic Lasso Bandit
Min-hwan Oh, *Garud Iyengar*, *Assaf Zeevi*

We consider a stochastic contextual bandit problem where the feature vectors are 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. We propose an algorithm which does not require a priori knowledge of sparsity and establish tight regret bounds under relatively mild conditions. We also comprehensively evaluate our algorithm numerically and show that it consistently outperforms existing methods.

2 - Thompson Sampling with Information Relaxation Penalties
Seungki Min, *Ciamac Moallemi*, *Costis Maglaras*

We consider a finite-horizon multi-armed bandit (MAB) problem in a Bayesian setting, for which we propose an information relaxation sampling framework. With this framework, we define an intuitive family of control policies that include Thompson sampling (TS) and the Bayesian optimal policy as endpoints. Analogous to TS, which, at each decision epoch pulls an arm that is best with respect to the randomly sampled parameters, our algorithms sample entire future reward realizations and take the corresponding best action. However, this is done in the presence of "penalties" that seek to compensate for the availability of future information. We develop several novel policies and performance bounds for MAB problems that vary in terms of improving performance and increasing computational complexity between the two endpoints. Our policies can be viewed as natural generalizations of TS that simultaneously incorporate knowledge of the time horizon and explicitly consider the exploration-exploitation trade-off. We prove associated structural results on performance bounds and sub-optimality gaps. Numerical experiments suggest that this new class of policies perform well, in particular in settings where the finite time horizon introduces significant exploration-exploitation tension into the problem. Finally, inspired by the finite-horizon Gittins index, we propose an index policy that builds on our framework that outperforms the state-of-the-art algorithms in our numerical experiments.

3 - A Two- Stage Mechanism for Online Grocery Recommendation using Bayesian Bandits
Nandini Seth, *Dinesh Kumar*

Due to high purchase frequency and customer stickiness, grocery e-tailing has emerged as an attractive profitable online business. Like other e-retailers, online grocery retailers employ personalised Recommender Systems (RS) to increase sales and learn customer preferences. Unlike existing RS, the mechanism for grocery RS is different due to the frequency and recurrence of purchase, absence of explicit customer rating and difficulty in predicting item pairs bought together.While most RS are targeted at improving immediate sales, a better understanding of a customer's preferences is imperative in grocery context because customer engagement period is longer. This paper aims at presenting a better, iterative recommendation mechanism for online groceries based on the explore-exploit dilemma of the Multi-Armed Bandit models. We propose a two-stage mechanism to optimally choose grocery recommendations for a customer which balance the economic goal of sales while sequentially learning about evolving customer preferences. Stage-I uses frequency of purchase to reveal the offline propensity of choice for each customer-item pair. This output is

used in Stage-II to calculate reward priors for Bayesian bandit model which is employed to make the final online recommendations. We have used the customer basket data from one of largest grocery e-tailer in India to validate the model. The current work can be used for designing RS for other items characterised by repeat and frequent purchases.

■ FB-10

Friday, 10:00-11:40 - Room 10

OR in Natural Resources

Stream: OR in Natural Resources
Invited session
Chair: *Mikael Rönnqvist*

1 - Modeling the risk in multi-criteria evaluation of producing biofuels from construction and demolition waste
Taraneh Sowlati, Krishna Teja Malladi, Shaghaygh Akhtari, Faisal Mirza

In this study, a new multi-criteria decision making model for evaluating different waste management alternatives is developed. The contribution of the study relates to the incorporation of risk in the decision-making. Risk is quantified using the mini-max regret approach for decision making under uncertainty. The risk values (regrets) are used in the multi-criteria model to determine the alternative that minimizes the worst-case regrets. The developed model is applied to a case study of producing biofuel from construction and demolition waste in the City of Vancouver, Canada. Waste management alternatives are defined based on the capacity and the type of equipment pieces used in the facility. The three criteria considered for the evaluation are the total annual worth, the total savings in GHG emissions, and the total savings in landfill space. For equal weights of criteria, the results suggest full-sized capacity with electrical equipment pieces for the facility. However, when the economic criterion has more weight than other criteria, a facility with half the size is recommended.

2 - Economies of scale in forest harvesting: optimization and visualization.
Andrés Weintraub, Antonio Alonso-Ayuso, Monique Guignard-Spielberg, Shanshan Luo, Jean-Christophe Kalka, Jingyi Pan, Takeshi Shirabe, Zhen Xiong

Harvesting in a forest subdivided into cutting units, over multiple periods, can see its net return substantially increased if one applies economies of scale (EoS). We describe a system that combines optimization and visualization. The main idea is that if it is possible to combine harvesting of two (twins) or three (triplets) units sharing a portion of common boundaries in a way that allows a single combined harvesting operation, substantial savings may be realized by moving harvesting machinery only once. We wrote a GAMS code to compare the net profit from using, or not, EoS, and designed a corresponding map system that allows the representation, and if necessary the computation of the potential surface areas to harvest for the data input phase, and the visualization of which areas to harvest as singles, twins or triplets, for EoS, or just as singles if no EoS is considered. The computational experiment is done using forests of 23 to 900 stands. The improvement in net income is substantial for the dataset used. The visualization of the solutions allows the decision makers to accept or reject the proposed solutions, and by altering the map and/or the data, to test modified assumptions by passing new input data to the optimization tool.

3 - Farm land collaboration
Mikael Rönnqvist, Mikael Frisk, Patrik Flisberg

The set farm lands or parcels belonging to a farmer often has a fragmented structure. There are several reasons including heritage processes and a reduced number of larger farms. This fragmentation leads to higher logistic costs and there is a potential of introducing swapping of farm lands between one or several farmers. This can also be viewed as a collaboration between a set of farmers where there is no need to sell their land but instead to lend it out for the next year. The main idea is to reduce the distance needed to move tractors and other equipments back and forward for the operations needed on the farm lands. This results in reduced diesel consumption and decreased CO2 emissions. We develop a number of optimization models to include fairness, efficiency and rationality concepts. We report on a number of large case studies done in Sweden. The potential savings are very high and we discuss how the proposed swapping of lands can be introduced in practice.

Friday, 12:00-13:40

■ FC-02

Friday, 12:00-13:40 - Room 2

Logistics, Transportation and Traffic 7

Stream: Logistics, Transportation and Traffic (contributed)
Contributed session
Chair: Edison Betancourt

1 - Workforce planning with crowdsourced logistics under regulations
Juntaek Hong, Kangbok Lee, Gwanhee Lee

This study deals with workforce planning of a last-mile delivery service company utilizing outsourcing companies and a crowdsourced driver pool. This study also deals with working environment of drivers crowdsourced by the company, a crowdsourced driver's revenue or required daily working hours. In addition, comparison of the situation prior to and after regulations(e.g. minimum wage enforcement and congestion fee) is presented.

2 - UAM Vertiport Site Selection Criteria
Keumsik Yu, Min-chul Jung, Moon Gil Yoon

Various social problems such as traffic congestion and environmental pollution has been arising because of rapid urbanization. Urban aviation mobility (UAM) is a three-dimensional transportation system that uses the sky in the city to overcome the limitations of existing two-dimensional transportation. In order to foster UAM industry, ground infrastructure (vertiport) will be an important factor. However, not only governments and regulators but also private companies around the world have yet to establish standards for location, size, and networking for Vertiport. And there is a lack of research about Vertiport, either. This study aims to establish a 'UAM Vertiport Site Selection Criteria' by deriving weighting and evaluation factors for Vertiport location selection in urban areas. To achieve meaningful result, this study choosed a vertiport location selection consideration general factors through prior research, airport location research criteria, helicopter location consideration factor, and airport passenger survey, and then derived the key factor of UAM vertiport location selection consideration through interviews with UAM Team Korea experts (FGI). In addition, correlations between the location selection factors were analyzed through surveys and interviews with UAM experts, and weights of vertiport location factors were determined through ANP analysis.

3 - Air travelers' acceptance level and perceived value on airline ancillary services -focusing on a Mongolian Airline
Otgonbayar Orosoo

This study is focused on analyzing the perceived value and acceptance of air travelers for airlines' ancillary services. In competitive markets, airlines must develop strategies to attract demand by providing valuable services to customers at attractive prices. Because customers' airline choices are affected by a variety of attributes, they should be able to effectively attract customers by designing and delivering customer-centric products by analyzing customer preferences and perceived value for each service. Therefore, this study will investigate the perceived value and acceptance of customers for individual ancillary services in the airline's product configuration process. We will also investigate how air travelers want to be compensated, such as accumulating basic fares or deducting them from bundle fares for side services not used by air travelers.

4 - The importance of factors affecting the quality of air navigation services
Edison Betancourt

Within the sectors involved in the great globalization dynamic, the aviation industry deserves special importance, where safety stands out as the main factor to maintain optimal levels in all processes carried out within the activity, especially airlines, airports and air navigation services. Studies in this matter have been conducted with some ease and solvency relating the perception of service quality of airports and airlines, compared to air navigation service providers, where many limitations can be found. For this study, a quantitative methodology will be established, which through a survey tool will determine the perception values of quality of air navigation service that pilots receive in Ecuador and Korea; and in the same way, the perception of service quality that air traffic controllers provide in both countries. The analysis will be carried out through the application of the SERVQUAL model, which has been widely studied and applied in various fields and organizations, applying an adaptation mechanism of the evaluation dimensions considered within this model to the specific case of air navigation services. The findings of the study, will be used to make a comparison between the two realities, and to establish the strengths and weaknesses of the system in terms of service quality perceptions, and through proper management, the performance of the organizations providing air navigation services can be increased; and thus offer a better service to users.

■ FC-03

Friday, 12:00-13:40 - Room 3

Logistics in maritime studies

Stream: Discrete Optimization and Urban Operations Research
Invited session
Chair: Zhou Xu
Chair: Lu Zhen

1 - An ADP-based approach for dual cycle operations on floating containerized cargo handling platform
Chenhao Zhou, Mengxue Yuan

Floating Containerized Cargo Handling Platform (FCP) is an open-water movable floating platform for ship-to-ship cargo transfer or providing servicing. Among its many applications, such as supply replenishment, refueling, temporary cargo storage, the platform is especially useful for handling flammable or toxic cargo which have a high risk to be handled onshore, such as liquefied natural gas. This study looks into an FCP equipped with gantry cranes to move containerized gas tanks between vessel and platform. Due to the tight connection between discharging and loading, dual cycle operations are needed to maximize operation efficiency. To solve this problem, two methods were proposed: approximated dynamic programming (ADP) with greedy policy, and ADP based neighborhood search. The numerical experiment results show that both methods can provide a handling sequence that significantly reduce the container ship turnaround time within acceptable computational time.

2 - Competition and cooperation for the design of feeder networks by multiple carriers
Kap Hwan Kim, Yanjie Zhou

This study proposes a game theoretic approach for multiple carriers to cooperate in designing their feeder network connecting multiple feeder ports and a hub port. Each feeder vessel carrier is assumed to have their own cargo demand between various industrial areas and the hub port. Through the cooperation, the carriers attempt to reduce the transportation cost and increase the utilization of their vessels by sharing the capacities of their vessels. It is assumed that the carriers only agree with each other in that they share the loading capacity. Various competition and cooperation models among carriers are analyzed: independent operation in which each carrier maximizes its own profit independently; cooperative operation in which a central decision-maker

design the feeder network and allocate the benefit from the cooperation among participating carriers in the same coalition; coopetitive operation in which carriers in the same coalition cooperate with each other only in sharing their vessel carrying capacities but compete with each other in designing and operating feeder networks. Numerical experiment compares various competition and cooperation models.

3 - Co-opetition in the port capacity management
Yifu Li

Ports are key nodes in the global logistics network. When there are multiple ports serving the same hinterland, ports may act in a co-optitive way, such that they both compete and cooperate with each other in different ways. They may compete with other with price and service quality, and ports may formulate alliances and share their capacity when their own capacity cannot satisfy the demand. In this study, we investigate the port expansion and capacity sharing decision problem. We derive the condition when to invest one's own capacity. In addition, we consider the negative impact of capacity sharing. Shared demands may diminish the service level of the port, and hence the demand from the other port may be discriminated against. We will examine the equilibrium and reveal the implication of the optimal scheme.

4 - Intermodal container routing optimization with service requirements
Yifan Shen, Jun Xia

Nowadays, liner shipping carriers take advantage of their inland service networks to provide intermodal container shipment services. To increase customer satisfaction, service quality-related issues are considered when optimizing the container shipment routes. In this paper, we study the container routing problem for fulfilling the intermodal cargo shipment demand between container freight stations, while several practical requirements are incorporated to constrain the length and structure of the container routes, so as to guarantee customer satisfaction. For this problem, we develop two mixed-integer linear programming models, with the objective of fulfilling all cargo shipment demands and minimizing total operating cost. A Benders decomposition-based method is proposed to obtain the exact solution for the problem. Computational results based on China-Europe Land Sea Express instances validate the effectiveness and efficiency of our proposed solution method.

■ FC-04

Friday, 12:00-13:40 - Room 4

Applications of DEA 3

Stream: Data Envelopment Analysis and Performance Measurement
Invited session
Chair: *Maansi Gupta*

1 - Application of DEA to investigate distinctive operational efficiencies for Asia-Pacific 3PL firms
Hyun-Soo Han, Ancilla Katherina Kustedjo

In this paper, we present the DEA(Data Envelopment Analysis) case study results investigating the regionally distinctive 3PL operational efficiencies for the Asia-Pacific 3PL firms. This study attempts to exploit the implications of DEA for the assessments of core operational capabilities of 3PLs. Accordingly, we firstly select input variables of CAPEX (capital expenditure), operational expense, and the number of employees, each of which can reflect the competitiveness of core processes such as facility utilization, process efficiency, and labor productivity of 3PLs. The computation results are analyzed to understand the characteristic performance differences across the country with a total of 117 3PL firms selected from 12 Asian countries. The results offers managerial implications useful for international business and collaboration management of logistics industry.

2 - Integration of linguistic cues with context-dependent DEA for performance forecasting and improvement
Sin-Jin Lin, Fu-Hsiang Chen, Jehun Zeng, Ming-Fu Hsu, Cathryn Jiang, Jennifer Jiang

This study introduces a fusion model that integrates balanced scorecards (BSCs) and context-dependent data envelopment analysis (CD-DEA) to conduct a performance evaluation task from multiple perspectives. The model is able to capture the dynamics of production processes and sub-processes, uncover some of the components behind successful practices, and shed light on the needed action for decision makers. Furthermore, the model not only can support decision makers to plan for improvement, but also equip them with forecasting ability. In order to enhance its forecasting quality, this study goes beyond quantitative ratios and extends them to borrowed from computational linguistics. The results are then fed into artificial intelligence (i.e., random vector functional links networks: RVFLs) to construct the forecasting model. The results show that the poor readability score is highly associated with bad operations. One of the qualitative ratios (i.e., readability: the complexities of disclosure) critical weaknesses of neural network-based model is lacking of comprehensibility and even worse impedes its real-life applications. To enlarge the model's applicable fields, the study executes the genetic algorithm (GA) to open up the opaque nature of neural network's decision black box and depict them in an intuitive manner. The model, tested by real cases, is a promising alternative for performance evaluation and forecasting.

3 - Evaluating the performance of firms with market equilibria: efficiency and market share
Soobin Choi

In this paper, we study a game-theoretical framework that evaluates the relative performance of firms in a competitive environment with a market equilibrium. Specifically, two normative performance measures in terms of equilibrium prices are considered: efficiency and market share. Defined by the ratio of revenue to cost, efficiency measures a firm's ability to transform inputs into outputs without waste. Meanwhile, market share, defined by the proportion of a firm's revenue to industry's total revenue, assesses the firm's dominance in the market. Since increases and decreases in efficiency and market share reflect the effectiveness of production strategies, the two performance indicators display firms' relative competitiveness. To evaluate these indicators in terms of revenue and cost at an equilibrium, we first characterize the set of equilibrium prices by a Fisher market model with production. In our market model, we describe the production possibilities of firms by using a Data Envelopment Analysis technique, which enables to construct a piecewise-linear estimation of a multi-input, multi-output production set from past input-output production data. With the set of equilibrium prices, we derive formulations that evaluate upper and lower bounds of efficiency and market share. All these formulations, based on convex programming, can be easily implemented by an existing algorithm. We also establish properties regarding our market model and performance measures.

4 - Performance Evaluation of Indian Judiciary: A Case of Indian District Courts
Maansi Gupta, Nomesh Bolia

The purpose of a judicial system is to provide a fair and timely dispensation of justice. Indian courts are known for their inability to meet the public's demand, slow resolution of cases, and the building backlog. The conventional wisdom believes that the primary reason is a severe shortage of judges and inability to fill judicial vacancies. There are over 35 million cases pending across Indian courts, of which over 85% belong to district courts. Such high pendency levels necessitate a study into the efficiency of these courts, possible causes of inefficiencies and appropriate reforms to improve performance. The goal of the current study is to measure the performance of district courts in India using Data Envelopment Analysis (DEA). The first DEA model considers only judicial resources as an input, and two outputs, viz., number of civil and criminal cases disposed. The second model incorporates the effect of judicial burden and additionally considers the number of civil and criminal cases instituted during the year as inputs.

Output-oriented, variable returns to scale DEA models are used. Results identify the specific courts that are efficient in disposing cases, point to policy imperatives and overall peer learning.

■ FC-05

Friday, 12:00-13:40 - Room 5

Graphs and Networks 4

Stream: Graphs, Networks and Combinatorial Optimization with Applications (contributed)
Contributed session
Chair: Akane Wada

1 - A Note on Enumeration of 3-Edge-Connected Spanning Subgraphs in Plane Graphs
Yasuko Matsui, Kenta Ozeki

In this talk, we present a simple algorithm that enumerates all the 3-edge-connected spanning subgraphs of a given plane graph with n vertices in O(n2) time, using reverse search method by Avis and Fukuda. For this problem, Yamanaka et al. proposed the algorithm that enumerates all the k-edge-connected spanning subgraphs of a given general graph with n vertices and m edges. Their algorithm generates each k-edge-connected spanning subgraph of the input graph in O(mT) time, where T is the running time to check the k-edge-connectivity of a graph. From the result by Gabow, it can be observed that T = O(m + k2 n log(n/k)) holds. So, their algorithm enumerates all the 3-edge-connected spanning subgraphs in an input plane graph and requires O(n2 log n) time per each. Note that m ≤ 3n - 6 holds for a plane graph. On the other hand, this talk also gives an algorithm that generates each 3-edge-connected spanning subgraph of an input plane graph in O(n2) time by using an algorithm which can check 3-edge-connectivity in O(n) time for a given plane graph. In 2017, for a given graph, Mehlhorn et al. already proposed an algorithm for checking 3-edge-connectivity in O(n) time. So, both algorithms require the same time complexity. However, ours is extremely simple and short. It has an advantage.

2 - A General Trick for Designing Pareto Optimal Reliable Networks
Rei Sakagami, Natsumi Takahashi, Shao-Chin Sung

We are dealing with a bi-objective network design problem which maximizes the all-terminal network reliability and minimizes the total building cost of networks. On one hand, trade-off between these two objectives is obvious, since both the network reliability and the total building cost increase when an additional edge is included in a network. Hence, the problem is to be solved by providing the so-called Pareto Frontier, i.e., the set of all Pareto solutions. On the other hand, the problem of finding network reliability is known to be computationally intractable in the sense that it is #P-complete, and so is the problem under consideration. For this reason, approaches based on heuristics or meta-heuristic are proposed for finding a set of pairwise non-dominated solutions which is closed the Pareto Frontier. In this study, based on computing process of factorization (or backtracking) methods for network reliability, we propose a general trick for approaches to the problem in order to reduce running time of numerical experiments, so that one may increase the scale of problem instances, and the effectiveness of our trick is shown by numerical experiments.

3 - A Pareto Dominance Relaxation Approach to Bi-objective Shortest Path Network Interdiction
Akane Wada, Natsumi Takahashi, Shao-Chin Sung

We are concerned with the problem of selecting arcs to be interdicted in networks in order to maximize the shortest s-t path length and to minimize the total interdiction cost, where interdiction of an arc is the action to increase the arc's length by paying the arc's interdiction cost. From the trade-off between the two objectives, the problem is to be solved by finding the so-called Pareto frontier, i.e., the set of all Pareto optimal solutions. It is known that the problem is computationally intractable. Hence, exact approaches based on branch-and-bound, and meta-heuristics approaches based on evolutional algorithms are proposed in the literatures. In this study, in order to improve the efficiency of exact approaches, we propose a branch-and-bound based algorithm to the problem in which the technique so-called relaxation of Pareto dominance are applied. By numerical experiments, we show that, by our algorithm, the running time for solving the problem is significantly improved from previously proposed algorithms.

■ FC-06

Friday, 12:00-13:40 - Room 6

Simulation, statistical learning and applications

Stream: Statistical learning, stochastic optimization and applications
Invited session
Chair: Xinyun Chen

1 - On the convergence of an improved and adaptive kinetic simulated annealing
Michael Choi

In this talk, I will first introduce various simulated annealing algorithms based on Langevin diffusions for stochastic optimization. Next, I will focus on an improved and adaptive kinetic simulated annealing algorithm, based on a trick that I call landscape modification. I will conclude by highlighting the interplay between sampling and optimization. This talk is based on the paper https://arxiv.org/abs/2009.00195v2

2 - Neural Learning of Online Consumer Credit Risk
Qi Wu, Di Wang, Wen Zhang

We take a deep learning approach to understand consumer credit risk when e-commerce platforms issue unsecured credit to finance customers' purchase. The model captures both serial dependences in multivariate time series when event frequencies differ, and nonlinear cross-sectional interactions among different time-evolving features. Through an unique dataset at JD finance, we decompose the predicted default probabilities into: the subjective risk indicating the consumers' willingness to repay, the objective risk indicating their ability to repay, and the behavioral risks.

3 - Online optimal pricing and capacity sizing for G/G/1 queue with demand learning
Xinyun Chen

We consider a pricing and capacity sizing problem in a G/G/1 queue with unknown demand curve. The objective is to adaptively adjust the service price and service rate jointly to maximize cumulative expected revenues over a given finite time horizon. We develop an adaptive algorithm based on stochastic gradient descent and provide asymptotic bounds for the regret. We also discuss possible accelerating methods for the algorithm.

4 - From Hotelling to Nakamomo: The Economic Meaning of Bitcoin Mining
Wei Jiang

We develop a continuous-time dynamic model for Bitcoin mining from the miners' perspective by borrowing idea of the classic Hotelling model for exhaustible resources. The model is rich enough to incorporate declining Bitcoin rewards and random transaction fees as well as inventory and demand levels, and is able to calibrate to empirical

data. We find that high jump risk and transaction fees are major forces driving miners to reduce their inventory even when Bitcoin prices are quite low or very volatile. Our model can also explain why the average transaction fee rate stays flat from 2014 to 2016 and increases dramatically in 2017.

■ FC-07

Friday, 12:00-13:40 - Room 7

MCDA Applications 1

Stream: Multiple Criteria Decision Aiding
Invited session
Chair: Irit Talmor

1 - Using OR methods for allocating budget of a political campaign

Irit Talmor

The Israeli system of government is characterized by a multiplicity of parties. During the pre-election campaign, parties spend a lot of money persuading constituents to vote for them. Furthermore, new parties have smaller budgets and fewer resources than veteran parties. In particular, the more heterogeneous the party's electorate, the more critical the issue of resource allocation is. Regarding to this issue, we developed a simple model that was implemented during the intensive political period before the April 2019 elections in Israel. Our goal was to help a new party, "Z," allocate its campaign efforts efficiently to maximize its voters. A sub-set of Israeli localities was created using Pareto's principle, and an MCDM approach was applied to this sub-set. We combined the party's confidential data with official data from the state open to all. The result was a model whose weighting and grading processes were clear and unbiased. These advantages made it effective and user-friendly for the strategic team and the campaign managers.

2 - Food market segmentation using outranking multicriteria approaches

Marina Segura, Concepción Maroto, José Carlos Casas-Rosal

Market segmentation is a key concept in marketing that groups consumers by their needs, characteristics or purchasing behaviour. Multivariate statistical analysis and neural networks have been the main tools for this purpose. Multiple Criteria Decision Making provides a new approach, which allows the generation of robust segmentation based on consumer preferences. The objectives of this research are to develop outranking multicriteria models based on PROMETHEE in order to segment food consumers and apply them to a survey of healthy and sustainable meat. The models consider two categories of purchasing criteria; one related to product and another to the distributor process. One model generates ordered segments of consumers, while the other obtains four segments according to consumer performance in both criteria categories. Both outranking multiple criteria methods provide a robust market segmentation, as they clearly identify the profile of consumers showing a high preference for the product and distribution criteria and those whose assessment is low. The profile of segments shows the significance level of variables such as gender, but mainly those related to food-related lifestyles, when characterizing the consumer groups. This proposal represents a robust approach, which is useful in the effective design of marketing campaigns and policies.

3 - A recommender system that reacts to buyers feedbacks - A new TOPSIS model with hesitant fuzzy data

Eshika Aggarwal

This work proposes an MADM model recommender system (RS) that reacts to buyers' feedbacks. The products in MADM are assessed as hesitant fuzzy sets(HFS). A new TOPSIS (techniques for order preference by similarity to ideal solution) method is introduced to solve MADM problem. The buyers' changed opinions, after coming across new products with altered features is realized using entropy. Our focus is mainly on two types of buyers' feedbacks (1) buyers' hesitation (2) information inadequacy. Proposed RS is sensitive as high degree of hesitation and less information (measured as entropy level) may lead to poor product rating. The buyers' changed feelings are judged through the hesitation degrees and entropy levels. The TOPSIS takes maximum satisfaction levels of the attributes as a vector of ideal point and the minimum satisfactions as an anti-ideal point. Our paper attaches weights to the attributes depending on the measure of entropy and calculates products' closeness to ideal or anti-ideal points after incorporating the hesitation. As degrees of entropies and hesitations differ from one attribute to another in the same product, and vary from one product to another in same attribute, the attribute weights and hesitations are derived differently amongst products. The TOPSIS calculates distances from ideal and anti-ideal points after taking above aspects. The product that is closest to the ideal and furthest from anti-ideal is taken as the buyers' best choice.

4 - Applying TRIZ and DEMATEL to evaluate the influencing factors of stakeholder network promoting mobile payment service

Dong Shang Chang, Yi-Chun Chen, Tsung Yen Wang

The adoption of mobile payment in Taiwan is being diffused towards the stage of early majority. It will face significant challenges in promoting mobile payment service systems in various fields. From the perspective of Socio-Technical System, the mobile payment technology subsystem that uses smart phones will co-evolve with social subsystems and environmental subsystems. Previous studies on the mobile payment are conducted from the perspective of users, operators or mobile payment platforms. It is difficult to grasp the needs and interactions between the network of stakeholders in the entire mobile payment system. The study uses the theory of solving inventive problems (TRIZ) to heuristically infer the influencing factors of stakeholder network promoting mobile payment service and employs the decision analysis method DEMATEL to assess the causal relationship and importance between the various influencing factors. This study result shows three key innovation principles, that is G4 (The government establishes special units to coordinate all ministries and local governments to promote mobile payment comprehensively), G3 (Preferentially promote mobile payment applications in transportation, medical institutions and public facilities) and G1 (Conduct rolling review on laws related to e-payment to adapt to the applications in various fields).

Friday, 14:00-15:40

■ FD-01

Friday, 14:00-15:40 - Room 1

EJOR: Policy, Facts and Highlights

Stream: Journals
session
Chair: Roman Slowinski

1 - A multi-depot two-echelon vehicle routing problem with delivery options arising in the last mile distribution
Lin Zhou, Roberto Baldacci, Daniele Vigo, Xu Wang

In this paper, we introduce a new city logistics problem arising in the last mile distribution of ecommerce. The problem involves two levels of routing problems. The first requires a design of the routes for a vehicle fleet located at the depots to transport the customer demands to a subset of the satellites. The second level concerns the routing of a vehicle fleet from the satellites to serve all of the customers. A feature of the problem is that customers may provide different delivery options, allowing them to pick up their packages at intermediate pickup facilities. The objective is to minimize the total distribution cost. To solve the problem, a hybrid multi-population genetic algorithm is proposed. An effective heuristic algorithm is designed to generate initial solutions, and several procedures are designed to better manage the population as well as exploit and explore the solution space. The proposed method is tested on a large family of instances, including a real-world instance; the computational results obtained show the effectiveness of the different components of the algorithm.

2 - Soft consensus cost models for group decision making and economic interpretations
Huanhuan Zhang, Gang Kou, Yi Peng

In a group decision-making (GDM) process, experts reach a consensus after discussion and persuasion, which requires a moderator to spend time and resource to persuade experts to change their original opinions. Since a unanimous agreement is hard to achieve and costly, a consensus degree or soft consensus was used and various approaches have been proposed to measure the level of consensus in GDM. Though cost is an important factor in GDM, few works have calculated consensus cost occurred during the process. Moreover, the degree of consensus was not considered in the minimum cost consensus study. The objective of this paper is to propose consensus models under a certain degree of consensus, which considers both consensus degree and cost in GDM. To do this, we develop a generalized soft cost consensus model under a certain degree of consensus, which is built by defining a consensus level function and a generalized aggregation operator. A soft minimum cost consensus model is constructed based on arithmetic weighted average operator (AWAO), and the maximum return model is constructed through its dual model. The cost (compensation) is studied from both the perspectives of a moderator and individual experts. The relationships between the two soft consensus cost models are analyzed, and the economic significance of the models are also discussed. Numerical examples are used to explain the proposed models. In addition, to show the usability of the proposed models in real-world context, we apply the proposed models to a loan consensus scenario using data from an online peer-to-peer lending platform.

3 - Policy and facts about the European Journal of Operational Research (EJOR)
Roman Slowinski, Emanuele Borgonovo, José Fernando Oliveira, Steffen Rebennack, Ruud Teunter, Mike Yearworth

The session starts with two presentations done by authors of representative and highly cited papers published recently in EJOR. They represent two categories: Innovative Application, and Theory & Methodology. Some further research developments and practical implications that followed these publications will be given by their authors. Then, the editors of EJOR will explain their editorial policy and will give some current characteristics of the journal. They will also describe their approach to evaluation and selection of articles and will point out topics of OR that recently raised the highest interest. In the last part of the session, the editors will answer some general questions from the audience.

■ FD-02

Friday, 14:00-15:40 - Room 2

Inventory and Warehousing

Stream: Supply Chain Management
Invited session
Chair: Miao Song

1 - Quality screening and pricing decisions in inventory models with defective items
Boualem Rabta, Zsuzsanna Hauck, Gerald Reiner

Consistent quality is one of the basic requirements customers expect from any products they have demand for. Although, it takes a lot of effort to provide good quality products steadily. Most manufacturers screen all of their items before selling, but this screening process can be imperfect. We consider the problem of optimal decisions under the assumption that the defect detection rate (and therefore the quality of the batch) as well as the screening cost depend on the time the company spends with screening. Demand also is a function of price and quality. The proposed relationships could be linear or nonlinear. The optimization problem is solved in two stages. First, the strategic decision is made by finding the optimal level of price and screening time. In the second step, i.e. the operational stage, the third decision variable, i.e. the optimal lot size is determined. The analytical solution is followed by numerical examples as practical illustration.

2 - Scattered storage assignment: mathematical model and VNS meta-heuristic to optimize the intra-order item distances
Harol Mauricio Gamez Alban, Trijntje Cornelissens, Kenneth Sörensen

This paper considers the scattered storage assignment (SSA) problem, a new kind of storage allocation policy. In SSA, products of the same type can be stored in different locations throughout the warehouse. In this policy, travel times can be reduced during order picking since it increases the probability of finding items belonging to the same order in nearby locations. Such type of storage policy is adequate for a typical e-commerce environment where customers demand more than one type of item but in small quantities. This research proposes an optimization model and a heuristic algorithm that minimizes the sum of pairwise distances between the same order positions. We propose an efficient variable neighborhood search (VNS) metaheuristic that can get nearly optimal solutions in reasonable computational times. Computational results show that the VNS improves the objective function between 5% and 12% compared to the literature's exact results. Finally, we prove that the sum of pairwise distances between the same order items is better for our storage allocation policy than a more traditional storage allocation policy.

3 - Feature Centralized Multiproduct Newsvendor with Substitution
Alba Olivares-Nadal

In this paper we aim to improve the decisions taken in a centralized multi-product newsvendor problem by making use of information provided by exogenous features. We rely on dual theory and the well-known kernel trick in order to account for nonlinearities and interactions between features without drastically increasing the dimensionality of the problem. In the case of a single item, the problem reduces to a Support Vector Quantile Regression. In the multi-product case we allow for substitutions between products in case of scarcity and we

show that the problem can be equivalently reformulated as a continuous quadratic program. Moreover, the problem is linear when constraining the direction of the substitution demand flow, and its regularized version permits the application of the kernel trick. The numerical results show that incorporating information from features and accounting for nonlinearities and interactions tractably provides statistically significantly better performance than the benchmark approaches.

4 - Joint pricing and inventory control with fixed and convex/concave variable production costs
Miao Song, Peng Hu, Ye Lu

This study considers a periodic-review joint pricing and inventory control problem for a single product, where production incurs a fixed cost plus a convex or concave variable cost. Our objective is to maximize the expected discounted profit over the entire planning horizon. We fully characterize the optimal policy for the single-period problem. As the optimal policy for the multi-period problem is too complicated to be implemented in practice, we develop well-structured heuristic policies, and establish worst-case performance bounds on the profit gap between the heuristic policies and the optimal policies. Numerical studies show that our heuristic policies perform extremely well. To further reveal the structural properties of the optimal policies, we also introduce two new concepts named kappa-convexity and sym-kappa-convexity, provide the associated preservation results, and then characterize the optimal policies.

■ FD-03

Friday, 14:00-15:40 - Room 3

Financial mathematics and OR 2

Stream: Financial Mathematics and OR
Invited session
Chair: Gerhard-Wilhelm Weber

1 - A multivariate Hawkes-type jump diffusion model for stock prices
Anqi Liu, Xiaodi Zhu, Jing Chen

We propose a new jump diffusion model with self-exciting and mutual-exciting effects for stochastic equity prices. This model is an improvement of the Merton's jump diffusion model. We design the model based on our previous empirical findings that "both positive extreme returns and negative returns may lead to higher chances of subsequent negative extremes," and "increasing occurrences of positive extreme returns are often following only the positive extremes." These arguments reflect the human nature of herding behaviour and loss aversion, but are neglected in existing stochastic return models. In our model, stock returns are modelled by a mixture of Brownian motion and two Hawkes jump processes. The two Hawkes processes control the occurrence of positive and negative price jumps respectively and involve both self-exciting and mutual-exciting between the two. We attempted a variety of distributions for jump sizes, including half-normal distribution, lognormal distribution and exponential distribution. The model calibration is conducted by the Monte Carlo EM algorithm. We apply this model on both market indexes and individual stocks. The calibration results indicate the role of short-range dependence of jumps in stochastic returns, as well as confirm previous empirical findings.

2 - A General Method for Analysis and Valuation of Drawdown Risk under Markov Models
Lingfei Li, Gongqiu Zhang

Drawdown risk is a major concern in financial markets. We develop a novel algorithm to solve the first passage problem of the drawdown process of general one-dimensional time-homogeneous Markov processes. We compute its Laplace transform based on continuous time Markov chain (CTMC) approximation and numerically invert the Laplace transform to obtain the first passage probabilities and the distribution of the maximum drawdown. We prove convergence of our algorithm for general Markovian models and provide sharp estimates of the convergence rates for a general class of jump-diffusion models. We apply the algorithm to calculate the Calmar ratio for investment analysis, price maximum drawdown derivatives and hedge the risk of selling such derivatives with a highly volatile asset as the underlying. Various numerical experiments document the computational efficiency of our method. We also develop extensions to solve drawdown problems in models with time dependence or stochastic volatility or regime switching.

3 - Asset pricing on multiple segmented markets
Ahmed Badreldin, Bernhard Nietert

The literature understands asset pricing on segmented markets with a single restriction, but does not consider markets where more than one restriction exists. We find that risk premia of restricted assets are not identical to unsegmented markets due to a demand deficit term resulting from investor exclusion, which becomes greater, the more levels of restricted exist leading to further divergence between segmented and unsegmented markets. We check statistical and economic significance of the identified differences highlighting the importance of taking into consideration multiple segmentation.

■ FD-04

Friday, 14:00-15:40 - Room 4

Applications of DEA 1

Stream: Data Envelopment Analysis and Performance Measurement
Invited session
Chair: Miguel Pereira

1 - Operational and financial efficiency of northeast Asian countries international container ports by using Data Envelopment Analysis (DEA)
Qaiser Farooq Dar, Young-Hyo Ahn

International trade productivity and efficiency have dependences significantly upon the import and export volume of a country. The import and export volume is all about the transportation of goods and services from one country to the rest of the world and directly correlated with the operational and financial efficiency of that country's waterborne transport. This study applies DEA to explore the international comparisons of the operational and financial efficiency of top international container ports in northeast Asian countries. The DEA is a powerful optimization technique to evaluate the efficiency of resolving international container port efficiency measurement because the calculations are non-parametric. The procedure does not require an explicit a priori determination of relationships between output and inputs like other conventional procedures of efficiency using production functions. The study considers the six inputs and actual container throughput as output for operational efficiency. In contrast, three input and three output DEA model is used for the evaluation of financial efficiency. The study also extended to identify the ranking by using the X-inefficiency measures and extract the benchmark information of inefficient DMU's by SBM measures. Our estimates suggest that overall technical inefficiencies of inefficient container ports are primarily due to pure technical rather than scale.

2 - Use of DEA model in assessing digitalization impact of the top 50 German banks on firm's efficiency
Roland von Horn, Armin Varmaz

As the economically strongest country in Europe, Germany has increasingly weakened banks. For 50 years, German banks have shown an ever-decreasing profitability. Germany is next to Japan the epitome of the bank-based economy (Franklin Allen, 2001). The exogenous factors of a low interest rate environment, regulatory requirements, the increasing shift of banking to online channels and the development of new business models in the context of digitization represent further key

challenges. This study examines the impact of digitization on the efficiency of the financial industry in Germany. We use DEA models to show the efficiency of banks considering the effect of digitization. The study use the balance sheet data of the 50 largest banks (2013 to 2018) and a digitization model, which is based on the analysis of digitization key words of the balance sheets, the analysis of the banks' digital product and service offerings and the development of the mobile Banking usage. We use the traditional efficiency models and two-stage production process to measures the efficiency and to illustrate the impact of digitalization on firm's performance. The one-step and two-step DEA models show that banks can increase efficiency by investing in digitization. The return on assets (ROA) increases for those banks that digitize compared to those banks that digitize compared to those that digitize less. Our study offers a novel approach to measure banks' digitalization effort and efficiency.

3 - A Choquet based aggregation model for incorporating preferences in DEA
José Rui Figueira, Miguel Pereira, Rui Marques

Data Envelopment Analysis (DEA) is a non-parametric and data-driven technique that is typically used in ex post efficiency measurement and performance evaluation assessments. Despite its flexibility and robustness, DEA does not take into account the incorporation of preference information, which is vital for decision-making. Thus, this work proposes using the Choquet multiple criteria preference aggregator embedded in an additive DEA model to link the fields of DEA and multi-criteria decision-making, by means of preference learning to compute the weights and the interacting criteria coefficients. In the end, this methodology was applied to the Portuguese public hospitals, with the purpose of assessing their performance over several perspectives to test its robustness and yield valid results for policy-making.

4 - A range directional vector 'benefit of the doubt' composite indicator: The case of Portuguese public hospitals
Miguel Pereira, Ana Camanho, José Rui Figueira, Rui Marques

Understanding the complexity of an age when systems deal with increasing amounts of data is vital to the survival of public and private entities. Composite indicators (CIs) arise as aggregators of key performance indicators via a single measure, reflecting those quantitative and/or qualitative dimensions. Data envelopment analysis (DEA) is one way to build such measures. Some DEA models are employed to compute CIs, but only a handful of them can handle desirable and undesirable outputs and the preference information of decision-making actors at the same time. Building on the envelopment formulation of the 'benefit of the doubt' approach with weight restrictions, we propose using a range directional distance function to yield a single CI that assesses the performance of the Portuguese public hospitals according to two key points of view (the users' and the providers') across distinct perspectives that test its robustness. Ultimately, possible policy implications were withdrawn from this cooperative application with the Portuguese Ministry of Health.

■ FD-05

Friday, 14:00-15:40 - Room 5

Energy, Environment and Climate1

Stream: Energy, Environment and Climate (contributed)
Contributed session
Chair: Manuel Wetzel

1 - Probabilistic forecasting of an air quality index
Jooyoung Jeon, James Taylor

Air pollution has emerged as a major issue affecting human health, with the resulting burden on health systems having economic and political implications. Urban air pollution is believed to be the cause of more than a million premature deaths worldwide each year. Respiratory illnesses are the main health risk factor, but the prevalence of heart disease, stroke and cancer is also increased. Air quality indices are widely-used to summarise the severity of the level of a set of pollutants, with a traffic light signal often used to provide a visual indicator. The index is a convenient measure used by policy makers, but is also used, on a day-by-day basis, by health professionals and the public, especially those with a history of respiratory conditions. Forecasts of the index are typically produced each day for lead times up to several days ahead. The predictions are usually provided by meteorologists using atmospheric models that have chemistry features incorporated. Probabilistic forecasting from such models is not straightforward, and hence is very rare. We consider the use of time series models to produce density forecasts for the index. The approach involves the fitting of a multivariate model to a set of six pollutants. To capture the dependencies between the pollutants in a practical way, we use an empirical copula. The empirical work uses hourly data from South Korea, where more than half the population are considered to be exposed to dangerous levels of pollutants.

2 - Mixed-Integer Nonlinear Programming techniques for the European entry-exit gas market system
Lars Schewe

In this talk, we are presenting recent results on how techniques from mixed-integer nonlinear programming can be used to contribute to the understanding and improvement of the European Entry-Exit Gas Market System, which decouples the trading and transport of natural gas. A core problem is for a transmission operator is to compute the so-called technical capacities. We will show both results on the computational complexity of the relevant problems and preliminary computational results to solve them.

3 - Speeding up optimizing energy system models - lessons learned from heuristic approaches, parallel solvers and large scale models
Manuel Wetzel, Karl-Kiên Cao, Kai von Krbek, Hans Christian Gils, Yvonne Scholz, Frieder Borggrefe

Most state-of-the art optimizing energy system models are characterised by a high temporal and spatial resolution to include detailed information of local weather conditions. This became necessary through the integration of renewable energy sources such as photovoltaics and wind energy. Similarly the integration of cross-sectoral technologies for the decarbonisation of the energy, heating and transportation sector makes energy system models more complex and as a consequence the time required for solving the problem.

To address this increasing computational demand the BEAM-ME project brought together experts from the fields of energy systems analysis, mathematics, operations research, and informatics to establish interdisciplinary solutions. The talk provides an overview of the final project results and more in-depth highlights from two stage heuristic approaches and the parallel interior point solver PIPS-IPM++. Depending on the problem at hand and available computation resources a speed-up factor of up to 26 was achieved.

Taking up the results from the BEAM-ME project an outlook on the follow-up project UNSEEN shows how the significant reduction in time required for solving the problems can be used to generate a more holistic view on the near-optimal solution space. This allows providing decision makers with a wide range of alternatives showing the trade-offs between several decision criteria.

■ FD-06

Friday, 14:00-15:40 - Room 6

Logistics Systems Optimization

Stream: Logistics in new economies
Invited session
Chair: *Shuguang Zhan*

1 - A novel hybrid multi-objective optimization approach for sustainable delivery systems with a case study of Izmir, Turkey
Giray Resat

The main novelty of this study is to present a novel two-stage solution method designed for sustainable last-mile delivery systems in urban areas. A proposed hybrid solution methodology includes multi-criteria decision-making system to select the most efficient logistics providers by considering different performance indicators, and a mixed-integer linear optimization model in operations of last-mile cargo distributions by drones within metropolitan areas by considering time windows for customer services. We present the multi-objective modelling approach, data analysis and outline important characteristics of the mathematical programming problem to minimize transportation cost (in the mean-time carbon dioxide emissions) and total sustainability score of the system by using epsilon constraint method to find out the Pareto frontier. The proposed solution methodology is applied into an illustrative case by using real-life data of one of the metropolitan in Turkey. The approach is shown as comparative analysis, after defining some pre-processing, symmetry breaking steps, valid inequalities, and logic cuts.

2 - Energy-efficient high-speed train rescheduling in a disruption
Shuguang Zhan, S.c. Wong, S. M. Lo

Disruptions are inevitable in daily train operations, which causes high-speed trains to deviate from their official schedule, and thus efficient rescheduling of disrupted trains is critical. We sought to determine the appropriate arrival and departure times and orders of trains at each station during a disruption, and the speed profile of each train, to reduce the train's delay cost and energy consumption. To embed the train-speed profile corresponding to energy saving into the train rescheduling problem, a space-time-speed network is applied for problem formulation. Thus, the energy-efficient train-speed profile is embedded in the speed dimension in the space-time-speed hypernetwork. The detailed train-speed profile between two stations is formulated as a multiple-phase optimal control model, which is solved using a pseudospectral method. Then, an integer linear programming model based on multicommodity flow is built to solve the train rescheduling problem. We decompose it via the alternating direction method of multipliers into a series of easy-to-solve shortest-path subproblems. Each subproblem is then efficiently solved using a dynamic programming algorithm. Finally, the Xian-Chengdu high-speed railway line is used to tested our model and algorithms to demonstrate the trade-off between passenger-service quality and energy efficiency.

3 - Three-level operator-attacker-operator models for increasing the operational resilience of transportation networks
Hande Kucukaydin, Necati Aras

Transportation networks become completely or partially inoperable, when a disruption occurs due to intentional man-made attacks such as terrorist activities. Since these non-random attacks are realized by intelligent agents, the extent of the disruption can be excessive. Thus, it is important to increase the operational resilience of the components in a transportation network by making suitable protection decisions. In order to determine the components to protect, two different multi-period operator-attacker-operator models are formulated. These mathematical models are three-level programming models, where the first-level player is the system operator who wants to increase the network resilience by deciding which components to protect. The second-level player is the virtual attacker who wants to cause the most damage to minimize the passenger flow. Finally, the third-level player is the system operator who maximizes the flow after the attacks. The two models differ in the type of interdiction. In the first model, the interdictions are assumed to be complete such that an interdicted component cannot fulfil any service, whereas in the second model, the interdictions can be partial such that an interdicted component can still render service at a reduced capacity. Both models are converted into equivalent bilevel models and solved via tabu search heuristics, where the search is performed in the upper level problem over the protection decision of the system operator.

4 - Bikeway Network Design with Selective Nodes
Chin Sum Shui

This paper introduces a novel bikeway design problem which determines an optimal bikeway layout that covers all potential cycling demand sources with minimal total travel time and under budget constraints. Providing that a station can cover multiple demand sources and a demand source can be covered by multiple stations, selecting part of the stations can cover all the demand. Meanwhile, the selected station set can influence the travel times between the stations and the construction cost of the network. A two-stage solution method, by combining the genetic algorithm and a novel elimination heuristic, is proposed to solve the problem by firstly determining the subset of nodes (selected nodes) that can cover all the demand sources and then designing the bikeway network that connects all selected nodes within a given budget. Numerical studies illustrate the advantages of elimination heuristics in solving the proposed problem and the effect of the budget and size of the station set towards the solution fitness.

■ FD-07

Friday, 14:00-15:40 - Room 7

Decision theories

Stream: Decision Support Systems
Invited session
Chair: *Shaofeng Liu*

1 - Multiple beliefs, dominance and dynamic consistency
Tommi Ekholm, Erin Baker

We investigate multi-period decisions under multiple beliefs. We explore the dynamic consistency of both complete and incomplete preference orderings; focusing on a dominance concept that supports decision-making under multiple characterizations of uncertainty by ruling out strategies that are dominated across a set of beliefs. We uncover a distinction between two types of dynamic inconsistency, which we label fallacious and fallible inconsistency. We introduce corresponding definitions of dynamic consistency and show that they are equivalent for complete orderings, but differ for incomplete orderings. Subjective expected utility is dynamically consistent and non-expected utility decision rules, such as minmax, are not. We show that the dominance relation over beliefs falls between these two: it is immune to the more severe fallacious inconsistency, but not to the less problematic fallible inconsistency. We illustrate the method and concepts using a numerical example addressing a focal, real-world problem of deep uncertainties regarding climate change.

2 - Decision analytics using data-driven modelling and evidential reasoning
Yu-Wang Chen

Decision analytics allows individuals and organizations to transform data and combine evidence to support informed decision making. However, most real-world decision making problems are often characterised by different types of information, and it is important to combine them together rigorously in order to prioritise a set of decision options or alternatives. As a result, it is crucial to develop theories, methods and tools to better understand complex decision making processes and provide robust decision support in business and society. The

evidential reasoning (ER) rule has been established from the seminal Dempster-Shafer (D-S) theory of evidence to combine multiple pieces of information conjunctively. Through implementing the orthogonal sum operation on weighted belief distributions with reliabilities, the ER rule takes into account both individual and collective support from multiple pieces of evidence reasonably, and it constitutes a generalised Bayesian inference process. The ER rule can be used to model the causal relationship between antecedent attributes and the consequent as well as to aggregate information for multiple criteria decision analysis. Optimal learning can also be constructed to train prior parameters in the ER rule-based approximate reasoning model when data are available.

3 - Use of mechanisms design and algorithmic pricing for a medical market analysis
Christine Huttin

This research on physicians' choice models is a collaboration between Professor Christine Huttin and Professor Jerry Hausman, to better understand the impact of physicians' choices, either prognostic, diagnostic or treatment choices (especially drug choices) when patients are covered under public versus private insurance schemes or need to decide to switch from the private plans to the Federal Medicare coverage ; this research question is investigated with new types of mixed logit models to analyze the impact of heterogeneity of physicians' choices and patients' characteristics , for various decisions with and without independence of irrelevant alternatives among the choice sets. It improves current statistical estimation of predictive expenditure models from conventional logit or probit forms by using random preference components for prices of medical services, proxies for various public and private insurance plans, fixed characteristics associated with patient profiles such as age sex and risk factors or comorbidities (e.g. obesity) and new specification tests on Independent of Irrelevant Alternatives assumptions (IAA). These series of models move the development of the economic models away from the type of decision models used in medical schools, mainly called the step models, usually representing the likelihood of providing a treatment and the patterns of utilization and expenditures of various medical services and nested logit models.

4 - Proposal of text mining and interpretable machine learning methodologies to identified valuable UGCs and alleviate information overload on online community
Jiho Kim, Young Jun Jang, Hong-Chul Lee

In the web 2.0 era, Electronic Word of Mouth (eWOM) plays an important role in sharing valuable information. At the same time, User-Generated Contents (UGC) is generated in various areas on the online platform community. However, due to the time-space-free nature of the Internet, a lot of information is formed and shared and causing information overload problems. This requires more effort to find valuable information. One of the UGC, online reviews, has structured features and unstructured features that user-written. Specifically, user-written semantics features are written in text and require quantification for analysis. Therefore, this study proposes a variable extraction method in online reviews by applying seven text mining methodologies such as sentiment analysis. The online reviews were collected on online community using python web scraping. The existing structured data and extracted variables are used as input for several machine learning methodologies such as boosting algorithms, to analyze the review's valuables. Furthermore, we compare each performance of machine learning methodologies and adopt the highest performed model, and identified key variables using interpretable machine learning methodologies. As a consequence, the result of our research can help to identified valuable information and helpful reviews in the online community and alleviate information overload. Moreover, we provide insights on how to manage information goods to online community managers.

■ FD-08

Friday, 14:00-15:40 - Room 8

MIP and LP software

Stream: Mathematical Optimization Software
Invited session
Chair: Timo Berthold

1 - Recent improvements to the FICO Xpress-Optimizer
Timo Berthold

We will present what is new in the linear, mixed integer and non-linear programming solvers within the FICO Xpress Optimization Suite.

2 - Introduction to the Cardinal Optimizer
Qi Huangfu

The Cardinal Optimizer (COPT) is a mathematical optimization solver for large-scale optimization problems. It is independently developed by Cardinal Operations and was released to public in July 2019. Since then, it has been tested and evaluated by many academic users and commercial customers. In this talk, we will introduce the main components of COPT and the new features we have added since its first public release.

3 - Solving MINLPs with SCIP
Ksenia Bestuzheva, Benjamin Müller, Felipe Serrano, Stefan Vigerske, Fabian Wegscheider

SCIP is a general-purpose mixed-integer programming solver which implements the LP-based spatial branch and bound method. This presentation provides an introduction into the new framework for solving problems which remain nonlinear and possibly nonconvex when the integrality requirements are dropped. Building upon SCIP's general plugin-based structure, this framework consists of the core and nonlinearity and expression handlers which work with specific nonlinear structures and expressions. Several recent improvements are presented such as new cutting planes, convex relaxations and bound propagation methods.

4 - Pseudocost sharing in NuOpt
Yasumi Ishibashi, Koichi Fujii

Currently, multi-core CPUs are mainstream in order to reduce heat generation and power consumption. In addition, cloud computing services provide virtual servers with multi-core CPUs. Furthermore, by building a computer cluster, it is easy to prepare a many-core computing environment. In order to achieve performance of such a many-core environment, parallel computing technology is necessary. We have been developing NuOpt, a software for solving mixed integer linear programming (MIP) problems by branch-and-bound method. NuOpt is parallelized using a method similar to the Ubiquity Generator (UG). Since MIP solver stores informations obtained during branch-and-bound process, sharing such informations among threads or processes may lead to further speed-up. In this presentation, we focus on the pseudocost used to determine branching variables, and report the method of sharing the pseudocost and results of computational experiments.

■ FD-09

Friday, 14:00-15:40 - Room 9

Performance Measurement and Valuation

Stream: Operational Research in Financial and Management Accounting
Invited session
Chair: Matthias Amen

1 - Assessing success factors as drivers for company value
Matthias Amen

In this conceptual presentation, the value of a company is interpreted as a result of success factors. The relevance and robustness of the success factors can be assessed by the Analytic Hierarchy Process (AHP) method. In a kind of benchmark, pairwise comparisons between the companies of a peer group within the same industry have to be performed with respect to a given set of success factors. Even without the knowledge of any market value we are able to calculate relevance weights by pairwise comparisons.

Another way to estimate the weights of the success factors is a backward approach. If we know the company value of a set of competitors, we can link this value vector to the matrix of company comparisons at the disaggregated criteria level. As the number of companies is expected to differ from the number of criteria, an analytical solution would not be possible. Therefore, a regression analysis is suggested. As a result, we will get market driven estimates for the weights of the success factors. In comparison to the well-known PIMS-study we are able to concentrate on causal success factors and not on past accounting measures.

2 - Does Politics Matters in U.S. Bank Efficiency?
Thao Nguyen, Jeremy Cheah

We examine the role of political party on U.S. bank efficiency at state level and the District of Columbia from 1966 to 2019. Specifically, we find that a win at the state level by Republicans tend to increase the bank efficiency at the state level after controlling for bank-specific variables and also for U.S. macroeconomic variables. At the national level, our results show that when the incumbent Republican government is replaced by a Democratic government, it would lead to an increase in the bank efficiency. This observation seems to provide some evidence to the contentious view that Republicans tend to be favoured as the party of business at the state level. Republicans are typically perceived as more likely to favour deregulation than Democrats so states that are controlled by Democrats deregulate later than those controlled by Republicans (Riley and Luksetich, 1980 and Kroszner and Strahan, 1999). Our results provide new evidence between politics and bank efficiency in the U.S. at the state level. We therefore recommend that a combination of government in different levels enhances the efficiency of the U.S. banking system.

3 - Exploring Green Financial Opportunities
Kevyn Stefanelli

Green finance consists of a wide range of projects and investments aimed to ensure a better environmental outcome, in line with the Sustainable Development Goals (citeunagenda). Several new financial instruments have been designed with the aim to have responsible or sustainable investments. However, the Green securities have been found to show different performances, with some of them which result more attractive than traditional securities, and others quite the opposite. In this paper, we aim to identify through a large literature review the common features in environmentally responsible investments, in order to provide a taxonomy of the securities according to risk preferences and the chosen time horizon. We analyze seventy recent empirical and theoretical researches which deal with the modeling of responsible investments. We are able to classify the results according to the i) country of analysis (Europe, US and rest of the world); ii) time frame (decades or shorter); iii) data used (monthly vs daily data); iv) methodology (structural or market analysis).

■ FD-10

Friday, 14:00-15:40 - Room 10

OR, Human Behavior and Society

Stream: OR, Human Behavior and Society (contributed)
Contributed session
Chair: *Jong-In Choi*

1 - Release Time and Price: Optimal Delayed Release with Consumer Learning in The Freemium Model
Xiaoyan Chen, Wei Geng, Xuan Zhao

Freemium has become a common business model for selling digital products. Based on the assumption that both consumer's preference or taste and consumer learning are heterogeneous, we consider a delayed release strategy in the freemium business model. The 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 threshold on discount rate to guarantee that such a delayed release is desirable is first found, which is affected by the adoption cost and the network externality of the product. When the adoption cost is low and the network externality is weak, the firm more likely to delay releasing the premium version of the product. Given all external parameters fixed, the optimal release time of the premium version and corresponding price of the premium version are then obtained under different conditions. Furthermore, we also demonstrate the robustness of our findings by giving a different learning function. The results of the numerical analysis show that although using different learning functions in the two-stage model will yield some different conclusions, the main optimization conclusions still hold, say, the model has better robustness. Our research obtains some key managerial insights that are useful to firms selling digital products in their product release strategy search and implementation.

2 - Human-in-the-loop System to Investigate Perception-driven Evacuation Behaviors for Modeling and Simulation: Focused on Radiological Emergency
Soohyung Park, Namhun Kim

Emergency response plans for radiation accidents in South Korea and Japan focus on the macroscopic scale from the perspective of the national or local governments. However, the Fukushima disaster in 2011 has revealed the existence of gaps between the plan and actual situation. The inappropriate evacuation orders that failed to consider individual behaviors of residents acted as the root cause, and the residents of the indoor sheltering zones voluntarily evacuated, resulting in disorganized mass evacuation. In the case of other disasters such as hurricanes, large-scale evacuation simulations using an agent-based model (ABM) are being developed for planning, but modeling and simulation (M&S) for radiation accidents are constrained by the lack of quantitative data on individual behaviors. To overcome this limitation, this study proposes a method of observing evacuee's behaviors under the nuclear power plant (NPP) accident by building the virtual reality (VR) based human-in-the-loop (HITL) system. For proof of concept (PoC) about the HITL system, we conduct the test constructed with reference to the Fukushima disaster. Finally, the PoC test results show that the HITL system is suitable for observing evacuation behaviors of human. The quantified data collected from the HITL system can be applied to M&S for an effective emergency management tool.

3 - Searching for any possible influences among the five dimensions of SERVQUAL model
Jong-In Choi

The dimensions of SERVQUAL model were reduced to five categories known as reliability, assurance, tangibles, empathy and responsiveness or RATER from ten preliminary dimensions by Parasuraman et al., and since then, these dimensions of the model have been used to measure the quality of services offered in various industries through various studies. Many studies on if these five dimensions of SERVQUAL model can be applied unilaterally to all industries for service quality measurement can be found, however, not many studies on if the five dimensions of SERVQUAL model can make any influences to each other, which may influence the result of service quality measurement, can be found. This study first reviews the studies on how service quality measurement models are applied to various industries and then presents the way of searching for any influences that may exist among the five dimensions of SERVQUAL model. This study presents the way of searching for the possible influence among the

five dimensions of SERVQUAL model through analytic hierarchy process or AHP developed by Saaty in the 1970s as well as analytic network process or ANP, which is a more general form of the AHP used in multi-criteria analysis. Although this study only suggests the way of searching for the possible influences among the five dimensions of SERVQUAL model, it is considered that an improved or even a new model for service quality measurement can be presented in the future through further studies.

4 - Analysing the impact of online news on individuals' sequential trading decisions
He He, Tiejun Ma, Ming-Chien Sung, Johnnie Johnson

Several empirical studies have reported that the consequences of prior actions can affect subsequent risky decisions. However, little work has investigated how the news environment in which prior actions were taken alters the impact of prior consequences. In this study, we examine to what extent the effects of individual traders' prior gains on their subsequent trade size are contingent on different news sentiment environments in which these gains were secured. The results are derived from an individual-level trading dataset containing details of 285,725 trades of 4,857 traders between 2004 and 2013, complemented by a news archive that contains over 20 million news items. We find that individuals increase trade size following prior gains, but the magnitude of the increase depends on the type of the news sentiment environment - amplified/reduced by the news sentiment that was consistent/inconsistent with the prior decisions that generated gains. We suggest the news environment affects individual sequential risky decisions through its effects on emotions - prior gains lead an individual to have positive emotions, and the emotions are amplified/reduced when the individual receives positive/negative feedback from the news sentiment that is consistent/inconsistent with the gain-generating trading decisions. This study contributes to the literature on the roles of contexts and emotions in decision-theory models.

■ FD-11

Friday, 14:00-15:40 - Room 11

OR analytics in human resource management and related challenges 1

Stream: OR Analytics in Human Resource Management
Invited session
Chair: *Magdalena Graczyk-Kucharska*

1 - Automated vehicle fleet management in manufacturing environments combining network analysis, parameter prediction and optimization techniques
Júlia Bergmann, Dávid Gyulai, József Váncza

In the era of industrial digitization, complex optimization-based solutions are more than welcome by innovative manufacturing companies. Today's shop-floor logistics are not only based on human resources anymore, but also the machines are frequently served by Automated Guided Vehicles (AGVs). A dynamically changing industrial environment possesses many constraints and exceptions in terms of logistics. Therefore, the efficient real-time dispatching of thousands of tasks among the vehicles of an AGV fleet is a complex puzzle to solve. In this study, a novel dispatching approach is proposed and then compared with other methods. The approach consists of network analytics, prediction, integer programming and dispatching logic configuration. It considers not only the possible routings of the AGVs' tasks, but also the prediction of material flow intensity among machines on the shop-floor. The optimal clusters of tasks are identified by performing modularity maximization on the directed line graph of the material flow. Each AGV is then assigned to certain clusters with respect to load balancing. Finally, each task is dynamically matched with an AGV by a special distance-based dispatching logic. The process is validated on a discrete-event simulation model which is inspired by an existing manufacturing environment. A comparative analysis with traditional shop-floor logistics methods is executed with respect to key performance indicators, such as task duration or AGV utilization.

2 - Data mining methods used for designing the acceleration model of creativity competence development
Magdalena Graczyk-Kucharska, Robert Olszewski, Maciej Szafranski

Theory of knowledge-based economy is becoming strong movement described by analysis of the real socio-economic situation. Social capital and undertaken by the society competences ensure human resources. The consequence of it is foster sustainable economic development. Among competences needed by entrepreneurships for a wide range of professions are among others: team collaboration, creativity, communicativeness or entrepreneurship. The main objective of this paper is to develop the model, that indicates different variables, which may influence acceleration of creativity competence developed among students. Collected research data were analyzed with the used of Multiple Linear Regression Model, Nonparametric Regression Methods, e.g., Multivariate Adaptive Regression Splines, also Data Mining Techniques - Decision Trees and Artificial Neutral Network. Presented models allow to explain almost 90% of variability of the phenomenon described by collected data. The studies allow for selecting of key explanatory variables describing acceleration of transversal competence occurrence, also help in comparison of efficiency of particular methods. The results may be used in decision making process for choosing the best teaching methods of the students, thus helping them in acceleration of creativity competence development needed almost at each workstation in different professions.

3 - ICT as a determinant of inefficiency: An efficiency measurement in education of selected OECD countries
Muhammad Mujiya Ulkhaq, Kristof De Witte, Giorgia Oggioni, Rossana Riccardi

The role of information and communication technologies (ICT) in education is well established. There seems to be a consensus among scholars and practitioners that ICT enables the educational process to be managed efficiently. Regarding the efficiency measurement of educational institutions, there is a large literature examining this issue. However, the role of ICT as a determinant of inefficiency is scarcely addressed. This paper aims to investigate the efficiency of selected 24 OECD countries in terms of education by including ICT as a determinant of inefficiency. Using the OECD PISA data of 2009 to 2018, we used the parametric approach of efficiency measurement, namely, stochastic frontier analysis, to accomplish the objective of the study. Four random components of the stochastic frontier model, i.e., statistical noise, individual heterogeneity, persistent inefficiency, and time-varying inefficiency, were incorporated into the model. This study represents the first attempt of an efficiency analysis in an international comparison by modelling the four-component heteroscedastic model, where the ICT plays as a determinant of the inefficiency. This study is expected to allow more purposeful policy recommendations as well as expand the literature regarding efficiency measurement in education.

Friday, 16:00-17:40

■ FE-01

Friday, 16:00-17:40 - Room 1

Cryptocurrency Pricing

Stream: Contemporary Issues in Cryptocurrency Markets
Invited session
Chair: *Jeremy Cheah*

1 - The First Step of Pricing Bitcoin: a Model-free Approach
Jinqiang Ye, Jeremy Cheah, Ming-Chien Sung, Johnnie Johnson

In this paper, we map risk and return onto Euclidean distance and find evidence for cross-market convergence pattern for both risk and return properties in Bitcoin markets. We also find that negative events enlarge the distance but have no significant impact on the speed of convergence. We contribute towards the pricing of cryptocurrency literature in two ways. First, we introduce a novel approach to explore the pricing issue of Bitcoin via the use of distance measure. Second, we observe the implications of speed of convergence on the choice of risk-return profile for an investor.

2 - Characteristics of Volume and Fluctuation at Specific Times in Bitcoin Trading
Changhoon Lee, JaeHo Myeong, Jae-Hyeon Ahn

Despite the extremely high volatilities compared to the stock markets, interest in cryptocurrency represented by Bitcoin has increased as well as prospects for its potential in the future. This study is the first attempt to uncover the time-dependent trading patterns of Bitcoin. We found that there is a statistically significant difference between when it is on the hour (o'clock) and when it is not, as well as when it is 0 o'clock and when it is not. When it is on the hour or 0 o'clock, the trading volume and the amount of fluctuation increase. This study reveals that investors' investment behavior is not uniform in a time period that is constantly repeated, but rather consistently shows a specific tendency.

3 - PreBit: an NLP enhanced prediction model for Bitcoin price using Twitter
Yanzhao Zou, Dorien Herremans

Bitcoin, with its ever-growing popularity, has also demonstrated unparalleled price volatility since its origin. This volatility, together with its decentralised nature, make Bitcoin highly subjective to speculative trading as compared to more traditional assets. We are interested in studying whether social media discussions from the general public on Bitcoin have predictive power for extreme future price movements. To obtain such discussion contents, a dataset of 5,000 daily Tweets (or the maximum number available that day) were collected from 2015 to 2019 containing the keyword "bitcoin". Previous studies have used the Bag of Words (BoW) approach with logistic regression to show that a link exists between Twitter sentiment and daily price on a short time frame of twenty-one days (Colliani, 2015). In our study, sentence-level BERT embeddings pre-trained on financial lexicons were utilised in an attempt to capture not only the sentiment but also the contents of the tweets. By combining these embeddings with a Convolutional Neural Network, we closely examine the link between the public tweet contents and significant market movement over a much longer period of time. We also propose an ensemble of our NLP model and a baseline price model to explore how we can augment the performance of traditional price models with NLP based on Tweets for extreme price movement prediction.

■ FE-02

Friday, 16:00-17:40 - Room 2

Logistics, Transportation and Traffic 3

Stream: Logistics, Transportation and Traffic (contributed)
Contributed session
Chair: *Breno Alves Beirigo*

1 - Seniority in airline manpower planning
Adam Wojciechowski

Airline manpower planning involves creating a plan for how to balance the supply and demand of correctly qualified crew. Making a manpower plan involves taking decisions on vacation planning, production distribution, base transfers, new hires and qualification training. In many airlines, decisions regarding new hires and qualification training are governed by seniority rules enabling senior crew members to claim an open position before junior crew members or new hires. In this presentation we will address how seniority is handled inside the Jeppesen Manpower Planning product using a mixed integer programming formulation.

2 - Matheuristics for the Vehicle Routing Problem with Drone Stations
Konstantin Kloster, Mahdi Moeini, Daniele Vigo, Oliver Wendt

We study the Vehicle Routing Problem with Drone Stations (VRP-DS). In the VRP-DS, a depot, a set of customers, and a set of drone stations are given. A drone station is a parcel storage place equipped with autonomous drones (or robots). Starting from the depot, the trucks deliver parcels to the customers and return to the depot by the end of their tour. In addition, within their tours, the trucks can also visit (and activate) a limited number of drone stations. Through an activation process, a truck visits a drone station and hands over packages. Then, a set of drones, located at that drone station, can start serving customers within a given range and by round trips, i.e., starting from the drone station, visiting a customer location (to deliver a parcel), and ending at the same drone station. After each delivery, the drones are recharged (instantly) at the drone station and can start a next delivery, if required. The objective of the VRP-DS is to serve all customers by either trucks or drones while minimizing the makespan. We formulate the VRP-DS as a mixed integer linear program (MILP), to be solved by any standard MILP solver, and present two matheuristic algorithms for addressing large-scale instances. According to the results of our computational experiments, the use of drones and drone stations can significantly improve the makespan. Furthermore, the numerical results show that our algorithms provide high-quality solutions in short computation time.

3 - Accounting for demand uncertainty when designing the network of express integrators
Jean-Sébastien Tancrez, Jean-Charles Lange, Jose Miguel Quesada

The Express Shipment Service Network Design (ESSND) problem consists in determining a schedule of daily flights to efficiently deliver packages in large regions overnight. Even though express integrators face demand variability from day to day, the ESSND literature only considers deterministic demands. In this work, we account for demand uncertainty and aim to balance service level and cost when designing the network. We propose the aircraft routing model with demand uncertainty (ARMdu), which builds on composite variables to account for demand uncertainty. Thanks to their small size, the service level of the composite variables can be computed efficiently using simulation. Then, the network service level can be estimated as a function of the selected composite variables. The ARMdu maximizes this estimation of the network service level while limiting the network cost. An alternative model, minimizing the cost to reach a given service level, is also formulated. The effectiveness of our approach is shown on instances of realistic size provided by an express integrator in Europe. We show

that, compared to the deterministic approach used in practice, the AR-Mdu allows to significantly improve either the network service level (number of undelivered packages reduced by 24%) or the network cost (reduced by 1.1%), and it does so in a short computational time (around three minutes).

4 - A business class for autonomous mobility-on-demand: Optimization- and learning-based strategies to model service quality contracts in ridesharing systems
Breno Alves Beirigo, Frederik Schulte, Javier Alonso-Mora, Rudy Negenborn

With the popularization of transportation network companies (TNCs) (e.g., Uber, Lyft) and the rise of autonomous vehicles (AVs), even major car manufacturers are increasingly considering themselves as autonomous mobility-on-demand (AMoD) providers rather than individual vehicle sellers. However, matching the convenience of owning a vehicle requires providing consistent service quality, taking into account individual expectations. Typically, different classes of users have different service quality expectations, especially in terms of reliability and responsiveness. Nonetheless, planning models presented in the AMoD literature do not enable active control of service quality, sometimes allowing extensive delays and user rejections. In this study, we propose both learning- and optimization-based strategies to actively control service quality in AMoD systems, increasing and decreasing the number of used vehicles in the short term to meet diversified user expectations. We have used these expectations to establish service quality contracts, allowing heterogeneous users to choose ride experiences that best match their preferences. Based on an experimental study using New York City taxi data, we show how providers can adequately cater to each segment of the customer base without necessarily owning large fleets through a service-quality-oriented on-demand hiring approach.

■ FE-03

Friday, 16:00-17:40 - Room 3

Games, strategies and optimization for health and life sciences

Stream: OR in Health, Medicine and Life Sciences
Invited session
Chair: *Milagros Baldemor*
Chair: *Gerhard-Wilhelm Weber*

1 - The Effect of Epidemic Outbreak on Healthcare Usage: Lessons from 2015 Middle East Respiratory Syndrome Outbreak in South Korea
Jinhwan Park, Duk Bin Jun

When an epidemic outbreak occurs, the demand for healthcare services may increase because more people may seek medical care regardless of their infection status. On the other hand, it may decrease because of the fear of getting infected while seeking treatment. Armed with a representative and detailed individual level healthcare usage dataset, we examine the dynamic effect of the Middle East Respiratory Syndrome outbreak which occurred in South Korea in 2015. To be more specific, we set patients who live in regions where Middle East Respiratory Syndrome outbreak took place as treatment group, and set patients who live in regions where MERS(Middle East Respiratory Syndrome)-related events never occurred to be control group. Using this sample, we use the difference-in-difference approach with propensity score matching to investigate the effect of epidemic disease on individuals' healthcare service usage. We find that healthcare visits to treat minor diseases during the period of Middle East Respiratory Syndrome significantly decreased by 3.7% in South Korea. This effect was pronounced in large tertiary hospitals (22.7%) and among minors under age 10 (10.1%). We could not find significant changes in the visits to treat serious diseases. However, visits to emergency department showed a significant decrease. As an underlying driver of observed effects, the general public's perception on the safety of healthcare service during epidemic disease seems to play an important role.

2 - Analysis of typographies using statistical methods and game theory
Xavier Molinero, Montserrat Tàpias, David Baena

In this work, we have studied the readability of four typographies: Times New Roman, Helvetica, Roboto, and "Optotipica_2" (own typography developed at our Faculty). All these typographies have been used in their regular form. The study has been performed on 30 patients with, corrected or not, normal binocular visual acuity. 26 uppercase and 26 lowercase letters for each typography with different sizes around patients' visual acuity threshold have been binocularly presented to each one, using a monitor screen performed for the experiments. All sessions had the same environmental and luminance. We have analyzed the results (success and fail) for each capital and lowercase letter in each typography. The results have been analyzed in two different topics, using statistical methods and using game theory. The main novelty of this work is accurately this latter part, to determine whether a typography is suitable or not using game theory. X. Molinero has been partially supported under grants PID2019-104987GB-I00 (JUVOCO).

3 - Prediction and Early Hospitalization to Reduce Emergency Department Length of Stay
Eunbi Kim, Taesu Cheong, Joonyup Eun

Overcrowding has long been a problem faced by Emergency Departments (EDs) worldwide and causes negative impacts on patients' satisfaction and safety. Overcrowding is often derived from boarding time delays of ED patients to inpatient beds. Therefore, if we predict a patient's hospitalization early enough and accurately in the ED, an inpatient bed for the patient can be prepared in advance. We predict an ED patient's hospitalization using machine learning techniques and analyze the results focusing on sensitivity and specificity that are critical to ED crowding reduction. In addition, we verify the effectiveness of the prediction models by estimating the reduction in the ED Length of stay and time costs in Inpatient beds caused by prediction errors.

4 - Predicting hearing loss using logistic regression model and machine learning approaches
Ko-Han Sun, Tang-Chuan Wang, Wei-Chun Chen, Mingchang Chih

Excessive noise exposure is a global health hazard with considerable physiological and social impacts, and as the prevalence of noise-induced hearing loss (NIHL) has not changed much in the past two decades, what factors affect hearing loss is an important issue. One of the most common health injuries caused by exposure to noise is NIHL. NIHL is a prevalent cause of hearing difficulties among adults. Hearing loss is almost irreversible, and proactive biomarkers that identify hidden hearing loss are valuable for both clinicians and patients to prevent further disease progression. In our work, we aim to identify risk factors associated with hidden hearing loss and establish a prediction model for NIHL based on a medical university hospital database in Taiwan. One hundred sample cases surveyed in 2018 were considered, to determine the hearing loss threshold, the audiometric test was carried out using a calibrated audiometer. The stepwise technique and random forest are utilized as the approaches to select the predictive and explanatory variables. The selected variables are employed to build the hearing loss models using logistic regression, multilayer perceptron (MLP), and support vector machine (SVM). Our results show that the machine learning techniques can be used as an effective approach to identify hearing hazards and predict hearing loss. Our proposed model consisting of comprehensive information regarding patient characteristics and assessment of hearing ability.

■ FE-04

Friday, 16:00-17:40 - Room 4

Humanitarian Logistics and Crisis Management

Stream: Applications of OR (contributed)
Contributed session
Chair: Jan Boeckmann

1 - Refugee Allocation Mechanisms: Theory and Applications for the European Union
Petros Xepapadeas, Yiannis Mourtos

We study a relocation problem which consists of allocating a given number of refugees – who are heterogeneous with respect to country of origin and characteristics such as gender, age or educational level – from Greece to other European Union countries which have pledged to accept a certain number of refugees. To study this problem, we developed a conceptual framework consisting of three allocation methods: sequential multi-agent resource allocation, simultaneous allocation, and two-stage allocation. In these methods we incorporate preferences by assuming that the destination countries have their own preferences regarding refugee characteristics, but that they also try to consider the refugees' preferences for the destination countries. While these methods vary in design and execution, all three aim to create a more equitable allocation methodology for both the refugees and the destination countries. These methods could also be applied to other similar types of allocation problems.

2 - Establishing an Optimal Model on the Total Implementation Cost in Preventing the Occurrence of Dengue Outbreak using Integer Linear Programming
Gabriel Bucu, Alexis Joseph Baarde, Rosarie Joy Balneg, Lara Isabelle Cabral, Maria Jocelyn Cerezo

Dengue is the fastest spreading vector-borne disease in the world endemic in 100 countries. The virus imposes a substantial burden on communities and health systems in most tropical and subtropical countries. It is also one of the major public health problems in the Philippines supported with the disease being endemic in the 17 regions, 81 provinces, 1,634 municipalities/cities, and 40,086 barangays of the country. A statistical report from the Department of Health states that there have been a total number of 322,693 dengue cases and 1,272 deaths in the country covering the period of January 1, 2019, to September 21, 2019, which is 115 percent higher compared to the period last year (149,849 dengue cases). With the continuous surge of dengue cases, the Department of Health declared the Philippines to be under the National Dengue Alert last July 15, 2019. Following the announcement, all DOH regional offices were urged to step up their Dengue Preparedness and Outbreak Response. The research aims to minimize overall implementation costs and to prevent the occurrence of dengue outbreaks through the use of Integer Linear Programming. The researchers also conducted a Multiple Linear Regression equation to determine the coefficients needed to predict the change in the number of dengue cases after implementing the present preventive measures used by a community.

3 - Planning of Health Resources After Earthquake with Optimization Approach
Sema çiftçi, Sami Sakalli

Earthquakes are the most common type of disasters with high effects. The chaotic states that occur after the earthquake complicate the intervention and recovery process. The effective management of this difficult process depends on the successful allocation of available resources (material, health personnel etc.) to the affected areas. Intervention of the injured in the first hours after the earthquake, according to the severity of injury (severe, delayed) are more likely to survive. It is necessary to intervene the injured who are taken out from under the rubble and transfer them to the hospital urgently. Thus, health resources planning is major in reducing ruinous effects of earthquake. In this study, a mixed integer mathematical model has been developed aiming to minimize the number of casualties who died after an earthquake. In the model it is required to allocate health units (doctor etc.) to perform crime scene triage to the affected areas, appoint an ambulance for the transfer of injured to the hospital and decide which hospitals should be directed to. The multiperiod modeling of the developed model and the evaluation of the change in the health status of the injured as a Markov process flash as a contribution to the literature. Model, Kirikkale/Turkey for a possible earthquake scenarios based on data GAMS program was tested using the CPLEX solver. The results of its model show that it can be used as an effective planning tool for the allocation of health resources.

4 - An optimization and incentive system for municipal flood mitigation
Jan Boeckmann, Clemens Thielen

As a result of climate change, heavy rains are increasing in frequency and intensity. Regionally limited exceptional heavy rain events, as frequently observed in recent years, can hit many regions, e.g., in Central Europe. For technical and economic reasons, however, municipal drainage systems cannot be designed to handle such exceptional rainfall events. Instead, flood prevention adapted to the site-specific requirements is needed as part of municipal heavy rain risk management. Moreover, flood prevention measures often require the participation of property owners, who might not always be intrinsically motivated to implement selected measures (e.g., when an interceptor is to be built on one citizen's property in order to protect other citizens' properties).

This talk presents results of the project "Incentive Systems for Municipal Flood Mitigation" funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), in which a versatile optimization and incentive system for the identification and implementation of optimized overall solutions for municipal flood prevention has been developed. We first show how processing networks and mixed integer programming are used in order to compute optimal strategies for reducing the damage incurred in case of heavy rain events. Afterwards, we present how (non-) participation of property owners is taken into account.

■ FE-05

Friday, 16:00-17:40 - Room 5

Games and Applications 1

Stream: Dynamics and Games
Invited session
Chair: Nadia Pourmohammad-Zia

1 - On the Existence of Energy Market Equilibria with Convex and Nonconvex Players
Julia Grübel, Olivier Huber, Lukas Hümbs, Max Klimm, Martin Schmidt, Alexandra Schwartz

Motivated by examples from the energy sector, we consider a special type of market equilibrium problems (MEPs) involving players both with convex and nonconvex strategy spaces or objective functions. Such problems naturally occur in settings, where equilibrium problems for energy trading are combined with aspects of the actual energy transport through networks. We propose an algorithm that decides on the existence of equilibria of MEPs of this type and that computes a market equilibrium in case of existence. Moreover, we provide both a uniqueness and a non-existence result for MEPs that include players with unique best responses. Finally, we test the proposed algorithm on well-known energy market instances from the power and gas literature. There, nonconvexities mainly arise from considering the transmission system operator as an additional player who, e.g., switches lines or faces nonlinear physical laws. Our numerical results indicate that an equilibrium often exists, especially for the case of continuous nonlinearities in the context of gas market problems.

2 - Decision support for non-pharmaceutical interventions and vaccination policy for disease spreading model under population mobility constraints
Mariusz Kaleta, Tomasz Sliwinski, Izabela Zoltowska

We propose a new model for disease spreading that considers the spatial structure of the population. In contrast to many works that use compartmental SIR-like (Susceptible, Infectious, and Recovered) models assuming perfect mixing whole population, our model assumes that individuals travel daily to different locations, and they do not mix perfectly. Perfect mixing only takes place locally in different locations, while between locations, mixing pattern depends on an individual's traveling habits. The model we developed can be used for simulation, which enables for what-if analysis. Still, moreover, we use it to build an optimization model that generates suggestions of non-pharmaceutical interventions and vaccination policy. We show that our model can be solved for reasonable time horizons and different granularity, which can be considered separately at decision levels and disease spreading model. As an illustrative example, we use COVID-19 data based on the real data acquired for Poland.

3 - Evolutionary Generalized Nash equilibrium in the competition for the diffusion of online contents
Georgia Fargetta, Laura Rosa Maria Scrimali

In this paper, we show how the competition for the diffusion of online contents in the case of coupled constraints and in a time-dependent setting can be transformed into and studied as an infinite-dimensional quasi-variational inequality. Specifically, we consider a two-layer network consisting of content providers and viewers. Each content provider seeks to maximize the profit by determining views and quality levels. The problem is formulated as a Generalized Nash equilibrium model and is described by an infinite-dimensional quasi-variational inequality. The existence of solutions is discussed and a numerical example is given.

4 - Platform-based Platooning to Connect Two Autonomous Vehicle Areas: A Game-Theoretic Optimization Approach
Nadia Pourmohammad-Zia, Frederik Schulte, Rudy Negenborn

Automated driving has been successfully applied in closed environments such as ports and controlled industrial areas, but there remain multiple challenges to bring Autonomous Vehicles (AVs) into open areas and public roads. In this work, we model and evaluate a way to overcome this limitation by introducing platooning as a transfer mode between two AV-suitable zones. The leading vehicle of the platoon is human-driven, followed by the AVs. This study investigates a transportation problem between a port and demand points in its hinterland, where the platform facilitates collaborative transportation. Both zones are suited for automated driving, whereas the route connecting the zones is not. The platform provides a platooning service to move AVs through non-autonomous roads. It specifies the carriers' transportation schedules and service fees, based on which the carriers decide whether to use AVs or trucks for each delivery task. This interactive process is modeled as a constrained Stackelberg competition, transformed into a conventional mixed-integer model through backward induction. The approach enables demand and resource pooling between the port and industrial area. The findings imply that if platoon formation costs are managed, AVs can considerably enhance drayage operations' efficiency. The benefits of the proposed structure may also create incentives for establishing new companies in underdeveloped industrial zones.

■ FE-06

Friday, 16:00-17:40 - Room 6

Maintenance scheduling and traffic capacity

Stream: Graphs and Networks
Invited session
Chair: Tomas Lidén

1 - An operations research supported methodology for the dynamic planning of construction and maintenance activities on railway networks
Bryan Adey,

This paper proposes the first mathematically supported methodology to determine the set of coordinated construction and maintenance activities to be performed on railway networks. The methodology is based on a mathematical model with an objective function that maximizes net benefit, e.g. making, optimal trade-offs between the costs of performing construction and maintenance activities, and the effects on service. The model considers economical, structural and topological dependencies, as well as the uncertainties associated with the future condition state of the assets, i.e. due to the environment and traffic loads. The methodology is demonstrated by generating the optimal set of coordinated construction and maintenance activities for a railway network at preliminary stages, and illustrating how additional activities are optimally integrated over time. The work increases the strategic planning and decision-making ability of railway managers, and lays the foundation for further developments, e.g. by providing increased clarity on the type, extent and detail of information required to optimally manage assets.

2 - Using a two level network flow model with side constraints to develop optimal intervention programs
Marcel Burkhalter, Bryan Adey

Intervention programs contain information as to the interventions to be executed in the next planning period and how they are to be grouped together. Their development on railway networks requires the consideration of the railway as a network of objects, who's performance affects each other. The relationship between the effects on traffic and the combinations of interventions is non-linear due to topological dependencies between objects, e.g. repairing two sections of track with two crews at the same time causes approx. the same amount of traffic disturbances as repairing one section with one crew. This non-linearity makes the search for optimal intervention programs using operations research methods particularly challenging. In this paper, a two level network flow model with side constraints is proposed to develop optimal intervention programs for railway networks. The two levels represent the objects and the network. The object level represents the possible interventions on the objects. The network level represents the provided traffic service dependent on interventions selected on the object level. The non-linear relationship is modelled using sink edges at the network level. These sink edges allow the sinking of flow at one node dependent on the flow on another node. The two level network flow model is demonstrated by using it to determine the optimal intervention program for a railway line in Switzerland consisting of 63 track sections, 4 bridges, and 23 switches.

3 - Joint optimization of train scheduling and maintenance planning in a railway network: a heuristic algorithm using Lagrangian relaxation
Chuntian Zhang, Yuan Gao, Lixing Yang, Ziyou Gao

Train scheduling and maintenance planning compete for the resources in a railway network. A commonly used way is dealing with maintenance planning first and then train scheduling, or vice versa. In this paper, we develop a layered space-time network, which simultaneously captures the characteristics of the two problems. Based on the space-time network, we formulate an integer linear programming (ILP) model, which considers train scheduling and maintenance planning at the same time. In order to solve the model, a heuristic algorithm

using Lagrangian relaxation is proposed. Due to the large number of constraints, we use a dynamic constraint-generation technique in the iterations of the sub-gradient optimization procedure. We apply the model and algorithm on the problem of scheduling sunset-departure and sunrise-arrival trains (SDSA-trains) in China, which is a joint optimization problem in a railway network with train route choices. The computational results show that the heuristic algorithm can find acceptable solutions in acceptable computation times.

4 - Advancements in joint scheduling of maintenance windows and train services
Tomas Lidén

The coordination of railway infrastructure maintenance and train service operations is essential for achieving an efficient and well functioning transportation system. We study the long term tactical problem of designing regular maintenance windows and the effect they will have on the desired railway traffic by developing and using an optimization model which jointly schedules both individual train services and maintenance opportunity windows. The model uses an aggregate view of both the network and the traffic capacity control. The presentation concerns recent advancements for handling cyclic plans, coupling of train services and conflict regulation for traffic on multi-track lines during capacity reductions. Experimental results from three different case studies of varying size and complexity will be reported, some of which solve large weekly instances with more than 1500 trains optimally.

■ FE-07

Friday, 16:00-17:40 - Room 7

Data Science meets Optimization

Stream: Data Science meets Optimization
Invited session
Chair: *Ender Özcan*
Chair: *Ziyi Chen*

1 - Using rank information to improve the performance of matrix completion algorithms.
Tacildo Araújo, Cristiano Torezzan

Numerical matrices are a core component of many data science applications. In several situations, such as recommendation systems, location of sensors, interaction on social networks, and distance geometry, there is often a lack of data, for which some approximation or imputation technique is desirable. The problem of estimating the missing entries of a low-rank matrix is known as the matrix completion problem. Several cost-effective algorithms have been proposed to solve this problem, mainly using some optimization approaches. In some cases, it is possible to know, in advance, the rank of the desired matrix. This information can be used to improve the performance of some completion algorithms, especially those based on the singular value decomposition. Based on massive numerical experiments, in this work, we show that it is possible to improve the performance of soft-impute-based algorithms for a general class of low-rank matrices. Our approach allows us to reduce the number of iterations by up to 70% and recover matrices with more than 99% of missing data.

2 - Learn-heuristic algorithm for large-scale combinatorial optimization problems: The case of the Travelling Salesman Problem
Christos-Georgios Xanthopoulos, Pantelis Lappas, Manolis Kritikos

The purpose of this work is to introduce a learn-heuristic algorithm for exploring and analyzing computational results of large-scale combinatorial optimization problems. The proposed approach consists of evolutionary optimization and supervised machine learning algorithms, as well statistical and correlation methods for finding hidden patterns and discovering knowledge. The main goal is to optimize the selection of genetic operators and associated genetic parameters' values for high-quality results. Several datasets for the Travelling Salesman Problem are used to verify the effectiveness of the proposed learn-heuristic approach, whereas various graphical presentation formats are provided to convey meaningful insights into the problem.

3 - Non-monotone Adaptive Trust-Region Method
Dimitri Papadimitriou

For the solving of nonconvex (unconstrained) minimization problems, we present an adaptive trust region algorithm that guarantees convergence to approximate second-order stationary points. This algorithm find wide applicability in algorithmic data modeling methods such as neural networks. We demonstrate and analyze its worst-case complexity. The proposed method extends the nonlinear stepsize control framework by conditioning the (curvature-aware) update strategy for the trust-region radius to the actual model decrease. We then relax the monotonicity assumption of the objective function to propose a non-monotonic variant of this algorithm.

4 - Neural networked assisted tree search for the personnel rostering problem
Ziyi Chen, Patrick De Causmaecker, Jorik Jooken

The personnel rostering problem is the operations research problem of finding an optimal way to assign empolyees to shifts, subject to a set of hard constraints which all valid solutions must follow, and a set of soft constraints which define the relative quality of valid solutions. The problem has received significant attention in the literature and is addressed by a large number of exact and metaheuristic methods. In order to make the complex and costly design of heuristics for the personnel rostering problem automatically, we propose a new method combined neural network and tree search. By treating schedules as matrices, the neural network can predict the distance between the current solution and optimal solution and solution strategies by analyzing existing (near-)optimal solutions to personnel rostering problem instances. Combined with branch and bound, the network can give every node a probability which indicates the distance between it and the optimal one, so that a well-informed choice can be made on which branch to choose next and to prune the search tree.

■ FE-08

Friday, 16:00-17:40 - Room 8

Lot-sizing 1

Stream: Lot Sizing, Lot Scheduling and Production Planning
Invited session
Chair: *Younsoo Lee*

1 - Mixed integer non-linear programs of (s,Q) policy in non-stationary stochastic lot-sizing problem
Xiyuan Ma, Roberto Rossi, Thomas Archibald

This paper addresses the single-item single-stocking location non-stationary stochastic lot-sizing problem under a reorder point - reorder quantity strategy. We consider the reorder quantity to be fixed once and for all at the beginning of the planning horizon as either a single or a series of time-dependent constants; this leads to policies (s, Q) and (s, Qt) respectively. We present a stochastic dynamic program (SDP) to determine optimal policy parameters and introduce mixed integer nonlinear programming (MINLP) heuristics that leverage piecewise linear approximations of the cost function. Our solution method efficiently computes near-optimal parameters. Numerical experiments demonstrate that optimality gaps from the optimal policy are 12.07% and 5.43% for the (s, Q) and (s, Qt) policies, respectively. Meanwhile, the MINLP approximations to the SDP formulations of (s, Q) and (s, Qt) policies are within 1.13% and 1.43%, respectively.

2 - A multi-objective optimization approach for stochastic capacitated lot sizing with multiple decision stages
Fabian Friese

Classical capacitated lot sizing generally aims at minimizing operational costs. In many cases, complete timely satisfaction of customer demand is assumed.

In stochastic problem settings with uncertain demand, however, backlogs generally cannot entirely be avoided. Hence, the maximization of delivery reliability could be considered an additional objective. In many publications this objective is instead framed as a constraint. In practical application, however, stipulating a target service level can be difficult due to lack of knowledge about the exact economic consequences.

Approaches with multiple decision stages use demand-realization information for the adjustment of the production plans. These adaptations to the actual demand situation can lead to both an increase of delivery reliability and a decrease in costs at the same time. On the downside, nervousness in the planning system is induced, which can lead to unwanted effects, especially in supply chains. Therefore a low level of nervousness can be recognized as another objective.

This research presents methods from multi-objective optimization applied to stochastic capacitated lot sizing with multiple decision stages. The proposed methodology systematically takes prior demand-realization information into account, thus supporting the decision maker in taking an informed and economically reasonable position between prioritizing low operational costs, high delivery reliability and low nervousness.

3 - New Integer Optimization Models and Approximate Dynamic Programming Algorithm for the Lot-sizing and Scheduling Problem with Sequence-dependent Setups
Younsoo Lee, Kyungsik Lee

In this study, we propose new integer optimization models for the lot-sizing and scheduling problem with sequence-dependent setups, based on the general lot-sizing and scheduling problem. To incorporate setup crossover and carryover, we first propose a standard model that straightforwardly adopts a formulation technique from the literature. Then, as a main contribution, we propose a novel optimization model that uses the notion of the time-flow. We then derive a family of valid inequalities to compare the tightness of the linear programming relaxations of the models. In addition, we provide an approximate dynamic programming algorithm. Then, we conduct computational experiments to demonstrate the competitiveness of the proposed models and the solution algorithm. The test results show that the newly proposed time-flow model has considerable advantages compared to the standard model in terms of tightness and solvability. The proposed algorithm also shows clear benefits over the algorithm provided by the standard mixed integer programming solver.

■ FE-09

Friday, 16:00-17:40 - Room 9

Applications in Business Analytics

Stream: Business Analytics
Invited session
Chair: *Vera Miguéis*
Chair: *Toon Vanderschueren*

1 - Developing a hybrid recommender system to identify the next best action
Hermano Maia, Vera Miguéis, Isabel Horta

Nowadays, companies are strengthening their analytical competences to achieve customer orientation. The identification of the best action to take for each customer is a key part of customer-centricity strategies, with recommender systems (RS) playing an important role in anticipating customer needs. This study focuses on a Portuguese financial services company that intends to identify the next best action (NBA) to perform for each customer. We propose to develop a hybrid RS through the following methodology. Firstly, traditional RS are considered, by applying collaborative filtering (CF) and content-based (CB) algorithms in their different versions (e.g., matrix factorization and neighbor-based). Secondly, a hybrid model, based on the aggregation of the outputs of CF and CB algorithms, is developed. We apply several alternative approaches to build the hybrid model, e.g., a weighted hybrid model (i.e., a linear combination of CF and CB outputs) and a hybrid model based on classification algorithms (the features are the outputs of CF and CB and some socio-demographic variables). All alternatives are compared through offline evaluation and an analysis of historical natural behavior of customers. The hybrid model based on classification algorithms has the best performance, with a mean average precision of more than 0.6. Therefore, this methodology results in a useful engine able to improve marketing actions and to boost customer engagement and hyper-personalization.

2 - Profit-driven churn prediction via robust optimization and machine learning
Sebastian Maldonado, Carla Vairetti, Julio López

Churn prediction is a well-known business analytics task whose goal is to identify customers that are likely to leave a company voluntarily. Once potential churners are detected, a retention campaign is performed for enhancing customer loyalty. This is extremely beneficial for customers since engaged customers generate more revenue than other clients, it reduces operational costs, and it avoids the misspending of money caused by inefficient marketing campaigns. In this study, a novel profit-driven method is presented for churn prediction. The Minimax Probability Machine (MPM) method is extended to business analytics. Unlike most profit-based approaches that use profit metrics for choosing between classification techniques and/or to define the optimal classification threshold, our proposal maximizes the profit of a retention campaign directly in the objective function using a robust optimization setting. Experiments on well-known churn prediction datasets demonstrate that our proposal leads to the largest profit in comparison with other binary classification methods.

3 - Reconstructing the UN E-Government Development Classification of Nations through the Lenses of Machine Learning Techniques
Nigussie Mengesha, Anteneh Ayanso

The UN E-Government Development Index (EGDI) has been ranking and classifying the UN Member States into four categories based on a weighted average of normalized scores on online service, telecom infrastructure, and human capital. The ranking is vital to discover and communicate the current state of each nation's e-government status and to track their ranked positions from time to time. However, a mere increase or decrease of a nation's rank by few positions does not provide a bigger picture of their evolution towards making a major transformation over time. A nation's attempt to bring major transformations needs to be informed by its past and current profiles and the movement from one comparison set to another. The method used in EGDI is intuitive and easy to follow, however, constructive refinements can be applied to improve upon several aspects of the methodology. We argue that the EGDI fails in informing nations and policymakers as to what and from whom to draw policy lessons. Using the UN EGDI data from 2014 to 2020, we profile the UN Member States and show the relevance of machine learning techniques in addressing these issues. We examine the resulting cluster profiles in terms of theoretical perspectives in the literature and derive policy insights from the different groupings of nations and their evolution over time. Finally, we discuss the policy implications of our proposed methodology and the insights obtained.

4 - Instance-dependent cost-sensitive learning: Do we really need it?
Toon Vanderschueren, Bart Baesens, Wouter Verbeke, Tim Verdonck

Traditionally, classification algorithms aim to minimize the number of errors. However, this approach can lead to sub-optimal results for many (business) applications where the actual goal is to minimize the total cost of errors, not their number. For example, in customer churn, the algorithm's predictions should be especially reliable when dealing with highly valuable customers, even at the cost of misclassifying churners with insignificant value. Cost-sensitive learning aims to address this issue by incorporating costs in the learning algorithm. Recently, a number of cost-sensitive classifiers have been suggested that deal with the case of instance-dependent costs (a.k.a. observation- or record-dependent costs). This work presents the results of a benchmarking experiment, comparing the performance of instance- and class-dependent cost-sensitive, as well as cost-insensitive learning methods. Using real-life data from a range of application areas, we analyze the effects of incorporating costs at the instance-level, as well as the influence of thresholding and regularization, on the performance of the resulting model, which is evaluated both using cost-sensitive and cost-insensitive performance measures.

■ FE-10

Friday, 16:00-17:40 - Room 10

OR and Analytics Education

Stream: OR and Analytics Education
Invited session
Chair: *Ayşe Cilacı Tombuş*

1 - Introduction of SimplexV4 Online Assistant for Linear and Nonlinear Programming Problems
Gyongyi Bankuti

Linear programming is mostly the first topic of Operations Research courses all over the world. The classical Simplex Method, implemented by manual calculation is usually used for the solution. In our accelerated and technology-based world students cannot be forced to calculate several dimensional tables several times even if from the methodological point of view teaching this technique is most desirable. In the framework of a "Visegrad Fund"-supported project, a Free Online Assistant (SimplexV4.org) was developed - using the idea mentioned above, filling this gap on the market. The - registered - user can submit any type of starting Simplex Tableau as the names of the variables and the rows are modifiable. After choosing the pivot element pressing the basis change button, the next table appears. Going back and forward among the tables is possible. It can handle parametric, hyperbolic, multiobjective, and integer problems and dynamically creates the graph - the feasibility space and goal function (s) - for the two-dimensional problems for every case above. An e-assessment tool is also possible, as the table-history is saved into the cloud. It can be commented on and shared with the teacher who can also comment and evaluate it. SimplexV4 EAT part of the program is not open for the public, can be only paid service for universities, teachers. The introduction of this program will be delivered through the presentation at the conference.

2 - Introducing the INFORMS Early Career Teachers' Network (ECTN) Master Teacher Initiative
Neil Desnoyers

Proposed, introduced, approved, and implemented for the 2020-2021 year, the INFORMS Early Career Teachers' Network (ECTN) goals are to develop Master OR/MS/Analytics Teachers and increase the likelihood that INFORMS members in teaching-stream roles achieve tenure. The INFORMS Teaching Effective Colloquium (TEC) has been offered for a number of years. The TEC is a one-day teaching workshop offered as a pre-conference event in conjunction with the INFORMS Annual Meeting that includes sessions on topics focused on best practices in teaching OR/MS/Analytics. Participation in the TEC has lagged in recent years, so much so that 2016 an informal committee, after studying the TEC, submitted a report to the INFORMS board containing recommendations to improve the workshop. In 2020 the INFORMS Early Career Teachers' Network (ECTN) was proposed as an alternative to the TEC.

The ECTN has been designed to foster long-term commitment to improved OR/MS/Analytics teaching with the inclusion of two requirements missing from the TEC: The ECTN pairs participants with a teaching mentor for a minimum of three years and ECTN participants are required to provide volunteer services in support of the ECTN for the participants' second year. Both of these requirements ensure that the ECTN Workshop (full-day introductory ECTN teaching workshop) is not viewed as a one-off event, which is how the TEC is viewed by participants. Details and success measures will be provided.

3 - A study on the relationship between the students' rapidity of response and their academic achievement
Choonho Ryu, Seungjun Yim

The purpose of this study is to identify the impact of a student's rapid response on academic achievement through the communication between professors and university students. We also found significant differences between 1) students taking major required courses and students taking elective courses, 2) male and female students, and 3) military titled and untitled for male students. We defined the rapidity of the response as the elapsed time between the task announcement and the task submission. The smaller the elapsed time, the faster the response rapidity. Regression analysis was conducted to measure the impact of the students' rapidity of the response for their academic achievement. Several meaningful results were found and future research were suggested.

4 - Market Size Estimation of Higher Education Industry in Turkey
Ayşe Cilacı Tombuş, Abbas Dündar, Önder Tombuş

Higher education industry has been a big market in Turkey with the increasing number of private universities and more than 141 K enrolled students in 2020. On the other hand, there is no detailed study on the economic market size of the higher education industry. In this study, we tried to make an estimation on the economic market size of higher education industry in Turkey. The study concentrates on the undergraduate education including two year vocational schools and 4-6 year licence education which are subject to Central Placement Exam. The data are obtained from the public resources such as Council of Higher Education (YÖK) and university web pages. In the study, the data collection methods and assumptions used in the analysis have been described. Economic market size estimation has been presented and demographic effects, programs' value and the share on the market have been examined. In the final section, validity of the estimates have been discussed.

■ FE-11

Friday, 16:00-17:40 - Room 11

Simulation, Stochastic Programming and Modeling 1

Stream: Simulation, Stochastic Programming and Modeling (contributed)
Contributed session
Chair: *Jeongsik Kim*

1 - Parametric performance analysis of multi-period compensation plans using simulation
Sascha Hägele, Alexander Baumeister

To prevent short-term suboptimization, companies are increasingly using long-term manager compensation plans. Opportunistic behavior by managers manifests itself e. g. in book or real accounting policies. However, the optimal design of multi-period incentive systems is not in the core of principal-agent literature. Therefore, a parametric multi-period decision support is presented, that is simulation-based

on different long-term incentives to avoid opportunistic managerial behavior. Purely positive incentives such as share-based compensation are used as reference case. They are compared to instruments, that tend to create a more symmetric risk situation with partial loss participation, such as bonus banks and clawback. The modeling is based on a stochastic stock price development according to the geometric Brownian motion as well as a stochastic project success. Due to the complexity, a simulation analysis is used. As one surprising result it is not always advantageous for principals to prevent opportunistic actions of agents due to increasing agency costs. In addition, the benefits of the various methods used in practice vary widely.

2 - MSPLib: A Library Of Problems For Benchmarking Stochastic Dual Dynamic Programming
Bonn Kleiford Seranilla, Nils Löhndorf

We present MSPLib, a library of multistage stochastic programming problems to measure the computational performance of different implementations of stochastic dual dynamic programming (SDDP). MSPLib contains various instances of large real-world problems as well as synthetic problems ranging from easy to difficult variations. We use the library to test prevailing implementations, including QUASAR, SDDP.jl, and MSPPy.

3 - Route optimization using deep reinforcement learning with simulation-based data generation: a case study of evacuation guidance in a radiological emergency
Jeongsik Kim, Adrian Chung Baek, Namhun Kim

The route planning problems have been successfully addressed by reinforcement learning (RL) techniques. However, it is a quite costly task for disaster researchers or policymakers to solve their specific cases with RL. Recently, machine training with simulation-based data generation has been suggested to cut down the cost of RL applications with the benefits of straightforward visualization and ease-of-use. This research demonstrates a route optimization for evacuation guidance by using the machine training strategy. A multi-agent system is built to simulate evacuation dynamics of people on a road network, near to Kori nuclear power plant in South Korea. There are two types of agents. One is in charge of an evacuee who has preset behavioral rules for individual responses, whereas the other tests and advances its routing strategy for evacuation guidance. In the different scenarios, related to social interactions on street and social networks, the training agent try to minimize the evacuation time of residents. The results indicate that the simulation-based strategy can provide a well-trained artificial intelligence to the specific case of evacuation guidance in a radiological emergency to improve the averaged evacuation dynamics. Therefore, this study contributes to practical applications of RL which have been barely incorporated in radiological emergencies.

Friday, 18:00-19:15

■ FF-01

Friday, 18:00-19:15 - Room 1

Plenary: Maria Conceição Silva

Stream: Plenaries
Plenary session
Chair: Bernard Fortz

1 - Honors & Awards: Administrative Committee Honors
M. Grazia Speranza

2 - The value of Analysing Data & the particular case of efficiency analysis
Maria Silva

"Those who fall in love with practice without science are like a sailor who enters a ship without a helm or a compass, and who never can be certain whither he is going."

Leonardo da Vinci

It is evident for many that our ignorance is much bigger than our knowledge. The calling for this reality comes from ancient philosophers, and time has not reduced much the dimension of our ignorance. What has changed a lot since ancient times is the amount of data at the disposal of every common person. According to some sources, there was 5 exabytes of information created between the Dawn of civilization through 2003, but over the last two years alone 90% of the data in the world was generated (Marr, 2018 and Acito and Katri, 2014). This increasing amount of data has produced and is producing many changes, one of which the value of data analysis tools and the value of data analysts. I spent a lot of my academic life analysing data. In particular I specialised in data analysis for benchmarking and efficiency measurement purposes. As a result of that experience, I expect in this talk to address some lessons learned from the analysis of data, in particular I will discuss some main outcomes in my research activity mainly related to public services in general and education in particular. I will also introduce the main tool that I have been using in my research which is a frontier technique based on which benchmarking can be done in a more comprehensive way - taking into account the type of returns to scale that fit the data, taking into account multiple dimensions and the trade-offs between the dimensions being evaluated.

Friday, 20:00-21:00

■ FG-01

Friday, 20:00-21:00 - Room 1

Closing session

Stream: IFORS Sessions
Invited session
Chair: *Bumsoo Kim*
Chair: *Bernard Fortz*

STREAMS

Advanced Statistical Methods in Finance and Actuarial Sciences

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Track(s): 8 10

Applications of OR

Track(s): 10

Applications of OR (contributed)

Track(s): 4 5

Behavioral OR

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Business Analytics

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Track(s): 9

Combinatorial Optimization

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Track(s): 4 5 6

Computational and Simulation Methods in Finance

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Track(s): 6 7 8

Contemporary Issues in Cryptocurrency Markets

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Continuous Optimization

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Continuous Optimization (contributed)

Track(s): 8

Cutting and Packing

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Data Envelopment Analysis and Performance Measurement

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Data Mining and Statistics

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Data Science meets Optimization

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Track(s): 7 11

Data Science, Analytics and Performance Measurement (contributed)

Track(s): 8 11

Decision Analysis and Decision Support Systems (contributed)

Track(s): 8 9

Decision Support Systems

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Track(s): 7 8

Deep Learning

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Track(s): 9

Discrete Optimization and Urban Operations Research

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Track(s): 3 4 5

Dynamics and Games

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Energy, Environment and Climate (contributed)

Track(s): 5 6 7

Financial Mathematics and OR

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Graphs and Networks

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Graphs, Networks and Combinatorial Optimization with Applications (contributed)

Track(s): 5 6 7

Human Behavior in Disaster and Humanitarian Operations Management

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IFORS Prize for OR in Development Finalists

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IFORS Sessions

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Track(s): 1

Innovative & Shared Mobility and Transportation

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Track(s): 7 9

Journals

Track(s): 1 10

Keynotes

Track(s): 1

Knowledge Work and Knowledge Analytics

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Track(s): 10

Logistics in new economies

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Logistics, Transportation and Traffic (contributed)

Track(s): 2 3

Lot Sizing, Lot Scheduling and Production Planning

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Track(s): 8 9

Low-Carbon Energy Transition

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Track(s): 10

Machine Learning, Data Mining and Analytics (contributed)

Track(s): 6 7 8

Mathematical Models in Macro- and Microeconomics

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Mathematical Optimization Software

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Meta-Analytics: A Marriage of Metaheuristics and Analytics

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Track(s): 7 8

Metaheuristics

Track(s): 5 6 8

Multicriteria Decision-Making and Multiobjective Optimization (contributed)

Track(s): 10

Multiobjective Optimization

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Track(s): 9

Multiple Criteria Decision Aiding

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Track(s): 6 7

Operational Research in Financial and Management Accounting

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Track(s): 9 10

OR Analytics in Human Resource Management

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Track(s): 11

OR and Analytics Education

Track(s): 10

OR and Ethics

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OR for Development and Developing Countries

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Track(s): 1

OR in Electricity Sector

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Track(s): 8 9

OR in Health, Medicine and Life Sciences

Track(s): 3 4

OR in Health, Medicine and Life Sciences (contributed)

Track(s): 6 7

OR in Natural Resources

Track(s): 10

OR in Natural Resources (contributed)

Track(s): 1 10

OR in Sports

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Track(s): 1

OR, Human Behavior and Society (contributed)

Track(s): 10

Plenaries

Track(s): 1

Production Management, Supply Chain Management and Location (contributed)

Track(s): 7 9

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