First Triennial Conference
July 26-29, 2017
Chicago, Illinois, USA

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University of Maryland

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Yafeng Yin, *University of Florida*, United States
Lei Zhao, *Tsinghua University*, China
Xuesong Zhou, *Arizona State University*, United States

Venue

The conference will be held on Loyola's Water Tower Campus, located along Pearson Street, just off North Michigan Avenue, Chicago's famed "Magnificent Mile. The Water Tower Campus derives its name from the famous Chicago Water Tower, which survived the Great Chicago Fire in 1871. The campus sits in the shadow of the iconic John Hancock Center. Other nearby architectural landmarks are the Tribune Tower, the Wrigley Building, the Trump Tower, and the site of Fort Dearborn, around which the city of Chicago was founded. Holy Name Cathedral and the Roman Catholic Archdiocese of Chicago are located just south of campus, across Chicago Avenue. Cultural points of interest include the Museum of Contemporary Art, the Newberry Library, and Navy Pier. In addition to the unparalleled shopping on Michigan Avenue, the Water Tower Campus is also within a few minutes' walk of numerous dining and entertainment options.

Social Agenda

In addition to a broad look at the future of transportation, this workshop will provide numerous opportunities to network with colleagues and establish new working relationships.

A welcome reception overlooking downtown Chicago will start the event on Wednesday evening. The welcome reception is open to all registrants and has been generously sponsored by APICS.

APICS is the premier professional association for supply chain management and the leading provider of research, education and certification programs that elevate supply chain excellence, innovation and resilience. The APICS Certified in Production and Inventory Management (CPIM), APICS Certified Supply Chain Professional (CSCP), APICS Certified in Logistics, Transportation and Distribution (CLTD) and APICS Supply Chain Operations Reference Professional (SCOR-P) designations set the industry standard. With over 45,000 members, over 130,000 certified professionals, and approximately 300 channel partners internationally, APICS is transforming the way people do business, drive growth and reach global customers. APICS is dedicated to building greater awareness of the supply chain profession and develops lifelong learning content to ensure that the number and quality of students and professionals meets industry's needs. For more information, visit apics.org.

On Friday evening, we will adjourn for dinner at the Chicago Museum of Contemporary Art, with an opportunity to explore the collection prior to and after dinner. This reception is open to all those who submitted a regular (non-student) registration.

Lunches will be provided on site each day of the conference.

Plenary Sessions

Dr. Kimberly Ross

Transportation Optimization – Experiences from the Field

Thursday, July 27, 11:00 – 12:00 PM

Dr. Kimberly Ross has spent over 20 years consulting and developing optimization solutions for some of the largest shippers in North America including well-known retailers, grocers, food, and wholesale pharmaceutical distributors. In this talk, she will share some of her unique transportation modeling experiences including large-scale inbound planning for multi-model, dynamic cross-dock optimization typical of big-box retail, outbound planning with restricted time windows, split deliveries, tandem orchestration, and backhauls that are pervasive in the grocery market, and high density multi-stop routing optimization for food and pharmaceutical distribution with relays, cross-docks, and hybrid static/dynamic routing considerations. Additionally, she will share some of the challenges her customers face as they look to take advantage of promising supply chain optimization synergies as well as explore options that new technologies in big data and cloud computing may provide.

Dr. Kimberly Ross is Vice President of Research & Development at Manhattan Associates responsible for the Science team overseeing all optimization capabilities across the product suite including Transportation Management, Warehouse Management, Slotting Optimization, Demand Forecasting, and Inventory Optimization. She received her B.S. from Sanford University in Mathematical Sciences and her Ph.D. from Princeton University in Operations Research and has over 20 years of experience designing and implementing mathematical optimization algorithms to solve highly complex real-world problems, mostly in the transportation and logistics industries.

Dr. Peter Frazier

Providing Reliable Transportation at Uber

Friday, July 28, 11:00 – 12:00 PM

Ridesharing is revolutionizing transportation in cities. A central task in ridesharing is providing reliable transportation to riders and attractive earnings to drivers when neither group is under centralized control. This is especially challenging given that weather, traffic, sporting events, and holidays frequently cause hard-to-predict imbalances between riders' and drivers' willingness to participate in the market. We discuss approaches and mathematical models used at Uber to overcome this challenge, and provide an overview of other exciting new research questions in transportation opened by the growth of ridesharing.

Dr. Peter Frazier is an Associate Professor in the School of Operations Research and Information Engineering at Cornell University, and a Staff Data Scientist and Data Science Manager at Uber. He received a Ph.D. in Operation Research and Financial Engineering from Princeton University in 2009. His research is in optimal learning, sequential decision-making under uncertainty, and machine learning, focusing on applications in simulation, e-commerce, medicine, and biology. He is an associate editor for Operations research, ACM TOMACS, and IISE Transactions, and is the recipient of an AFOSR Young Investigator Award and an NSF CAREER Award.

Program Overview

Wednesday, July 26

3:15 – 5:15 PM	Connected Traffic & Transportation (Joint Session with ISTTT)
5:30 – 7:00 PM	Welcome reception

Thursday, July 27

7:30 – 6:00 PM	Registration
8:30 – 10:30 AM	Parallel sessions
10:30 – 11:00 AM	Break
11:00 – 12:00 PM	Plenary talk (Dr. Kimberly Ross)
12:00 – 1:00 PM	Lunch
1:00 – 2:30 PM	Parallel sessions
2:30 – 2:45 PM	Break
2:45 – 4:15 PM	Parallel sessions
4:15 – 4:30 PM	Break
4:30 – 6:00 PM	Parallel sessions

Friday, July 28

7:30 – 6:00 PM	Registration
8:30 – 10:30 AM	Parallel sessions
10:30 – 11:00 AM	Break
11:00 – 12:00 PM	Plenary talk (Dr. Peter Frazier)
12:00 – 1:00 PM	Lunch
1:00 – 2:30 PM	Parallel sessions
2:30 – 2:45 PM	Break
2:45 – 4:15 PM	Parallel sessions
4:15 – 4:30 PM	Break
4:30 – 6:00 PM	Parallel sessions

Saturday, July 29

9:00 – 11:00 AM	Parallel sessions
11:00 – 11:15 PM	Break
11:15 – 12:45 PM	Parallel sessions
1:00 – 1:30 PM	TSL Cross-region Dissertation Grant Winner

Technical Program

Connected Traffic & Transportation (Joint Session with ISTTT)

Location: Conference Room L, Prentice Women's Hospital Building, 3rd Floor, 250 East Superior
Time: 3:15 – 5:15 PM
Session Chair: Karen Smilowitz

Planning Reliable Service Facilities Under Continuous Traffic Equilibrium and Disruption Risks – *Zhaodong Wang, Yanfeng Ouyang**

Design and Control of Driverless Fleets of Electric Vehicles using Approximate Dynamic Programming – *Warren Powell*, Andy Deng, Lina Al Kanj, Alain Kornhauser*

From 'No Data' to 'Some Data' to 'Big Data' Towards a Cyber-Physical System for Proactive Traffic Management – *Pitu Mirchandani*, Kerem Demirtas, Viswanath Potluri*

Logistical Challenges at Mass Participation Events: Operations Research Models for Marathon Planning – *Karen Smilowitz*, Mehmet Basdere, Sanjay Mehrotra, George Chiampas, Jennifer Chan, Mike Nishi*

THURSDAY **8:30 – 10:30 AM**	MULTIMODAL TRANSPORTATION SERVICES Session TA1: **Air Traffic and Air Networks**	TRAFFIC & MOBILITY Session TA2: **Traffic Equilibrium**	VEHICLE ROUTING MODELS & APPLICATIONS Session TA3: **EV Charging Logistics**	SUPPLY CHAIN LOGISTICS & METHODS Session TA4: **Humanitarian Logistics**
Session Chair	**David Lovell**	**Carlo Prato**	**Halit Uster**	**Lavanya Marla**
8:30 AM	Choice-Based Airline Fleet Assignment – *Chiwei Yan*, Cynthia Barnhart, Vikrant Vaze*	Analyzing Departure Time Choice in a Bottleneck with Stochastic Service Time – *Gege Jiang*, Hong Lo*	Locating Refueling Points on Lines and Comb-Trees – *Pitu Mirchandani, Yazhu Song**	Using Drones to Minimize Latency in Distribution Systems – *Mohammad Moshref-Javadi*, Seokcheon Lee*
9:00 AM	The Most Reliable Path Problem for Airline Travel with Connections – *Michael Redmond*, Ann Campbell, Jan Ehmke*	An Algorithm for Transit Assignment Problem with Flow-Dependent Dwell Times – *Yufeng Zhang*, Alireza Khani*	Modeling Electric Vehicle Charging Demand – *Guus Berkelmans, Wouter Berkelmans, Nanda Piersma, Rob van der Mei, Elenna Dugundji**	A Novel Formulation and a Column Generation Technique for a Rich Humanitarian Logistic Problem – *Ohad Eisenhandler, Michal Tzur**
9:30 AM	Modeling Flight Delay Propagation: A New Analytical-Econometric Approach – *Nabin Kafle, Bo Zou**	Statistical Inference of Probabilistic Origin-destination Demand Using Day-To-Day Traffic Data – *Wei Ma*, Zhen Qian*	Electric Vehicle Routing with Uncertain Charging Station Availability & Dynamic Decision Making – *Nicholas Kullman*, Justin Goodson, Jorge Mendoza*	Humanitarian Medical Supply Chain in Disaster Response: Role and Challenges – *Irina Dolinskaya*, Maria Besiou, Sara Guerrero-Garcia*
10:00 AM	Sources of Flight Inefficiency in the National Airspace System: An Econometric Approach – *Mark Hansen*, Yulin Liu, Michael Ball, David Lovell, Cara Chuang*	Threshold-Based Stochastic User Equilibrium Models – *David Watling, Thomas Rasmussen, Otto Nielsen, Carlo Prato**	Network Design for In-Motion Wireless Charging of Electric Vehicles in Urban Traffic Networks – *Mamdouh Mubarak*, Halit Uster, Khaled Abdelghany, Mohammad Khodayar*	Cooperative Humanitarian Logistics Models for Highly Resource-Constrained Settings – *Lavanya Marla**

THURSDAY	MULTIMODAL TRANSPORTATION SERVICES	TRAFFIC & MOBILITY	VEHICLE ROUTING MODELS & APPLICATIONS	SUPPLY CHAIN LOGISTICS & METHODS
1:00 – 2:30 PM	Session TB1: **IP Methods in Air Traffic Control**	Session TB2: **Pricing and Competition**	Session TB3: **VRP Exact Methods**	Session TB4: **Games and Collaboration**
Session Chair	**Michael Ball**	**Song Gao**	**Michel Gendreau**	**Nicole Adler**
1:00 PM	Optimizing the Slot Allocation on a Network of Airports – *Paola Pellegrini*, Tatjana Bolić, Lorenzo Castelli, Raffaele Pesenti*	Competitive Rebalancing in One-Way Car-Sharing – *Szymon Albinski*, Stefan Minner*	An Integer Programming Approach for the Time-Dependent Traveling Salesman Problem with Time Windows – *Agustin Montero, Isabel Mendez-Diaz, Juan Jose Miranda Bront**	Multi-Round Combinatorial Auctions for Carrier Collaboration – *Margaretha Gansterer*, Richard Hartl, Martin Savelsbergh*
1:30 PM	Greedy Policies for a Dynamic Stochastic Transportation Problem, and an Application to Air Traffic Management – *Alexander Estes*, Michael Ball*	The Costs and Benefits of Ridesharing: Sequential Individual Rationality and Sequential Fairness – *Ragavendran Gopalakrishnan*, Koyel Mukherjee, Theja Tulabandhula*	A Mixed-Integer Linear Program for the Traveling Salesman Problem with Structured Time Windows – *Philipp Hungerlaender, Christian Truden**	Collaborative Vehicle Routing with Excess Vehicle Capacity in Urban Last-Mile Deliveries – *Joydeep Paul*, Niels Agatz, Remy Spliet, René De Koster*
2:00 PM	A Mechanism for Auctioning Airport Landing Slots with Explicit Valuation of Congestion – *Michael Ball*, Alex Estes, Mark Hansen, Yulin Liu*	Cooperative Scheme - An Alternative Approach to Equitable and Pareto-Improving System Optimum – *Sayeeda Ayaz*, Song Gao, Hyoshin Park*	A Branch-and-Price Algorithms for a Multi-Attribute Technician Routing and Scheduling Problem – *Michel Gendreau*, Ines Mathlouthi, Jean-Yves Potvin*	Competition in Congested Service Networks: The Case of Air Traffic Control Provision in Europe – *Nicole Adler*, Eran Hanany, Stef Proost*

THURSDAY **2:45 – 4:15 PM**	MULTIMODAL TRANSPORTATION SERVICES Session TC1: **Airport Operations**	TRAFFIC & MOBILITY Session TC2: **Pricing Shared Mobility**	VEHICLE ROUTING MODELS & APPLICATIONS Session TC3: **VRP Extensions**	SUPPLY CHAIN LOGISTICS & METHODS Session TC4: **Delivery Service Network**
Session Chair	**Senay Solak**	**Tunay Tunca**	**Daniele Vigo**	**Niels Agatz**
2:45 PM	Efficiency, Equity and On-Time Performance Objectives in Airport Demand Management – *Alexandre Jacquillat*, Vikrant Vaze*	Split the Bill by Sharing the Ride-Sharing Services: A Study on Optimal Ride-Sharing Pricing – *Jagan Jacob*, Ricky Roet-Green*	Multi-Modal Variations of the Vehicle Routing Problem – *Marc-Antoine Coindreau, Olivier Gallay*, Zufferey Nicolas*	An On-Demand Same-Day Delivery Service Using Direct Peer-to-Peer Transshipment Strategies – *Wei Zhou, Jane Lin**
3:15 PM	A Data-Splitting Algorithm for Flight Sequencing and Scheduling on Two Runways – *Rakesh Prakash*, Jitamitra Desai*	Inventory Rebalancing and Minimum Stop-Over Routes for One-Way Electric Vehicle Sharing Systems – *Yinglei Li*, Sung Hoon Chung*	Multi-Commodity Two-Echelon Vehicle Routing Problem with Time Windows – *Tom Van Woensel**	Balancing Availability and Profitability in E-Fulfillment with Revenue Management and Predictive Routing – *Catherine Cleophas*, Jan Fabian Ehmke, Charlotte Köhler, Magdalena Lang*
3:45 PM	Lower Cost Departures for Airlines: Optimal Gate and Metering Area Allocation Policies Under Departure Metering Concept – *Heng Chen*, Senay Solak*	An Empirical Analysis of Price Formation, Utilization, and Value Generation in Ride Sharing Services – *Liu Ming, Tunay Tunca*, Yi Xu, Weiming Zhu*	The Vehicle Routing Problem with Private Fleet and Common Carrier: Extension and Exact Algorithm – *Said Dabia, David Lai, Daniele Vigo**	Heuristic Approaches to the Same-Day Delivery Problem – *Alp Arslan*, Niels Agatz, Rob Zuidwijk*

THURSDAY **4:30 – 6:00 PM**	MULTIMODAL TRANSPORTATION SERVICES Session TD1: **Bus and Taxi Transport**	TRAFFIC & MOBILITY Session TD2: **Optimization in Shared Mobility**	VEHICLE ROUTING MODELS & APPLICATIONS Session TD3: **Dynamic Routing**	SUPPLY CHAIN LOGISTICS & METHODS Session TD4: **Service Network Design**
Session Chair	**Mark Hickman**	**Carolina Osorio**	**Barrett Thomas**	**Mark Hewitt**
4:30 PM	Choice between Metro and Taxi under Travel Time Variability – *Gege Jiang*, Hong Lo*	Optimizing the Profitability and Quality of Service in Carshare Systems Under Demand Uncertainty – *Mengshi Lu*, Siqian Shen, Zhihao Chen*	Route-Based Markov Decision Processes for Dynamic Vehicle Routing Problems – *Justin Goodson*, Marlin Ulmer, Dirk Mattfeld, Barrett Thomas*	A Benders' Decomposition Approach for Airline Timetable Development and Fleet Assignment – *Keji Wei*, Vikrant Vaze*
5:00 PM	Multi-Cycle Optimal Taxi Routing with E-Hailing – *Xinlian Yu*, Song Gao, Hyoshin Park, Xianbiao Hu*	Ridesharing in a Mobility-on-Demand System – *Samitha Samaranayake*, Harshith Guntha, Kevin Spieser, Emilio Frazzoli*	Scalable Anticipatory Policies for the Dynamic and Stochastic Pickup and Delivery Problem – *Gianpaolo Ghiani, Emanuele Manni*, Alessandro Romano*	Service Network Design of Bike Sharing Systems: Formulation and Solution Method – *Bruno Albert Neumann Saavedra*, Dirk Mattfeld, Teodor Gabriel Crainic, Bernard Gendron, Michael Römer*
5:30 PM	Machine Learning Methods to Predict Bus Travel Speeds and Analysis of the Impact of Different Predictive Variables – *Jan Berczely, Ricardo Giesen**	A Discrete Simulation-Based Optimization Algorithm for Two-Way Car-Sharing Network Design – *Tianli Zhou*, Carolina Osorio, Evan Fields*	Enough Waiting for the Cable Guy - Estimating Arrival Times for Service Vehicle Routing – *Barrett Thomas*, Marlin Ulmer*	Enhanced Dynamic Discretization Discovery Algorithms for Service Network Design Problems – *Mike Hewitt**

FRIDAY **8:30 – 10:30 AM**	MULTIMODAL TRANSPORTATION SERVICES Session FA1: **Transit Fare and Revenue**	TRAFFIC & MOBILITY Session FA2: **Traffic Management**	VEHICLE ROUTING MODELS & APPLICATIONS Session FA3: **Dynamic Pick Up and Delivery**	SUPPLY CHAIN LOGISTICS & METHODS Session FA4: **Location Routing**
Session Chair	**Hai Yang**	**Lili Du**	**Martin Savelsbergh**	**Francesco Viti**
8:30 AM	Ticket Portfolio Planning for Urban and Regional Public Transport Networks – *Jörn Schönberger**	Morning Commute Problem with Queue-Length-Dependent Bottleneck Capacity – *Jin-Yong Chen, Rui Jiang*, Xin-Gang Li, Mao-Bin Hu, Bin Jia*	Dynamic Pickup and Delivery Problems with Transfers – *Afonso Sampaio, Martin Savelsbergh, Lucas Veelenturf*, Tom Van Woensel*	Finding Optimal Park-and-Ride Facility Locations in an Urban Network – *Pramesh Kumar*, Alireza Khani*
9:00 AM	Optimal Discount Policies for Transit Agencies: The Case of Pass Programs and Loyalty Programs – *Mehdi Nourinejad*, Amir Gandomi, Joseph Y. J. Chow, Matthew J. Rooda*	Modelling User Behavior at a Stochastic Bottleneck – *Daphne van Leeuwen*, Peter van de Ven*	How Many Vehicles Do We Need? Pickup and Delivery Problem with Synchronized Tasks and Transfers – *Monirehalsadat Mahmoudi*, Junhua Chen, Xuesong Zhou*	Reliable Facility Location Design with Imperfect Information: Continuum and Discrete Models – *Lifen Yun, Hongqiang Fan, Xiaopeng Li**
9:30 AM	Pricing for a Last Mile Transportation System – *Hai Wang*, Yiwei Chen*	Recasting Intersection Automation as a Connected-and-Automated-Vehicle (CAV) Scheduling Problem within Heterogeneous Traffic Environment – *Pengfei (Taylor) Li*, Xuesong Zhou*	Order Acceptance Mechanisms for Same-Day Delivery – *Mathias Klapp*, Alan Erera, Alejandro Toriello*	Location-Routing Problems with Economies of Scale – *James Bookbinder*, Xiaoyang Pi*
10:00 AM	A Fare-Reward Scheme for Commuters in Transit Bottleneck – *Yili Tang*, Hai Yang*	Distributed Computation Based Constrained Model Predictive Control for a Mixed Flow Platoon – *Siyuan Gong*, Lili Du*	Optimization Algorithms for Meal Delivery Operations – *Damian Reyes*, Alan Erera, Martin Savelsbergh*	Exact and Approximate Optimal Route Set Generation in Sensor Location Problems – *Marco Rinaldi*, Francesco Viti*

FRIDAY	MULTIMODAL TRANSPORTATION SERVICES	TRAFFIC & MOBILITY	VEHICLE ROUTING MODELS & APPLICATIONS	SUPPLY CHAIN LOGISTICS & METHODS
1:00 – 2:30 PM	Session FB1: **Transit Networks**	Session FB2: **Network Design and Location Decisions**	Session FB3: **Stochastic Routing**	Session FB4: **Freight Transportation**
Session Chair	**Juan Carlos Munoz**	**Yanfeng Ouyang**	**Stefan Minner**	**Ronald Askin**
1:00 PM	An Internal Bounding Method for Line and Shuttle Bus Planning – *Evelien van der Hurk**	Emission-controlled Pavement Management Scheduling – *Umit Tursun*, Hasan Ozer*	Vehicle Routing with Space- and Time-Dependent Stochastic Travel Times – *Stein W. Wallace*, Zhaoxia Guo, Michal Kaut*	Scheduled Service Network Design and Revenue Management with an Intermodal Barge Transportation Illustration – *Teodor Gabriel Crainic*, Ioana Bilegan, Yunfei Wang*
1:30 PM	Urban Transit Network Design and Timetabling Problem for Multi-Depot Round-Trip Routes – *James Chu**	Scheduling Work Zones in Transportation Service Networks – *Dening Peng*, Pitu Mirchandani*	A Two-Phase Safe Vehicle Routing and Scheduling Problem: Formulations and Solution Algorithms – *Aschkan Omidvar*, Eren Ozguven, Arda Vanli, Reza Tavakkoli-Moghaddam*	Load Commitment Policies for the Stochastic Advance Booking Problem for Truckload Trucking – *Juliana Nascimento*, Hugo Simao, Warren Powell*
2:00 PM	The Limited-Stop Bus Service Design Problem with Stochastic Passenger Assignment – *Guillermo Soto, Homero Larrain, Juan Carlos Munoz**	Reliable Sensor Location for Object Positioning and Surveillance via Trilateration – *Kun An, Siyang Xie, Yanfeng Ouyang*	Optimal A-Priori Tour and Restocking Policies for the Vehicle Routing Problem with Stochastic Demands – *Alexandre Florio, Richard F. Hartl, Stefan Minner**	Logistic Network Design for Daily Cyclic Truck Routes – *Ronald Askin*, Zhengyang Hu, Guiping Hu*

FRIDAY **2:45 – 4:15 PM**	MULTIMODAL TRANSPORTATION SERVICES Session FC1: **Containers Logistics**	TRAFFIC & MOBILITY Session FC2: **Traffic Flow Modeling**	VEHICLE ROUTING MODELS & APPLICATIONS Session FC3: **Statistical Data Analytics for Routing and Location**	SUPPLY CHAIN LOGISTICS & METHODS Session FC4: **Movement and Inventory Control in Supply Chains**
Session Chair	**Patrick Jaillet**	**Hillel Bar-Gera**	**Bruce Golden**	**Rajan Batta**
2:45 PM	Balancing the Trade-Off in Route Choice and Demurrage Costs in Inland Container Logistics – *Bernard Zweers*, Rob van der Mei, Sandjai Bhulai*	The Role of Stochasticity in Traffic Flow Instabilities – *Junfang Tian*, Rui Jiang, Martin Treiber*	A Novel Statistical Algorithm for Very Large-scale Vehicle Routing Problems with Time Windows – *Mayank Baranwal, Lavanya Marla*, Srinivasa Salapaka, Carolyn Beck*	Dynamic Capacity Logistics and Inventory Control – *Satya Malladi*, Alan Erera, Chelsea White III*
3:15 PM	An Integrated Model for Inbound Train Split and Container Loading in an Intermodal Railway Terminal – *Bruno Bruck*, Jean-François Cordeau, Emma Frejinger*	A Kalman Filter Approach for Dynamic Calibration of A Simplified Lower-Order Car Following Model – *Kerem Demirtas*, Pitu Mirchandani, Xuesong Zhou*	Facility Location and Design Decisions from Public Data – *Kalyan Talluri, Muge Tekin**	Planning the Fuel Supply to Gas Stations According to the Concept of Carrier-Mannaged Inventory - an Optimization Approach – *Paweł Hanczar**
3:45 PM	The Stochastic Container Relocation Problem – *Virgile Galle*, Setareh Borjian Boroujeni, Vahideh Manshadi, Cynthia Barnhart, Patrick Jaillet*	Representation Requirements for Perfect First-In-First-Out Verification in Continuous Flow Dynamic Models – *Hillel Bar-Gera*, Malachy Carey*	Addressing Uncertainty in Meter Reading for Utility Companies Using RFID Technology – *Debdatta Sinha Roy*, Bruce Golden, Edward Wasil*	Exploration of Strategies to Form Convoys to Facilitate Effective Movement of Items – *Rajan Batta*, Azar Sadeghnejad Barkousaraie, Moises Sudit*

FRIDAY **4:30 – 6:00 PM**	MULTIMODAL TRANSPORTATION SERVICES Session FD1: **Maritime Shipping and Fleets**	TRAFFIC & MOBILITY Session FD2: **Ride Sharing and Parking**	VEHICLE ROUTING MODELS & APPLICATIONS Session FD3: **Routing Applications**	SUPPLY CHAIN LOGISTICS & METHODS Session FD4: **Risk Analysis in Network Transportation**
Session Chair	**Stein W. Wallace**	**Yafeng Yin**	**Burcu Keskin**	**Laura Wynter**
4:30 PM	Speed Optimization Across Different Emission Control Zones – *Line Reinhardt*, Christos Kontovas*	Optimal Two-Sided Pricing Strategies of Shared E-Parking Platform with Elastic Demand – *Chaoyi Shao*, Hai Yang, Fangni Zhang*	Heuristics and Lower Bounds for Robust Heterogeneous Vehicle Routing Problems Under Demand Uncertainty – *Anirudh Subramanyam*, Panagiotis Repoussis, Chrysanthos Gounaris*	Hazardous-Materials Network Design Problem with Behavioral Conditional Value-at-Risk – *Liu Su*, Changhyun Kwon*
5:00 PM	A Column-Row-Generation Approach to Liner Shipping Network Design – *Jun Xia, Zhou Xu**	Integration of an Aggregated Dynamic Traffic Model with Advanced Optimization Techniques for Strategic Transit-Parking Planning – *Joana Cavadas*, António Pais Antunes, Nikolas Geroliminis*	Optimal Snow Plow Routing with Route Continuity Constraint – *Luning Zhang*, Jing Dong*	A Value-at-Risk (VaR)/Conditional Value-at-Risk (CVaR) Approach to Optimal Train Configuration and Routing of Hazmat Shipments – *S. Davod Hosseini*, Manish Verma*
5:30 PM	Planning for Charters: A Stochastic Maritime Fleet Composition and Deployment Problem – *Xin Wang*, Kjetil Fagerholt, Stein W. Wallace*	Optimal Parking Provision for Ride-Sourcing Services – *Zhengtian Xu*, Yafeng Yin, Liteng Zha*	Patrol Routing with Hybrid Electric Vehicles – *Mesut Yavuz*, Burcu Keskin, Huseyin Ergin*	Entity Resolution and Vessel Modeling for Maritime Situational Awareness – *Shiau Hong Lim*, Yeow Khiang Chia, Laura Wynter*

SATURDAY **9:00 – 11:00 AM**	MULTIMODAL TRANSPORTATION SERVICES Session SA1: **Rail Transport**	TRAFFIC & MOBILITY Session SA2: **Simulation-Based Analysis and Optimization**	VEHICLE ROUTING MODELS & APPLICATIONS Session SA3: **VRP in Services**	SUPPLY CHAIN LOGISTICS & METHODS Session SA4: **Behavioral Data and Demand Estimation**
Session Chair	**Dario Pacciarelli**	**Ronghui Liu**	**Lei Zhao**	**Yueyue Fan**
9:00 AM	The Load Planning Problem for Double-Stack Trains at Intermodal Terminals – *Serena Mantovani*, Gianluca Morganti, Nitish Umang, Teodor Gabriel Crainic, Emma Frejinger, Eric Larsen*	Traffic Management Strategies for Trucks in Urban Environments Based on a Fast Traffic Simulation Algorithm – *Michele Simoni*, Christian Claudel*	Self-Sustained Car-And-Ride Sharing Design and Optimization for Improving the Mobility of Underserved Communities – *Miao Yu*, Siqian Shen*	Household Use of Autonomous Vehicles: Modeling Framework and Traveler Adaptation – *Yashar Khayati, Jee Eun Kang*, Mark Karwan, Chase Murray*
9:30 AM	Tactical Block and Car Planning for Intermodal Trains – *Gianluca Morganti*, Teodor Gabriel Crainic, Emma Frejinger, Nicoletta Ricciardi*	Simulation Based Quantification of the Potential Impacts of Incidents on Connected Vehicle Applications – *Abdullah Kurkcu*, Fan Zuo, Jingqin Gao, Kaan Ozbay*	The Multi-Period Service Planning and Routing Problem – *Albert H. Schrotenboer*, Evrim Ursavas, Iris F.A. Vis*	Estimating Primary Demand of One-Way Vehicle Sharing Systems – *Chiwei Yan*, Chong Yang Goh*
10:00 AM	Optimization of Handouts for Rolling Stock Rotations Visualization – *Boris Grimm*, Ralf Borndoerfer, Thomas Schlechte, Markus Reuther*	An Efficient Sampling Method for Stochastic Simulation-based Transportation Optimization – *Timothy Tay*, Carolina Osorio*	Covering Tour Problem with an Application to School Bus Routing: Analysis of Single Vehicle Tours on a Grid – *Liwer Zeng*, Sunil Chopra, Karen Smilowitz*	Modeling the Acceptability of Crowdsourced Goods Deliveries – *Aymeric Punel, Alireza Ermagun, Amanda Stathopoulos**
10:30 AM	Real-Time Near-Optimal Train Scheduling and Routing in Complex Railway Networks – *Marcella Samà, Andrea D'Ariano, Dario Pacciarelli*, Francesco Corman*	A Within-Day Microscopic Dynamical Model of Route Choice and Responsive Traffic Signal Control – *Ronghui Liu*, Mike Smith*	Coordinated Delivery to Nanostores in Megacities – *Ruidian Song, Lei Zhao*, Jan C. Fransoo, Tom Van Woensel*	Travel Demand Estimation Using Heterogeneous Data Pieces: Addressing Stochasticity and Observability Issues – *Yudi Yang, Yueyue Fan*, Roger Wets*

SATURDAY	Multimodal Transportation Services	Traffic & Mobility	Vehicle Routing Models & Applications	Supply Chain Logistics & Methods
11:15 – 12:45 PM	Session SB1: **Multiobjective and Multidimensional Logistics**	Session SB2: **Traffic Data Analysis**	Session SB3: **VRP in Health and Food Delivery**	Session SB4: **City Logistics and Inventory Control**
Session Chair	**Fabien Lehuédé**	**Jiwon Kim**	**Ann Campbell**	**Teodor Gabriel Crainic**
11:15 AM	Multi-Criteria Decision Making when Planning & Designing Sustainable Multi-Modal Transportation in a Corridor – *Marie Louis*, Eric Gonzales*	Opportunities for Floating Car Data in Integrated Traffic Management: The Case of Queue Estimation – *Serge Hoogendoorn*, Erik-Sander Smits, Jaap Van Kooten*	An ALNS For a Rich Home Health Care Routing and Scheduling Problem – *Florian Grenouilleau*, Antoine Legrain, Nadia Lahrichi, Louis-Martin Rousseau*	Value Function Approximation-based Dynamic Look-ahead Policies for Stochastic-Dynamic Inventory Routing in Bike Sharing Systems – *Jan Brinkmann, Marlin Ulmer, Dirk Mattfeld**
11:45 AM	Bin-Packing Problems with Load Balancing and Stability Constraints – *Alessio Trivella*, David Pisinger*	A Data-Driven and Integrated Evaluation of Area-Wide Impacts of Double Parking Using Macroscopic and Microscopic Models – *Jingqin Gao, Kaan Ozbay*, Michael Marsico*	Team Orienteering with Uncertain Rewards and Service Times with an Application to Phlebotomist Intra-Hospital Routing – *Huan Jin*, Barrett Thomas*	Synchronizing City Logistics with Sliding Time Windows – *Saijun Shao*, Gangyan Xu, Ming Li, George Q. Huang*
12:15 PM	Multi-Directional Local Search for A Bi-Objective Vehicle Routing Problem with Lexicographic Minimax Load Balancing – *Fabien Lehuédé*, Olivier Péton, Fabien Tricoire*	Urban Trajectory Analytics: Day-Of-Week Movement Pattern Mining Using Tensor Factorization – *Jiwon Kim*, Kianoosh Soltani Naveh*	The Restaurant Delivery Problem – *Marlin Ulmer*, Barrett Thomas, Ann Campbell, Nicholas Woyak*	Multi-Modal Scheduled Service Network Design for Two-Tier City Logistics System with Resource Management – *Pirmin Fontaine*, Teodor Gabriel Crainic, Ola Jabali, Walter Rei*

TSL Cross-Region Dissertation Grant Winner

Time: Saturday, 1:00 – 1:30 PM
Session Chair: Maciek Nowak

Multi-objective stochastic optimization models for managing a bike sharing system – *Rossana Cavagnini*, Luca Bertazzi, Francesca Maggioni, Mike Hewitt*

Special Joint Session with ISTTT

Wednesday 3:15 – 5:15 PM Conference Room L
Session Chair: Karen Smilowitz Prentice Women's Hospital Building, 3rd Floor, 250 East Superior

3:15 **Planning Reliable Service Facilities Under Continuous Traffic Equilibrium and Disruption Risks**

*Zhaodong Wang, Yanfeng Ouyang**
University of Illinois Urbana-Champaign

Many service systems are composed of interrelated facilities that jointly serve spatially distributed demand. Establishment of such facilities could induce or alter customer traffic that exacerbates congestion in the neighborhood, as customers often choose their own service facility and access path. The situation is further worsened by the risk for the service facilities to be disrupted. This talk presents models for reliable service facility design under traffic equilibrium in a continuous space. We first discuss solution methods for a class of nonlinear partial differential equations (PDE) that describe continuous traffic equilibrium. We show that under certain conditions the PDE can be solved, either exactly or approximately, in closed analytical forms. We then develop several facility location/layout design models, including mixed-integer programs with equilibrium constraints that can be solved by Lagrangian relaxation with embedded PDE solution methods. When closed-form PDE solution is available, the reliable design models reduce to a much simpler nonlinear program.

3:45 **Design and Control of Driverless Fleets of Electric Vehicles using Approximate Dynamic Programming**

Warren Powell, Andy Deng, Lina Al Kanj, Alain Kornhauser*
Princeton University

Driverless fleets of electric vehicles offer significantly lower operating costs, higher utilization, lower insurance and reduced parking, suggesting the potential for a major transportation in personal transportation. However, there are open questions about the ability of such a fleet to reliably serve a complete set of trips, taking into consideration both spatial and temporal patterns. Unlike current ride services such as Uber and Lyft, a driverless fleet has to be centrally managed, and dispatch algorithms need to identify the best car given its current state of charge, the length of the trip and its destination (in addition to the availability of charging stations). We use approximate dynamic programming to optimize this fleet and analyze the economics of the fleet using a dataset of all the trips in New Jersey over the course of a day.

4:15 **From 'No Data' to 'Some Data' to 'Big Data' Towards a Cyber-Physical System for Proactive Traffic Management**

Pitu Mirchandani, Kerem Demirtas, Viswanath Potluri*
Arizona State University

The objective of the research reported is to synergistically use a cyber-physical infrastructure consisting of smart-phone devices; cloud computing, wireless communication, and intelligent transportation systems to manage diverse vehicles in the complex urban network – through the use of traffic controls, and route guidance to jointly optimize drivers' mobility and the sustainability goals of reducing energy usage and improving air quality. The system being developed, MIDAS, is to proactively manage the interacting traffic demand and the available transportation supply. A key element of MIDAS is the data collection and display device PICT that collects each participating driver's vehicle position, forward images from the vehicle's dashboard, and communication time stamps, predict traffic ahead and provide signal controls and route advisories to optimize given objectives. In this extended abstract, we highlighted the novel contribution in developing Lagrangian framework based traffic state estimation and prediction algorithms at a lane level

resolution, using PICT device information. Also briefed about the design of traffic signal control algorithm, for solving phase sequence optimization problem to accommodate efficient traffic movement through intersections, for fluctuating demands in real-time, using a forward recursion Dynamic Programming (DP) approach. And finally, a Route Guidance and Traffic Signal Optimization (RGTSO) model is advised for simultaneous real-time optimization of route guidance for vehicles and phase setting of traffic signals in the network, with time resolution of seconds.

4:45 Logistical Challenges at Mass Participation Events: Operations Research Models for Marathon Planning

[1]Karen Smilowitz, [1]Mehmet Basdere, [1]Sanjay Mehrotra, [2]George Chiampas, [1]Jennifer Chan, [3]Mike Nishi*
[1]Northwestern University, [2]Northwestern and Bank of America Chicago Marathon and Shamrock Shuffle, [3]Chicago Event Management

Mass participation events bring a host of significant planning and implementation challenges. The organizers of the Chicago Marathon have developed a holistic approach to event planning, referred to as the Chicago Model, which brings together major organizations (e.g., race organizers, fire and police departments, emergency management, Red Cross) to coordinate preparation and response for the event and surrounding areas. As we welcome the TSL community to Chicago, this talk will present (i) a brief overview of our ongoing research project to expand the capabilities of the Chicago Model through operations research methodologies and (ii) a more detailed look at marathon course design. As part of our efforts to formalize course design, we introduce the Lock-Free Arc Tour Problem (LFATP), a novel tour finding problem which ensures that the resulting tour does not block access to certain critical vertices. For endurance events, such as a marathon, a key consideration in course design is the proximity to medical care. Equally important, the course itself should not lock hospitals and other critical facilities within the course, thereby reducing access for the general public. The LFATP is formulated as a mixed integer linear program, addressing both considerations. Valid inequalities from the literature are adapted to the LFATP and new valid inequalities are derived from locking properties. The chosen objective function results in a clustered cost structure, yielding excessive subtour formation and causing standard branch-and-cut approach to fail. For this reason, we introduce an approach based on a provably stronger disjunctive programming formulation, where each subproblem is obtained by fixing the visit orders in which required arcs are visited. These approaches are promising for similar tour finding problems with visit requirements and length restrictions. A case study from the Bank of America Chicago Marathon is provided.

Multimodal Transportation Services

TA1: Air Traffic and Air Networks

Thursday 8:30 – 10:30 AM Schreiber 807

Session Chair: David Lovell

8:30 **Choice-Based Airline Fleet Assignment**

[1]Chiwei Yan, [1]Cynthia Barnhart, [2]Vikrant Vaze*
[1]Massachusetts Institute of Technology, [2]Dartmouth College

We propose models to incorporate customer choice behaviors into the airline fleet assignment model (FAM). Unlike network revenue management, the choice-based FAM is usually intractable for real-world instances. We thus devise efficient reformulation, approximation and decomposition approaches with provable performance guarantees. The approaches we developed naturally separates revenue calculation and fleet assignment into a two-step process so that the structure of FAM is independent of the assumptions made by the choice models. Preliminary computational experiments show superior performance over existing models.

9:00 **The Most Reliable Path Problem for Airline Travel with Connections**

[1]Michael Redmond, [1]Ann Campbell, [2]Jan Ehmke*
[1]University of Iowa, [2]Europe University Viadrina

Journeys between many origin-destination pairs can require multiple legs, such as several trains, shared rides, or flights, to arrive at the final destination. In this paper, we propose an approach to evaluate the reliability of a journey from origin to destination given a start time and travel time budget. Specifically, we focus on airline travel and making a priori decisions about flights based on reliability. Given publicly available data, we compute the likelihood of individual flights arriving and departing at different times and use these values in our reliability calculations for the entire journey. We also implement both a restricted and expanded network search for the most reliable path given the start time and budget boundaries. In addition, acceleration techniques are used in order to expedite this network search to find the most reliable path in an efficient manner. All of this is done with the goal of providing more transparent reliability information to the passenger to help improve decision-making on multiple leg journeys.

9:30 **Modeling Flight Delay Propagation: A New Analytical-Econometric Approach**

*Nabin Kafle, Bo Zou**
University of Illinois at Chicago

Flight delay presents a widespread phenomenon in the air transportation system, costing billions of dollars every year. Some delay originating from an upstream flight spreads to downstream flights. This phenomenon is defined as delay propagation. To understand the delay propagation patterns and associated mitigation measures, this study proposes a novel analytical-econometric approach. Considering that airlines deliberately insert buffer into flight schedules and ground turnaround operations, an analytical model is developed to quantify propagated and newly formed delays that occur to each sequence of flights that an aircraft flies in a day, from three perspectives on the ways that delays are absorbed by the buffer. With delays computed from the analytical model, we further develop a joint discrete-continuous econometric model and use the Heckman's two-step procedure to reveal the effects of various influencing factors on the initiation and progression of propagated delays. Results from the econometric analysis provide estimates on how much propagated delay will be generated out of each minute of newly formed delay, for the US domestic aviation system as well as for individual major airports and airlines. The impacts of various factors on the initiation and progression of propagated delay are quantified. These results may help aviation system planners gain additional insights into flight delay propagation patterns and

consequently prioritize resource allocation while improving system overall performance. Airlines can also be better informed to assign buffer to their flight schedules to mitigate delay propagation.

10:00 Sources of Flight Inefficiency in the National Airspace System: An Econometric Approach

[1]Mark Hansen, [1]Yulin Liu, [2]Michael Ball, [2]David Lovell, [2]Cara Chuang*
[1]University of California-Berkeley, [2]University of Maryland

We investigate causes of en-route flight inefficiency for US domestic flights into and out of 34 major US airports, using a dataset of several million flights from the years 2013 and 2014. Following earlier work, our inefficiency metrics compare the distance flown between airport terminal exit and entry points with the achieved distance, and further isolate the effects of pre-specified, and often not ideal, entry and exit points (TMA) and excess distance flown between these points (DIR). We find the TMA inefficiency decreases with flight distance, while DIR inefficiency is roughly constant with distance. Inefficiency varies considerably for flights between a given airport-pair, with median values generally less than 5%. To assess causes of inefficiency, we employ two different methodologies, both of which are based on clustering individual trajectories and identifying nominal trajectories within each cluster. In the first approach, the nominal trajectories are used to compute aggregate metrics related to different causal factors, for example exposure to convective weather. These metrics are then used as explanatory in regression models in which inefficiency metrics are the dependent variables. In the second approach, we model the cluster to which a given trajectory belongs based on characteristics of nominal routes and then estimate regression models which take into account the trajectory cluster as well as metrics related to the various causal factors. Results for inefficiency causes including convective weather, winds, and TMI actions are presented.

Multimodal Transportation Services

TB1: IP Methods in Air Traffic Control

Thursday 1:00 – 2:30 PM Schreiber 807

Session Chair: Michael Ball

1:00 **Optimizing the Slot Allocation on a Network of Airports**

[1]Paola Pellegrini, [2]Tatjana Bolić, [2]Lorenzo Castelli, [3]Raffaele Pesenti*
[1]IFSTTAR, [2]Università degli Studi di Trieste, [3]Università Ca' Foscari di Venezia

In this work, we introduce SOSTA for the Simultaneous Optimization of the SloT Allocation for a network of airports. Currently, twice a year, each main airport allocates its slots and then, at a IATA conference, negotiations and slot exchanges alleviate the possible mismatch between requests and allocations. By reproducing the current regulations and best practice, SOSTA allows the slot allocation for an entire network of airports. Using real data, our experimental analysis shows that SOSTA can deal with all the European airports within a good computational time. Moreover, it can be used as a scenario analysis tool to assess the impact of difference policies, as for example the elimination of grandfather rights.

1:30 **Greedy Policies for a Dynamic Stochastic Transportation Problem, and an Application to Air Traffic Management**

Alexander Estes, Michael Ball*
University of Maryland

The transportation problem is one of the most fundamental and well-known problems in combinatorial optimization. We provide a formulation for a variant of the transportation problem which is dynamic in the sense that the problem occurs over several time periods, and is stochastic in the sense that new supply and demand arrives according to a random process. We propose a class of greedy policies and provide sufficient and necessary conditions for the optimality of these policies. This work can be applied to the problem of planning a type of air traffic management initiative called a ground delay program. We propose a new dynamic formulation for planning ground delay programs and we provide a dynamic policy for this problem. Our results for the dynamic stochastic transportation problem imply that this policy is optimal.

2:00 **A Mechanism for Auctioning Airport Landing Slots with Explicit Valuation of Congestion**

[1]Michael Ball, [1]Alex Estes, [2]Mark Hansen, [2]Yulin Liu*
[1]University of Maryland, [2]University of California-Berkeley

This paper provides a conceptual design of a combinatorial auction to address the problem of auctioning airport landing slots. The innovative aspect of this approach is that rather than specifying strict limits on the number of slots in a time window, the bidders are able to place values on their slot packages under alternate slot limit vectors. Bidders would do this by computing associated congestion costs and the appropriate slot limits and congestion levels are then determined by the auction. We analyze the societal benefits of this approach and also benefits to the bidders/flight operators using both i) a continuous approximation and ii) a simulation using real data and an embedded integer program that solves the winner determination problem.

Multimodal Transportation Services

TC1: Airport Operations

Thursday 2:45 – 4:15 PM Schreiber 807

Session Chair: Senay Solak

2:45 Efficiency, Equity and On-Time Performance Objectives in Airport Demand Management

[1]Alexandre Jacquillat, [2]Vikrant Vaze*
[1]Carnegie Mellon University-Heinz College, [2]Dartmouth College

In the absence of opportunities for capacity expansion or operational enhancements, air traffic congestion mitigation may require scheduling interventions to control over-capacity scheduling at busy airports. Previous research has shown that large delay reductions could be achieved through comparatively small changes in the schedule of flights. While existing approaches have focused on minimizing the overall impact across the airlines, this paper designs, optimizes, and assesses a novel approach for airport scheduling interventions that incorporates inter-airline equity objectives. It relies on a multi-level modeling architecture based on on-time performance (i.e., mitigating airport congestion), efficiency (i.e., meeting airline scheduling preferences), and equity (i.e., balancing scheduling adjustments fairly among the airlines) objectives, subject to scheduling and network connectivity constraints. Theoretical results show that, under some scheduling conditions, equity and efficiency can be jointly maximized. Computational results suggest that, under a wide range of current and hypothetical scheduling settings, ignoring inter-airline equity can lead to highly inequitable outcomes, but that our modeling approach achieves inter-airline equity at no, or small, losses in efficiency.

3:15 A Data-Splitting Algorithm for Flight Sequencing and Scheduling on Two Runways

Rakesh Prakash, Jitamitra Desai*
Nanyang Technological University

In this research, we study the static aircraft sequencing and scheduling problem (ASP) on a dual runway system under both segregated and mixed-mode operating scenarios. This problem is formulated as a 0-1 mixed-integer program (MIP), taking into account several realistic constraints, including safety separation standards, wide time-windows, and constrained position shifting (CPS) constraints, with the objective of maximizing the total throughput of both runways. Recognizing the computational difficulties involved in solving large-scale (realistic) instances by a direct application of the 0-1 MIP formulation, the main contribution of this work features an extension of the novel data-splitting algorithm (DS-ASP), recently introduced in Desai and Prakash (2016), which has demonstrated remarkable computational speedups in obtaining optimal solutions for the ASP on a single runway. Under the DS-ASP framework, the given set of flights is divided into several disjoint subset-pairs, and the optimization formulation is individually applied on these smaller data sets, while taking into account the direct and induced effects of the leading and following sets of flights onto one another. Computational results show that the overall time taken to solve large-scale instances can be reduced significantly, while achieving the optimal solution in nearly all of the instances.

3:45 **Lower Cost Departures for Airlines: Optimal Gate and Metering Area Allocation Policies Under Departure Metering Concept**

[1]Heng Chen, [2]Senay Solak*
[1]University of Nebraska-Lincoln, [2]University of Massachusetts Amherst

Departure metering is an airport surface management procedure that limits the number of aircraft on the runway by holding aircraft at gates or at a predesigned metering area. We develop a stochastic dynamic programming framework to identify the optimal gate, metering area and departure queue allocation policies to minimize expected overall fuel burn costs. In addition, we introduce easy-to-implement practical departure metering policies and evaluate their performances. We also identify the optimal metering area capacity and quantify the value of the presence of a departure metering area at airports.

Multimodal Transportation Services

TD1: Bus and Taxi Transport

Thursday 4:30 – 6:00 PM Schreiber 807

Session Chair: Mark Hickman

4:30 **Choice between Metro and Taxi under Travel Time Variability**

Gege Jiang, Hong Lo*
Hong Kong University of Science and Technology

The modal choice problem has been investigated for many years, typically under deterministic travel conditions; not many studies have considered the effect of travel time variability endogenously. The context of this study is about the commute choices of travelers from home to work between two travel modes: metro services with a fairly constant or predictable travel time versus taxi that faces congestion and travel time variability.

5:00 **Multi-Cycle Optimal Taxi Routing with E-Hailing**

[1]Xinlian Yu, [1]Song Gao, [2]Hyoshin Park, [3]Xianbiao Hu*
[1]University of Massachusetts Amherst, [2]North Carolina A&T State University, [3]Metropia

An optimal taxi routing problem is investigated for a single taxi that accounts for multiple cycles of pick-up and drop-off into the future. Practical implementations are proposed to solve the multi-cycle optimal taxi routing problem in a reasonable time. The solution will be compared with observed searching behaviors from GPS trajectories in a mega city to demonstrate the advantage of the multi-cycle approach.

5:30 **Machine Learning Methods to Predict Bus Travel Speeds and Analysis of the Impact of Different Predictive Variables**

*Jan Berczely, Ricardo Giesen**
Pontificia Universidad Catolica de Chile

Among the key indicator of level of service for transit services is travel time reliability, which is very hard to achieve, since traffic congestion is normally increasing. Thus, being able to accurately forecast bus travel speeds and update these estimates with real-time data could be really useful. There are many models to predict bus travel speeds, and there is no consensus regarding the best method. In this paper, we compare three machine learning (ML) models: Multiple Linear Regression (MLR), Support Vector Machines (SVM) and Neural Networks (ANNs). Three bus services were used to study the performance of different predictive models. In the services analyzed, the model that showed the best results, in terms of the RMSE is Neural Networks, followed by Multiple Linear Regression and then by the Support Vector Machines. In all cases, ML models exceeded benchmark models, with a performance that varies between 10% and 25% decrease in the error. These results highlight the value of using real-time information and ML methods to improve the accuracy of predictions. Regarding the explanatory variables involved, we concluded that only speed variables have a relevant impact, whilst the addition of the other analyzed variables only had a minor effect, less than 2% reduction of errors. It seems that speed variables have implicit, in their value, the effect of the other variables.

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Multimodal Transportation Services

FA1: Transit Fare and Revenue

Friday 8:30 – 10:30 AM Schreiber 807

Session Chair: Hai Yang

8:30 **Ticket Portfolio Planning for Urban and Regional Public Transport Networks**

*Jörn Schönberger**
Technische Universität Dresden

A commuter ticket, independently whether it is a single trip ticket or a period ticket, is the "product" sold by a public transport company. As observed for the manufacturing of material products, the definition of such a product requires several preparatory steps. Although there is no "common theory" documented in the literature, one can group the decision tasks associated with the specification of offered commuter tickets into three categories ("layers") which have to be executed consecutively. These layers are (i) the fare zone planning (ii) the ticket portfolio compilation and (iii) the ticket pricing. After having structured the area of product specification in urban and regional public transport it turns out that there are several contributions to the planning of fare zone systems (the first layer). Furthermore, several contributions to the determination of fares for offered tickets are available (the third layer). However, more or less nothing is contributed to the portfolio planning for tickets in commuter systems. Therefore, there is a research gap associated with the second layer. In order to start closing the detected research gap we propose mathematical optimization models that support the planning of optimal ticket portfolios to be offered by commuter agencies. In these models, the decisions to be made correspond to the selection of possible tickets for inclusion into a ticket portfolio. Within these models we test different planning goals with respect to their appropriateness and the need to establish necessary constraints. Furthermore, we investigate the influence of restrictions imposed in order to make the resulting ticket portfolio as easily understandable for customers.

9:00 **Optimal Discount Policies for Transit Agencies: The Case of Pass Programs and Loyalty Programs**

[1]Mehdi Nourinejad,[2] Amir Gandomi, [3]Joseph Y. J. Chow, [1]Matthew J. Rooda*
[1]University of Toronto, [2]Ryerson University, [3]New York University

The proliferation of smart cards in public transportation has paved the way for successful implementation of two prominent discount policies: pass programs and loyalty programs. While pass programs have been around as early as the 1970s, loyalty programs are only now gaining unprecedented popularity in public transportation. In a loyalty program, riders get a discount on their fare if they complete a given number of trips within a time period (e.g., a month). Our review of several mass transit agencies shows that transit agencies are not unanimous in their choice of discount policy. While some offer only the pass program, others offer the loyalty program, and a few offer both. In this paper, we derive the optimal pass and loyalty program, and we investigate if one is superior to the other in terms of social welfare and profit. We find that each program has a unique impact on the transit agency. The pass program is superior to the loyalty program for public transit agencies because (i) it offers a higher social welfare, and (ii) social welfare and profit are maximized at the same pass price, thus indicating that agencies do not sacrifice profit for social welfare. The loyalty program, on the other hand, is beneficial for private agencies such as Uber and Lyft because it generates a higher profit than the pass program when riders have more non-mandatory than mandatory trips. We develop a simulation model to account for several sources of uncertainty including user heterogeneity. The simulation model validates our earlier findings from the analytical expressions and provides several insights as well.

9:30 **Pricing for a Last Mile Transportation System**

[1]Hai Wang, [2]Yiwei Chen*
[1]Singapore Management University, [2]Singapore University of Technology and Design

The Last Mile Problem refers to the provision of travel service from the nearest public transportation node to a home or other destination. Last Mile Transportation Systems (LMTS), which have recently emerged, provide on-demand shared transportation. We consider an LMTS with multiple passenger types—adults, senior citizens, children, and students. The LMTS designer determines the price for each passenger type, last mile service vehicle capacity, and service fleet size (number of vehicles) for each last mile region to maximize the social welfare generated by the LMTS. The level of last mile service (in terms of passenger waiting time) is approximated by using a batch arrival, batch service, multi-server queueing model. The LMTS designer's optimal decisions and optimal social welfare are obtained by solving a constrained nonlinear optimization problem. The pricing model is implemented in numerical experiments by using real data from Singapore. We show that by requiring the LMTS designer to offer discounted prices to some types of passengers, the optimal annual social welfare gained is large. We also analyze a counterpart LMTS in which the LMTS designer sets an identical price for all passenger types. We find that in the absence of price discounts for special groups of passengers, social welfare undergoes almost no change, but the consumer surplus of passengers in special groups suffers significantly.

10:00 **A Fare-Reward Scheme for Commuters in Transit Bottleneck**

Yili Tang, Hai Yang*
The Hong Kong University of Science and Technology

This paper analyzes a new fare-reward scheme for managing commuter's departure time choice in a rail transit bottleneck, which aims to incentivize commuters' shift of departure time to the shoulder periods of the peak hour to relieve queueing congestion at the transit stations. A framework of the rail transit bottleneck is provided and the user equilibrium with a uniform-fare and social optimum with service run-dependent fares are determined. A fare-reward scheme (FRS) is then introduced that rewards a commuter one free trip during the shoulder periods after a certain number of paid trips during the peak hour. For a given number of peak-hour commuters and ex-ante uniform fare, the FRS determines the free fare intervals and the reward ratio (the number of paid trips required for one free trip, which is equivalent to the ratio of the number of rewarded commuters to the total number of commuters on each day during the peak hour). The new fare under the FRS is determined so that the transit operator's revenue keeps unchanged before and after introducing the FRS. Our study indicates that, depending on the original fare, FRS implements an optimal reward ratio up to 50% and yields a reduction of system total time cost and average equilibrium trip cost at least 25% and 20%.

Multimodal Transportation Services

FB1: Transit Networks

Friday 1:00 – 2:30 PM Schreiber 807

Session Chair: Juan Carlos Munoz

1:00 **An Internal Bounding Method for Line and Shuttle Bus Planning**

*Evelien van der Hurk**
Management Science, DTU Management Engineering

This work presents a new method for solving line planning, and specifically shuttle planning problems. The proposed Internal Bounding Method is an exact approach which, starting from a high level representation of the network, iteratively solves an extended representation of the network until the optimal solution is found. In the worst case, the algorithm continues until the network is represented in full detail. However the expectation is that for most practical cases convergence will be much faster, thus increasing computational speed and tractability of realistically sized problems. The method will be applied to a case study for shuttle bus planning for the Danish railway, but the method is expected to also be applicable for general line planning problems.

1:30 **Urban Transit Network Design and Timetabling Problem for Multi-Depot Round-Trip Routes**

*James Chu**
National Taiwan University

Urban traffic arises from population movement and interaction between different regions of a city. Understanding movement patterns of various users in a traffic network is a key to designing and operating effective transport systems. Movements of individual travelers can be captured by various sensors such as GPS devices, Bluetooth detectors or public transit smart card systems. Recently, movement trajectory data have been collected at massive scales in many cities, providing the opportunity to gain insight into network-wide traffic dynamics and understand how the urban network is used and what changes can be made to improve the overall performance of traffic in the system. An important aspect of movement pattern mining is to discover regularity or periodicity in human mobility patterns. A particular research question addressed in this paper is whether there exist specific weekly patterns in network-wide movement data and whether we could learn and build knowledge of typical movement patterns for different days of the week from historical data. Such knowledge can be applied in predicting future movements and detecting anomalies, enabling better decision support systems for network planning, fleet management, and real-time traffic and incident management. To answer this question, this paper proposes a dynamic graph method that converts trajectory data for a given day into a time series of graph snapshots and represents aggregated flows between different regions using a compact graph structure. Using tensor decomposition on dynamic graphs, we obtain spatio-temporal patterns underlying population movement for any given day. By learning patterns from data that span over six months, we characterize day-of-week movement patterns and demonstrate that the resulting patterns can be distinguished by a classifier.

2:00 The Limited-Stop Bus Service Design Problem with Stochastic Passenger Assignment

*Guillermo Soto, Homero Larrain, Juan Carlos Munoz**
Pontificia Universidad Católica de Chile

Limited-stop services, which serve a subset of the stops along a corridor, can simultaneously improve the level of service and the cost efficiency of transit corridors when properly designed. In this article, we introduce a methodology for designing limited-stop services, accounting for stochastic user behavior. Our methodology was tested on nine scenarios, based on real-world corridors such as the Caracas Av. in Bogotá. Results show that our methodology yields solutions for the deterministic case significantly faster than an existing benchmark algorithm. We also show that assuming deterministic passenger behavior, as most existing algorithms do, can lead to overcrowding if passengers really behave in a stochastic manner.

Multimodal Transportation Services

FC1: Containers Logistics

Friday 2:45 – 4:15 PM Schreiber 807

Session Chair: Patrick Jaillet

2:45 Balancing the Trade-Off in Route Choice and Demurrage Costs in Inland Container Logistics

Bernard Zweers, Rob van der Mei, Sandjai Bhulai*
CWI

A problem encountered in practice in inland container transportation is to decide on the mode and day of transportation of a container. To this end, we present an integer linear programming. The method presented leads to a significant reduction in cost compared to a method based on current practice.

3:15 An Integrated Model for Inbound Train Split and Container Loading in an Intermodal Railway Terminal

Bruno Bruck, Jean-François Cordeau, Emma Frejinger*
Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT)

In the past decade or so intermodal transportation of containers has become a key component of the entire international trade system, as it allows safe and efficient intercontinental door-to-door transportation of freight by combining land and sea transportation services. Intermodal railway terminals are special components of such systems that allow container traffic to be consolidated from different sources and to be transported by trains over long distances. On a daily basis, terminal operators must be able to take several decisions such as: deciding on how inbound trains are split into sequences of railcars and where these railcars are parked on the terminal for loading/off-loading operations, or even for temporary storage; how containers are loaded into the slots of the available railcars; and the composition of the outbound trains. All these decisions are heavily interconnected and subjected to a range of constraints that considerably affect the complexity of the problem. Instead of approaching these decisions separately, we propose an integrated model and an iterative algorithm that are able to optimize these aspects altogether. Preliminary tests on generated benchmark instances based on realistic data show promising results and more research is being done to further improve the algorithms.

3:45 The Stochastic Container Relocation Problem

[1]Virgile Galle, [1]Setareh Borjian Boroujeni, [2]Vahideh Manshadi, [3]Cynthia Barnhart, [4]Patrick Jaillet*
[1]MIT-Operations Research Center, [2]Yale School of Management, [3]MIT-Operations Research Center and Civil & Environmental Engineering, [4]MIT-Operations Research Center and Electrical Engineering & Computer Science

The Container Relocation Problem (CRP) is concerned with finding a sequence of moves of containers that minimizes the number of relocations needed to retrieve all containers, while respecting a given order of retrieval. However, the assumption of knowing the full retrieval order of containers is particularly unrealistic in real operations. We study the stochastic CRP (SCRP), which relaxes this assumption. A new multi-stage stochastic model, called the batch model, is introduced, motivated, and compared with an existing model (the online model). The two main contributions are an optimal algorithm called Pruning-Best-First-Search (PBFS) and a randomized approximate algorithm called PBFS-Approximate with a bounded average error. Both algorithms, applicable in the batch and online models, are based on a new family of lower bounds for which we show some theoretical properties. Moreover, we introduce two new heuristics outperforming the best existing heuristics. Algorithms, bounds and heuristics are tested in an extensive computational section. Finally, based on strong computational evidence, we conjecture the optimality of the "Leveling" heuristic in a special "no information" case, where at any retrieval stage, any of the remaining containers is equally likely to be retrieved next.

Multimodal Transportation Services

FD1: Maritime Shipping and Fleets

Friday 4:30 – 6:00 PM Schreiber 807

Session Chair: Stein W. Wallace

4:30 **Speed Optimization Across Different Emission Control Zones**

[1]Line Reinhardt, [2]Christos Kontovas*
[1]Aalborg University, [2]Department of Maritime and Mechanical Engineering-Liverpool John Moores University

Air pollution from ships such as CO2, NOx and SOx is currently at the center stage of discussion by the world shipping community and measures with the aim at reducing the environmental externalities of maritime transport will get increased attention. Models are presented which by adjusting speeds minimize the bunker costs and the cost of externalities of the CO2 and SOx emissions of a liner shipping service. The emissions of CO2 and SOx under the cost minimized operations satisfying emission regulations are evaluated to see if the regulations may have undesired side effects. The preliminary results show that although emission control areas may help to reduce the emission inside them, companies have to increase the speeds, and thus emissions, outside the control areas.

5:00 **A Column-Row-Generation Approach to Liner Shipping Network Design**

*Jun Xia, Zhou Xu**
Hong Kong Polytechnic University

In this work, we study a problem that aims at creating a set of regular services (or rotations) for a designated fleet of oceangoing ships to transport containerized cargos among seaports. Containers can be transshipped from one ship to another at an intermediate port in order to improve a carrier's transportation efficiency, as well as to extend its market coverage. The major objective of LSND is to maximize the carrier's total profit, this being the total revenue from satisfied demands minus the total operating cost, which includes the transshipment costs. However, most of the existing works on LSND assume zero transshipment costs, and as a result, their models and solution methods cannot be applied to the problem with transshipment costs, which is significantly more challenging to solve. To tackle this challenge, we develop a new mixed-integer linear programming model, where transshipment costs are well captured. Since, in this new model, both decision variables (columns) and constraints (rows) are also proportional to the number of feasible rotations, there can be a large number of columns and rows. We therefore develop a novel optimization method, referred to as a Column-Row-Generation (CRG) approach, to solve the LP relaxation of the new model, which provides an upper bound on the optimal solution for LSND. We embed this CRG approach into a branch-and-price framework to compute optimal or near-optimal solutions for LSND. Numerical experiments have been conducted, and the results have demonstrated the effectiveness and efficiency of our new model and solution methods.

5:30 Planning for Charters: A Stochastic Maritime Fleet Composition and Deployment Problem

[1]Xin Wang, [1]Kjetil Fagerholt, [2]Stein W. Wallace*
[1]Norwegian University of Science and Technology, [2]Norwegian School of Economics

This study introduces a chartering problem that arises in the shipping industry. The chartering decisions determine the time-charter contracts to enter into, in particular, how many ships of each type to charter in, and for how long they are to be hired. We show that this problem can be modeled as a tactical fleet composition problem, with integrated fleet deployment and speed optimization, which also takes into account market uncertainties. We propose a two-stage stochastic programming model, and present a computational study based on the case of Odfjell, a leading chemical shipping company based in Bergen, Norway. We show how the charter plans produced can change depending on different modeling choices. We also show why and how different charter plans affect the company's overall performance, in order to provide guidance in helping the company make its chartering decisions.

Multimodal Transportation Services

SA1: Rail Transport

Saturday 9:00 – 11:00 AM Schreiber 807

Session Chair: Dario Pacciarelli

9:00 **The Load Planning Problem for Double-Stack Trains at Intermodal Terminals**

Serena Mantovani, Gianluca Morganti, Nitish Umang, Teodor Gabriel Crainic, Emma Frejinger, Eric Larsen*
CIRRELT and Université de Montréal

This paper presents a general methodology that addresses the load planning problem for intermodal trains. We propose a model that can deal with single- or double-stack railcars as well as arbitrary containers-to-cars matching rules. Moreover, we model center-of-gravity constraints, stacking rules and technical loading restrictions associated with specific container types and/or goods. We propose an integer linear programming (ILP) formulation, where the objective is to choose the optimal subset of containers and the optimal way of loading them on outbound railcars such that the resulting loading cost is minimized. An extensive numerical study shows that ignoring center-of-gravity constraints and containers-to-cars matching rules may lead to an overestimation of the train capacity and to load plans that are not feasible in practice. We also show that we solve realistic size instances to optimality in reasonable computational time using a commercial ILP solver.

9:30 **Tactical Block and Car Planning for Intermodal Trains**

[1]Gianluca Morganti, [2]Teodor Gabriel Crainic, [1]Emma Frejinger, [3]Nicoletta Ricciardi*
[1]CIRRELT and Université de Montréal, [2]ESG, UQAM and CIRRELT, [3]Sapienza University of Rome

We address the blocking problem of intermodal trains in the North American market. The problem is complex dues to the many different railcar and container types, which require to model the container-to-railcar assignment and the utilization of multiple types of resources. This makes the problem different and more complicated than the train blocking problems considered in the literature. We propose a MILP formulation based on a continuous-time, multi-layer network. It considers several types of containers and railcars, integrates the container-to-railcar assignment, accounts for the utilization of the railcar fleets, and selects the blocks to minimize the total cost of the system over the planning horizon, which encompasses the cost of selecting, operating and transferring blocks as well as the penalty for late arrival of demand and the cost of utilizing resources. We take advantage of the problem characteristics, e.g., the known train schedule, to build a solution method that considerably reduces the number of feasible blocks and may thus use a commercial solver. We present and discuss the model, solution method and numerical results for realistic instances.

10:00 **Optimization of Handouts for Rolling Stock Rotations Visualization**

Boris Grimm, Ralf Borndoerfer, Thomas Schlechte, Markus Reuther*
Zuse Institute Berlin

A railway operator creates (rolling stock) rotations in order to have a precise master plan for the operation of a timetable by railway vehicles. A rotation is considered as a cycle that multiply traverses a set of operational days while covering trips of the timetable. As it is well known, the proper creation of rolling stock rotations by, e.g., optimization algorithms is challenging and still a topical research subject. Nevertheless, we study a completely different but strongly related question in this paper, i.e.: How to visualize a rotation? For this purpose, we introduce a basic handout concept, which directly leads to the visualization, i.e., handout of a rotation. In our industrial application at DB Fernverkehr AG, the handout is exactly as important as the rotation itself. Moreover, it turns out that also other European railway

operators use exactly the same methodology (but not terminology). Since a rotation can have many handouts of different quality, we show how to compute optimal ones through an integer program (IP) by standard software. In addition, a construction as well as an improvement heuristic are presented. Our computational results show that the heuristics are a very reliable standalone approach to quickly find near-optimal and even optimal handouts. The efficiency of the heuristics is shown via a computational comparison to the IP approach.

10:30 Real-Time Near-Optimal Train Scheduling and Routing in Complex Railway Networks

[1]Marcella Samà, [1]Andrea D'Ariano, [1]Dario Pacciarelli, [2]Francesco Corman*
[1]Roma Tre University, [2]Delft University of Technology

This paper focuses on the development of new algorithms for the real-time train scheduling and routing problem in a complex and busy railway network. Since this is a strongly NP-hard problem and practical size instances are complex, simple heuristics are typically adopted in practice to compute feasible but low quality schedules in a short computation time. In order to compute good quality solutions, we consider a mixed-integer linear programming formulation of the problem and solve it with a commercial solver. However, the resolution of this formulation by a commercial solver often takes a too long computation time. Therefore, a new methodology based on the relaxation of some train routing constraints in the formulation is proposed for the quick computation of a good quality lower bound. The lower bound solution is then transformed via a constructive metaheuristic into a feasible schedule, representing a good quality upper bound to the problem. Computational experiments are performed on several disturbed traffic situations for two practical case studies from the Dutch and British railways. The results show that the new lower and upper bounds are computed in a few seconds and are often of similar quality to the ones computed by the commercial solver in hours of computation.

Multimodal Transportation Services

SB1: Multiobjective and Multidimensional Logistics

Saturday 11:15 – 12:45 PM Schreiber 807

Session Chair: Olivier Péton

11:15 **Multi-Criteria Decision Making when Planning & Designing Sustainable Multi-Modal Transportation in a Corridor**

Marie Louis, Eric Gonzales*
University of Massachusetts Amherst

Public transit is often promoted as a way to reduce congestion and transportation-related emissions in cities. To design transit service for a multimodal corridor in which people may also driver cars, there are three objectives to consider: minimize generalized cost to users (including direct costs to users and travel time), minimize agency cost for infrastructure and operations, and minimize emissions of pollutants such as greenhouse gas emissions. Analytical models of these three types of costs have been developed to compare private cars, buses operating in mixed traffic, buses in dedicated lanes, light rail in mixed traffic (i.e., tram), light rail in dedicated right-of-way, and grade-separated metro. A Pareto analysis is conducted to reveal the trade-off between cost and emissions when optimizing the stop spacing and service headway for the deployment of each mode to serve demand characterized by density of trip-generation, average trip length, and average value of time. The models have a general structure that allows for comparison across many transit modes, and the results allow for systematic evaluation of the sustainability of multimodal corridors under different demand conditions. This study plugs a research gap by directly targeting the effect that greenhouse gas emissions have on the design of transit service. Although emission costs do not have a big effect on the optimal design of transit service for a specific mode, it can have important consequences for mode selection and planning incentives for travelers to use transit. These models also provide estimates of total emissions in the corridor.

11:45 **Bin-Packing Problems with Load Balancing and Stability Constraints**

Alessio Trivella, David Pisinger*
Technical University of Denmark

In this work we extend the multi-dimensional Bin-Packing Problem (BPP) by integrating realistic constraints arising from transportation applications, such as load balancing of items, cargo stability and weight constraints. The problem has only been considered in the literature in simplified versions, e.g. in the context of loading a single container, and integrating such constraints in the BPP poses additional challenges due to the supplementary objective of minimizing the number of bins. We develop two methods to address the combined packing and balancing problem: a Mixed-Integer Program able to solve to optimality small instances, and a heuristic algorithm based on a multi-level local search to deal with large instances involving up to 200 items. The methods show that an effective load balancing can be achieved within a short running time. Moreover, we discuss how to further incorporate different types of stability constraints (e.g gapless packings, full or partial base support) and weight constraints (e.g. weight limit and distribution), illustrating the modelling implications on the two methods.

12:15 **Multi-Directional Local Search for A Bi-Objective Vehicle Routing Problem with Lexicographic Minimax Load Balancing**

[1]Fabien Lehuédé, [1]Olivier Péton, [2]Fabien Tricoire*
[1]IMTA-LS2N Nantes, [2]University of Vienna

In the last fifteen years, the need to integrate load balancing in the design of vehicle routes has been presented in various contributions. Several objective functions have been proposed to include equity considerations in the workload allocation between drivers. Nevertheless, to our knowledge, the existing objective functions are still not entirely accurate and consistent. On the other hand, the lexicographic minimax approach is now used to model equity in other scientific domains. In this presentation, we solve the vehicle routing problem with load balancing, using the lexicographic minimax approach to compare load balance between solutions. We extend some classical VRP heuristics to integrate this approach. These heuristics are embedded in a multi-directional local search algorithm to determine an approximation of the set of solutions that offer a compromise between cost and load balancing.

Traffic & Mobility
TA2: Traffic Equilibrium
Thursday 8:30 – 10:30 AM Schreiber 806
Session Chair: Carlo Prato

8:30 **Analyzing Departure Time Choice in a Bottleneck with Stochastic Service Time**

Gege Jiang, Hong Lo*
Hong Kong University of Science and Technology

The bottleneck model has interested researchers for many years since its original development by Vickery (1969). This model describes commuters' trip scheduling profile during the morning peak, and models congestion as queuing behind a single bottleneck, providing simplicity yet the ability to reasonably capture the performance of a bottleneck. Previous stochastic bottleneck studies usually calculated the departure profile to equalize the mean cost of each traveler. Few studies have established the connection between travel cost variability and departure time choice. Moreover, they cannot distinguish between people who choose to depart in the more congested period and those who depart in the period with less congestion. In other words, the motivation or incentive for a traveler to choose a specific departure time has not been considered extensively. To fill this gap, this study makes three contributions. First of all, this study introduces travel cost variation as an additional cost. The equilibrium condition is not only based on mean travel cost but also cost variation. Travelers trade between their cost mean and variance. When user equilibrium is achieved, we can infer their attitudes towards cost variability based on their chosen departure times. Secondly, the randomness of service time and travelers' sensitivity towards variability are investigated. We can conclude that the departure profile of travelers is influenced by both factors. Thirdly, we apply a one-step coarse toll during a specific time interval to investigate the effects of tolling on queuing time as well as cost variation. Such an understanding will shed light on developing traffic management strategies for stochastic bottlenecks.

9:00 **An Algorithm for Transit Assignment Problem with Flow-Dependent Dwell Times**

Yufeng Zhang, Alireza Khani*
University of Minnesota

In a typical transit network, bus dwell times are not constant but are affected by flows of passengers boarding and alighting, which also has impacts on how passengers choose their routes towards user equilibrium (UE). This forms an asymmetric transit assignment with link interactions. In this paper, the problem is formulated as Variational Inequalities (VI) and a solution algorithm is developed based on a linear constrained generalized Benders decomposition method. Some decent properties unique to transit network are explored, which simplifies the assignment problem by converting the original VI problem to a linear optimization problem. To test the validity and efficiency of the proposed algorithm, a hypothetical transit network example is included, which also gives some insights of the method. Computational results show that the proposed algorithm can successfully find UE solutions with high accuracy and a good convergence speed.

9:30 **Statistical Inference of Probabilistic Origin-destination Demand Using Day-To-Day Traffic Data**

Wei Ma, Zhen Qian*
Carnegie Mellon University

Recent studies on transportation network uncertainty and reliability call for modeling the stochasticity of O-D demand and network flow. Few studies focus on estimating the mean and variance of O-D demand from day-to-day traffic data. The day-to-day variation of flow measurements stems not only from O-D demand but also from travelers' random route choices that vary from day to day. This paper develops a novel theoretical framework for estimating the mean and variance/covariance of O-D demand considering the variation induced by travelers' day-to-day random route choices. The estimation problem is decomposed into two sub-problems. The entire solution algorithm converges quickly and is more user friendly for practical use. The observability of the probabilistic O-D demands is analyzed, and the non-uniqueness property of the probabilistic O-D under the disaggregated framework is also examined. Our proposed framework can guarantee the estimated O-D mean is statistically no worse than that estimated from deterministic O-D estimation methods. The methodology is tested on both a small network and a large scale network to provide solution insights and demonstrate computational efficiency.

10:00 **Threshold-Based Stochastic User Equilibrium Models**

*[1]David Watling, [2]Thomas Rasmussen, [2]Otto Nielsen, [3]Carlo Prato**
[1]University of Leeds, [2]Technical University of Denmark, [3]The University of Queensland

Stochastic User Equilibrium (SUE) models allow us to represent the perceptual and preferential differences that we know exist when drivers compare alternative routes through a transportation network. However, conventional formulations of this problem are based on the assumption that all available routes have a positive probability of being chosen, however circuitous. In this paper, two alternative approaches are presented for integrating an exogenously defined cost threshold on the set of paths that are used at equilibrium, within a Random Utility Model (RUM) framework. That is to say, the models both predict which routes are used and unused (the choice sets are equilibrated), while still ensuring that the distribution of flows on used routes accords to a RUM. The first approach is based on a kind of multinomial logit with truncated error distribution, and is shown to possess attractive properties of existence and uniqueness of solutions. A second approach is based on modifying our own recently-proposed Restricted SUE model with an additional threshold constraint on the travel costs. While in general this second model loses the theoretical guarantees of existence and uniqueness, it provides a formulation that gives an apparent benefit of calculation efficiency for large-scale applications (as we demonstrate). Both models are flexible in the specification of the thresholds, allowing them to move from zero (approaching a Deterministic User Equilibrium model) to very large ones (approaching an SUE model). Solutions algorithms are presented for both approaches, and numerical results reported from applying them to the Sioux Falls network.

Traffic & Mobility
TB2: Pricing and Competition
Thursday 1:00 – 2:30 PM Schreiber 806
Session Chair: Song Gao

1:00 **Competitive Rebalancing in One-Way Car-Sharing**

Szymon Albinski, Stefan Minner*
Technical University of Munich

Rebalancing is a key factor when it comes to make one-way car-sharing services more profitable and customer friendly. A common approach is to determine the optimal relocation plan under the assumption of a monopoly. We formulate a rebalancing problem that takes competition into account. In doing so, we discuss the cases of stock-out based as well as assortment based competition and compare them to the case of no competition. For our model, we formulate a newsvendor game subject to rebalancing constraints and show that there exists a unique Nash equilibrium. Furthermore, we develop an efficient algorithm for solving the rebalancing problem under competition. The analysis of our computational results underlines the importance of considering competition when computing the optimal rebalancing plan. Based on these results, we deduce managerial insights on the profit maximizing reaction of car-sharing providers to the presence of competitors.

1:30 **The Costs and Benefits of Ridesharing: Sequential Individual Rationality and Sequential Fairness**

Ragavendran Gopalakrishnan, Koyel Mukherjee, Theja Tulabandhula*
Xerox Research Centre India

We introduce a cost sharing framework for ridesharing that explicitly takes into account the "inconvenience costs" of passengers due to detours. We introduce the notion of "sequential" individual rationality (SIR) that requires that the "disutility" of existing passengers is nonincreasing as additional passengers are picked up, and show that these constraints induce a natural limit on the incremental detours permissible as the ride progresses. We provide an exact characterization of all routes for which there exists some cost sharing scheme that is SIR on that route, and under these constraints, for realistic scenarios, we also show a $\theta(\sqrt{n})$ upper bound and a $\theta(\log n)$ lower bound on the total detour experienced by the passengers as a fraction of the direct distance to their destination. Next, we observe that under any budget-balanced cost sharing scheme that is SIR on a route, the total amount by which the passengers' disutilities decrease (which can be viewed as the total incremental benefit due to ridesharing) is a constant. This observation inspires a "dual" notion of viewing cost sharing schemes as benefit sharing schemes, under which we introduce a natural definition of "sequential" fairness - the total incremental benefit due to the addition of a new passenger is (partly) shared among the existing passengers in proportion to the incremental inconvenience costs they suffer. We then provide an exact characterization of sequentially fair cost sharing schemes, which brings out several useful structural properties, including a strong requirement that passengers must compensate each other for the detour inconveniences that they cause. Finally, we conclude with an extended discussion of new algorithmic problems related to and motivated by SIR, and important future work.

2:00 Cooperative Scheme - An Alternative Approach to Equitable and Pareto-Improving System Optimum

[1]Sayeeda Ayaz, [1]Song Gao, [2]Hyoshin Park*
[1]University of Massachusetts Amherst, [2]North Carolina A&T State University

Almost all traffic equilibrium studies make the assumption that travelers are non-cooperative, for a good reason. With the large number of travelers, the time it takes for cooperation to emerge is too long for the assumption to be practically valid. Penalty to defectors (people who do not cooperate) has been suggested in the literature to promote cooperation. This study operationalizes the idea by performing theoretical analyses in a general network with heterogeneous VOT among travelers. In the preliminary analysis, it is shown that a under mild conditions, cooperative scheme always exists for a single-origin-destination (OD) two-route network to ensure equitable and Pareto-improving SO regardless of VOT distribution, even when the Pareto-improving is in terms of travel time only, exclusive of potential rewards received by cooperators. When the VOT is bounded from above, a cooperative scheme without financial transactions always exists, in which case the defector penalty is high enough so that all travelers cooperate. This last feature is especially appealing in that the public tends to view congestion pricing as tax and this perception almost dooms any such pricing schemes even if they are Pareto-improving. Intended contributions of planned work include: 1) extension of the analysis to a general network where a traveler might travel between multiple OD's, and 2) extension of the analysis to probabilistic route choice so that stochastic UE (SUE) emerges without interventions. Practical issues for implementation will also be discussed.

Traffic & Mobility
TC2: Pricing Shared Mobility
Thursday 2:45 – 4:15 PM Schreiber 806
Session Chair: Tunay Tunca

2:45 **Split the Bill by Sharing the Ride-Sharing Services: A Study on Optimal Ride-Sharing Pricing**

Jagan Jacob, Ricky Roet-Green*
University of Rochester

Ride sharing service providers (RSPs) like Uber and Lyft act as two-sided platforms where peer-to-peer interaction between potential drivers and passengers take place for one-time car sharing services. Customers can either ride alone (solo) and pay full fare or split the bill by sharing the ride with a fellow passenger (pool). Though pooling is less expensive, there is disutility associated with finding a potential match, longer journey time and, sharing the space with a potential stranger which we define as the cost of sharing. Assuming customers differ with respect to their cost of sharing and delay sensitivity, and given the difference in expected service time and pricing, we analyze customers' decision in equilibrium whether to pool or ride solo. Next we solve the RSP's problem of pricing the ride(s) such that the revenue is maximized. Assuming two types of passengers, the RSP offers one of the three pricing schemes: (1) Only solo rides with high fare (2) Only solo rides with low fare (3) Both solo and shared rides with price-induced passenger self-selection. We examine the RSP's optimal policy as a function of the market parameters, and compare the results in two cases: finite and infinite number of cars. Upon characterizing the optimal pricing schemes, we find that when the number of cars available is finite, the region where both solo and pool rides are offered in equilibrium is limited, indicating a potential limitation of ride-sharing as a tool for tackling traffic congestion and environmental pollution.

3:15 **Inventory Rebalancing and Minimum Stop-Over Routes for One-Way Electric Vehicle Sharing Systems**

[1]Yinglei Li, [2]Sung Hoon Chung*
[1]State University of New York at Binghamton, [2]Binghamton University

Electric vehicles are generally considered as an environmentally friendly alternative to conventional vehicles that use fossil fuels. Car sharing systems have gained an increasing attention due to their positive aspects such as increasing mobility, reducing pollution, and mitigating traffic congestion. Electric vehicle sharing systems then have a great potential to further promote environmental sustainability. In this paper, we tackle the problem of rebalancing the inventory of one-way electric vehicle sharing systems by proposing a novel dynamic pricing approach. We propose a model that helps establish a self-balancing inventory system through dynamic pricing for which a system operator proposes to incoming users a better price if they choose an alternative combination of pick-up and drop-off stations that will improve the system inventory balance. The inventory matrix is updated dynamically every time a reservation is made and a vehicle return occurs, and the requirement that electric vehicles need to be recharged after a return to be available for the next user is taken into account. In addition, we design a stop-over station recommendation system for trips longer than the range of electric vehicles, which we call minimum stop-over path cover problem. Furthermore, we present computationally tractable algorithms to implement the proposed model, which is a requisite for implementing dynamic pricing and stop-over station recommendation system. We provide examples in which the proposed dynamic pricing approach and a staff-based rebalancing method are compared.

3:45 An Empirical Analysis of Price Formation, Utilization, and Value Generation in Ride Sharing Services

[1]Liu Ming, [2]Tunay Tunca, [1]Yi Xu, [2]Weiming Zhu*
[1]University of Maryland, [2]IESE Business School

Ride-sharing platforms, such as Uber and Lyft and their Chinese counterpart Didi, set prices dynamically to balance the demand and supply for their services. Fare setting rules and proprietary algorithms used by these services for managing their operations play an important role in value generation for their customers as well as their drivers, and important questions centers around their pricing and regulation. In this paper, we provide an empirical model and analysis of price formation and surplus generation of these services. We first develop a two-sided-market discrete choice model, capturing the formation of mutually dependent demand (consumer) and supply (driver) sides that jointly determine the pricing. Based on this model, we then use a comprehensive data set obtained from Didi on two distinct and competing markets they host on their platform to estimate consumer and driver price elasticities as well as other factors that affect market participation. Based on the estimation results and counterfactual analysis, we demonstrate that proposed regulation imposing price caps that match current taxi rates can decrease consumer surplus by 61.31% while causing a relatively moderate 5.31% decrease in Kuaiche driver surplus. Further, we estimate that restricting driver capacity to equal local taxi levels would have more severe consequences, resulting in 50.06% and 56.35% reductions in consumer and Kuaiche driver surpluses respectively.

Traffic & Mobility

TD2: Optimization in Shared mobility

Thursday 4:30 – 6:00 PM Schreiber 806

Session Chair: Carolina Osorio

4:30 **Optimizing the Profitability and Quality of Service in Carshare Systems Under Demand Uncertainty**

[1]Mengshi Lu, [2]Siqian Shen, [2]Zhihao Chen*
[1]Krannert School of Management-Purdue University, [2]Industrial and Operations Engineering-University of Michigan

We consider allocating a carshare fleet to service zones under uncertain one-way and round-trip demand. We use a two-stage stochastic integer program, where in the first stage, we allocate shared vehicle fleet and purchase parking lots or permits; in the second stage, we generate finite samples to represent uncertain location-time-based carshare demand and construct a spatial-temporal network for each sample to model vehicle movement. We minimize the expected total costs minus profit, and develop branch-and-cut algorithms with mixed-integer rounding (MIR)-enhanced Benders cuts. We also implement the two-stage model in a rolling-horizon fashion for real-time vehicle relocation. We test instances generated based on Zipcar data in Boston to demonstrate the efficacy of our approaches and draw insights on carshare management.

5:00 **Ridesharing in a Mobility-on-Demand System**

[1]Samitha Samaranayake, [2]Harshith Guntha, [3]Kevin Spieser, [4]Emilio Frazzoli*
[1]Cornell University, [2]IIT Chennai, [3]Uber, [4]Massachusetts Institute of Technology

This abstract considers the problem of ridepooling in a Mobility-on-Demand (MoD) system, in which a shared fleet of vehicles, each capable of carrying two passengers at a time, is used to transport passengers. Inherent to the formulation are two important attributes: (i) the need to rebalance empty vehicles and (ii) the ability to identify lucrative ridesharing corridors by means of trip chaining. Note that although the later functionality is essential to capture ridesharing in its most general form, it is absent from the majority of existing works that, for a variety of reasons, limit the extent to which rides may be shared. We present a mixed-integer linear programming (MILP) formulation of the problem and show how a heuristic (feasible) solution to the problem can be obtained in polynomial-time by independently solving the ride-matching and rebalancing problems. This approximate solution can be used as an initial guess when solving the coupled problem via a MILP solver. Numerical results based on the NYC Yellow Taxi dataset show a performance improvement over existing results.

5:30 A Discrete Simulation-Based Optimization Algorithm for Two-Way Car-Sharing Network Design

[1]Tianli Zhou, [2]Carolina Osorio, [3]Evan Fields*
[1]MIT-CEE, [2]MIT-CEE/MIT-ORC, [3]MIT-ORC

Two-way car-sharing service requires customers to return the car to the same place where they picked it up. It is important for a car-sharing company to decide where to rent the parking spaces and how many spaces to rent in each area of the city for a certain period of time. From the company's perspective, we are looking to design a system to increase its profit; from the public perspective, we would like to design a system such that residents can have close access (from their home or workplace) to either a car-sharing station, a bike-sharing station, or a public transit stop. The goal of this work is to design a car-sharing network to complement the other existing mobility services (bike-sharing and transit). We propose a simulation-based optimization (SO) metamodel algorithm to assign a two-way car-sharing fleet. We use a simulator that samples from real data from a car-sharing company. We evaluate the performance of our proposed algorithm with a Boston case study. We compare its performance to analytical optimization algorithms, and to traditional discrete simulation-based optimization methods.

Traffic & Mobility
FA2: Traffic Management
Friday 8:30 – 10:30 AM Schreiber 806
Session Chair: Lili Du

8:30 **Morning Commute Problem with Queue-Length-Dependent Bottleneck Capacity**

[1]Jin-Yong Chen, [2]Rui Jiang, [2]Xin-Gang Li, [1]Mao-Bin Hu, [2]Bin Jia*
[1]University of Science and Technology of China, [2]Beijing Jiaotong University

The morning commute problem for a single bottleneck is extended to model the situation that bottleneck capacity increases from s1 to s2 as the queue length exceeds a threshold D1, and decreases back to s1 as the queue length reduces and becomes smaller than another threshold D2 < D1. This model is motivated by the facts such as activating more tollgates to alleviate traffic congestion in rush hours. Diverse situations have been identified. In particular, (i) multiple user equilibrium states and (ii) oscillation of queue length can be observed.

9:00 **Modelling User Behavior at a Stochastic Bottleneck**

Daphne van Leeuwen, Peter van de Ven*
CWI

We study the effects of variability by extending the Vickrey bottleneck model. We determine the difference in costs if we would use the original deterministic bottleneck model and show the effects for uncertainty in capacity and demand. To capture the effects of variability in arrivals and departures over time, we model the arrivals and departures in the system by a stochastic process. Furthermore, we use the arrival and departure rates to approximate the equilibrium for the stochastic model.

9:30 **Recasting Intersection Automation as a Connected-and-Automated-Vehicle (CAV) Scheduling Problem within Heterogeneous Traffic Environment**

[1]Pengfei (Taylor) Li, [2]Xuesong Zhou*
[1]Mississippi State University, [2]Arizona State University

It is a common vision that connected and automated vehicles (CAVs) will increasingly appear on the road in near future and share roads with traditional vehicles and we will live in a heterogeneous traffic environment for a long time before a 100% CAV market penetration. While both CAVs and traditional vehicles contribute to traffic flow characteristics such as volumes and speeds, CAVs can additionally share their real-time locations and receive guidance from infrastructure. As a result, it is possible to predict when CAVs will arrive and request for green lights at intersections along their routes. A CAV request for green is in essence requesting green light resource on a particular approach at a particular time point or window. When many CAVs from multiple approaches at intersections place such requests, a central challenge is how to develop an intersection automation policy (IAP) to schedule resources (green lights) to serve CAV requests at the intersection's full potential as well as at the minimal cost (delays) of all vehicles. We formulate the IAP optimization as a mixed integer programming problem within a heterogeneous traffic environment. The co-existence of CAVs and traditional vehicles makes it necessary not only to serve CAV requests but also to maintain an acceptable traffic mobility for all vehicles. To address these challenges, we first distinguish the CAVs from traditional vehicles and consider them in a dual role: contributors to traffic dynamics and request senders for green lights. Then a vehicle-centered traffic representation is presented as an extension of the classic flow-based traffic dynamics to explicitly model individual vehicles and their interactions. Then we view a traffic state within the heterogeneous environment is comprised of traffic signal status, traffic dynamics and CAV request service status. Furthermore, a new three-dimension Phase-Time-tRaffic (PTR) hypernetwork model is developed to represent traffic states and their transitions.

The phase-time plane of the PTR hypernetwork represents feasible traffic signal operations whereas the traffic-time plane represents traffic dynamics in road networks. Based on the concept of PTR hypernetwork, an algorithm is first developed to reduce the search space for optimal CAV schedules without losing global optimum and the second algorithm is developed to search the exact optimal IAP considering both CAV requests and total vehicle delays using a new sequential Branch-and-Bound search approach. At last, multiple numerical experiments are conducted to examine the performance of the proposed. It is found that intersections have maximum capability of serving CAV requests beyond which new CAV request must be rejected.

10:00 Distributed Computation Based Constrained Model Predictive Control for a Mixed Flow Platoon

Siyuan Gong, Lili Du*
Illinois Institute of Technology

This study seeks to develop a platoon control aiming to ensure both system level traffic flow smoothness and stability as well as individual vehicles' mobility and efficiency. To achieve this goal, this study developed a distributed computation based model predictive control (MPC) for a vehicle platoon mixed with human-drive vehicles and CAVs on a straight highway, leveraging the connectivity among CAVs through wireless sensing and communication technologies. Our study integrated/contributed the following approaches. Well-accepted Newell car-following model was used to model the movement of human-drive vehicles. Accordingly, an online curve matching algorithm was integrated to conduct online learning for the aggregated response delay of the human-drive vehicles using real-time trajectory data. The constrained MPC models were further developed to control the movement of CAV platoons in one or P steps so that we can ensure both transient traffic smoothness and asymptotic stability of the platoon under the mixed flow environment. Considering vehicle platoon as a self-organized system without centralized computation facilities, this study developed a distributed algorithm to solve the MPC based upon the sophisticated analyses of the properties of the MPC, such as uniqueness of the optimizer, sequentially feasibility, and nonempty interior point of the solution space. The convergence of the distributed algorithm to the global optimal solution was proved by both the theoretical analysis and the experimental study. The stability analysis under the unconstrained closed-loop condition provided importance guidance to select the penalty weights used in the objective function of the optimizer in MPC. The numerical experiments based on the field data validated the effectiveness and efficiency of the platoon control scheme.

Traffic & Mobility

FB2: Network Design and Location Decisions

Friday 1:00 – 2:30 PM Schreiber 806

Session Chair: Yanfeng Ouyang

1:00 **Emission-controlled Pavement Management Scheduling**

Umit Tursun, Hasan Ozer*
University of Illinois

This paper describes an analytic approach that can be used to evaluate and propose rehabilitation schedules based on economic, performance, and environmental considerations for various types of pavements. A mixed-integer nonlinear program (MINLP) is formulated to model the life-cycle cost and environmental impacts where the decision set consists of the maintenance overlay type and the thickness of the overlay proposed on a temporal scale over a planning horizon. The problem requires interaction of the integer and continuous variables that leads to MINLP formulation. Considering practical implications of the problem, the continuous variables are bounded into a finite and discrete set, while the integrality constraints are relaxed. The objective and constraints of the problem can be alternated to suit the needs of the agency, which may be interested in minimizing environmental impacts and restricting the cost to the agency, or vice versa, over the pavement life-cycle. Our goal is to evaluate and propose maintenance schedules for various types of pavement based on economic, performance, and environmental considerations. A mixed-integer nonlinear problem is formulated to model the life-cycle cost to the agency and the greenhouse gas emission due to both user and maintenance activities of a single pavement segment. There are two opposing motivations within each section of the objective function. While an increase in the International Roughness Index (IRI) value causes a linear surge in user emission, scheduling an overlay to lower the IRI value also leads to further emission due to construction activity. The decision set consists of maintenance type and thickness of overlay over the lifetime of the pavement. The problem requires interaction of integer and continuous variables within nonlinear equations leading to MINLP formulation. This work is the preliminary step of creating an algorithm that allows agencies to determine the maintenance planning of individual links under budget and emission constraints while complying with performance criterion. We were able to set up an MINLP model of maintenance schedule, overlay type and overlay thickness over lifetime of various types of pavements. Although the MINLP model is not tractable, by using relaxation and outer approximation techniques, we were able to solve the problem with a commercial solver. The uncertainty accompanying traffic growth over the planning horizon was also remedied by randomly generating an extensive set of data paths. As a result of this work we showed that by changing the schedule and type of overlay agencies can lower overall greenhouse gas emission while still staying within economic and performance requirements. The next scope of this ongoing study is going to be creating a mathematical model for PMSs at network level that takes into account traffic interaction of links as well as user behavior.

1:30 **Scheduling Work Zones in Transportation Service Networks**

Dening Peng, Pitu Mirchandani*
Arizona State University

This paper introduces a mixed integer linear programming model on scheduling work zones in transportation service (i.e., trucking service) networks. The model schedules lane closures of links that need maintenance in a transportation network. When some lanes of a link are closed, the available capacity of that link is reduced. In the assumed scenarios, there are given origin-destination (OD) flow demands and routing through the network based on the available capacities on the links to achieve total minimum flow cost for all the OD pairs. The link flow cost function is piece-wise linear such that regular flow cost is incurred for all the units flowing through the link at free flow and extra congestion cost is incurred for the

units exceeding the link's nominal capacity. The goal is to schedule the work zones, that is, the corresponding lane closures, so that all maintenance work can be completed before a given completion date while the total flow cost over the project period is minimized. An innovative randomized fix-and-optimize (RFO) heuristic is developed to solve the problem efficiently. Results from various test cases show that RFO is able to obtain good solutions with much less time than solving the entire problem solely with CPELX.

2:00 Reliable Sensor Location for Object Positioning and Surveillance via Trilateration

Kun An, Siyang Xie, Yanfeng Ouyang
Affiliation?

Object positioning and surveillance has been playing an important role in various indoor location-aware applications. Signal attenuation or blockage often requires multiple local sensors to be used jointly to provide coverage and determine object locations via mobile devices. The deployment of sensors has a significant impact on the accuracy of positioning and effectiveness of surveillance. In this talk, we present a reliable sensor location model that aims at optimizing the location of sensors so as to maximize the accuracy of object positioning/surveillance under the risk of possible sensor disruptions. We formulate the problem as a mixed-integer linear program and develop solution approaches based on a customized Lagrangian relaxation algorithm with an embedded approximation subroutine. A series of hypothetical examples and a real-world Wi-Fi access point design problem for Chicago O'Hare Airport Terminal 5 are used to demonstrate the applicability of the model and solution algorithms. Managerial insights are also presented.

Traffic & Mobility
FC2: Traffic Flow Modeling
Friday 2:45 – 4:15 PM Schreiber 806
Session Chair: Hillel Bar-Gera

2:45 **The Role of Stochasticity in Traffic Flow Instabilities**

[1]Junfang Tian, [2]Rui Jiang, [3]Martin Treiber*
[1]Institute of Systems Engineering-College of Management and Economics-Tianjin University, [2]MOE Key Laboratory for Urban Transportation Complex Systems Theory and Technology-Beijing Jiaotong University, [3]Technische Universität Dresden-Institute for Transport & Economics

This paper investigates the role of stochasticity in traffic flow instabilities, which is a typical self-driven system far from equilibrium. We demonstrate that stochasticity is necessary to correctly describe the observed spatiotemporal dynamics of growing traffic oscillation in the car following process. A heuristic analysis qualitatively explains the concave growth of the oscillation amplitude along the vehicles of a platoon. Based on this analysis, we propose a simple car-following model containing indifference regions and acceleration noise described by Brownian motion which reproduces well the experimental and empirical observations.

3:15 **A Kalman Filter Approach for Dynamic Calibration of A Simplified Lower-Order Car Following Model**

Kerem Demirtas, Pitu Mirchandani, Xuesong Zhou*
Arizona State University

In this study, we are interested in dynamic calibration of car following parameters in order to explore both inter-driver and intra-driver heterogeneity. Specifically, we offer an augmented state space system for a lower order linear spacing car following model, and implement a modified Kalman filter algorithm in order to track the leader-follower pairs and simultaneously predict and estimate the parameters related with the behavior of the following drivers. The augmented state includes the positions of the leader and follower as well as the behavioral parameters of the follower. The proposed approach is tested on the trajectories from the Next Generation Simulation (NGSIM) project data and show satisfactory results. Interpretation of the results and promising future research directions are given.

3:45 **Representation Requirements for Perfect First-In-First-Out Verification in Continuous Flow Dynamic Models**

Hillel Bar-Gera, Malachy Carey*
Ben-Gurion University of the Negev, Ulster University

Dynamic models of traffic require answers for many issues. One of them is the way priorities of different traffic streams (commodities) are managed. This is particularly challenging when flows are treated as continuous. It is common to consider the First-In-First-Out (FIFO) rule as a baseline for setting priorities; but most practical continuous flow dynamic models do not satisfy FIFO perfectly. This paper examines the difficulties associated with full adherence to network-wide FIFO. We examine six different ways to represent dynamic flow solutions over a network, and for each representation we discuss whether it is sufficient for verifying FIFO, whether the verification process is finite, and whether proving FIFO can be directly implied. Throughout the evaluation eight alternative definitions of FIFO are considered, seven of them are shown to be essentially equivalent, while the last definition is not, and may therefore be considered as "weak" FIFO. The most promising representation appears to be the one denoted as "cohort bundles," while somewhat more abstract than the other representations, supporting this representation directly shows perfect FIFO satisfaction. Further evaluation of this representation remains a subject for future research. In a nutshell, the key conclusion of this analysis is that in order to satisfy perfect network-wide FIFO the number of discretized elements of flow should probably be allowed to grow quickly and

unboundedly with model duration, and it cannot be determined a-priori. These insights about the challenges of incorporating FIFO in continuous flow dynamic models, which may be relevant also for other behavior-based priority rules, can help modelers and practitioners set realistic expectations regarding the level of control over priority rules that can be achieved within finite-dimensional continuous flow dynamic models.

Traffic & Mobility
FD2: Ride Sharing and Parking
Friday 4:30 – 6:00 PM Schreiber 806
Session Chair: Yafeng Yin

4:30 **Optimal Two-Sided Pricing Strategies of Shared E-Parking Platform with Elastic Demand**

Chaoyi Shao, Hai Yang, Fangni Zhang*
Hong Kong University of Science and Technology

Shared parking is a prospective way to eliminate the heavy burden of parking demand in city centers in some metropolises. In working hours, the temporarily vacant private parking slots in residential areas can be efficiently utilized to satisfy the parking demand of drivers who are working nearby or come for some other activities. This paper analyzes the pricing strategy on both private parking slot owners (O-users) and public users (P-users) of shared E-parking platform based on two-sided market model. The allocation of P-users to private parking slots is a function of the amounts of O-users and P-users which has been illustrated in our working paper. We can find that when platform serves as a reseller, a monopoly E-parking platform can maximize its profit under the condition that the ratio between optimal buying and selling prices should be less than a critical value when the parking slots are fully utilized. Meanwhile, the first best solution will make the E-parking platform always be deficit. While when the platform serves as an agent, the contract curve is a linear segment with a constant slope. By comparing with the two roles the platform serves, we find that when that the platform serves as an agent is profitable, the efficiency of the platform will always be greater than the reseller case. Moreover, both selling and buying prices are also greater than reseller case.

5:00 **Integration of an Aggregated Dynamic Traffic Model with Advanced Optimization Techniques for Strategic Transit-Parking Planning**

Joana Cavadas, António Pais Antunes, Nikolas Geroliminis*
University of Coimbra, École Polytechnique Fédérale de Lausanne

Short abstract is not available.

5:30 **Optimal Parking Provision for Ride-Sourcing Services**

Zhengtian Xu, Yafeng Yin, Liteng Zha*
University of Michigan, University of Florida

Ride-sourcing services have become increasingly important in meeting travel needs in metropolitan areas. However, the cruising of ride-sourcing vehicles for customers generates additional traffic demand that may worsen traffic conditions. This paper investigates the allocation of a certain portion of road space to on-street parking for vacant ride-sourcing vehicles. A macroscopic conceptual framework is developed to capture the trade-off between capacity drop and the reduction of cruising. Considering a hypothetical matching mechanism adopted by the platform, we further materialize the framework and then apply it to study the interactions between the ride-sourcing system and parking provision under various market structures.

Traffic & Mobility

SA2: Simulation-Based Analysis and Optimization

Saturday 9:00 – 11:00 AM Schreiber 806

Session Chair: Ronghui Liu

9:00 **Traffic Management Strategies for Trucks in Urban Environments Based on a Fast Traffic Simulation Algorithm**

Michele Simoni, Christian Claudel*
University of Texas at Austin

Urban freight distribution has considerable negative impacts on traffic in cities. Slow vehicles (such as trucks) that do not behave like the rest of traffic are described as "moving bottlenecks" and they are a very important modeling approach studied in the Traffic Flow Theory literature. In the first part of this study, we propose a fast numerical scheme that can efficiently compute the solutions to an arbitrary number of fixed and moving bottlenecks, for a stretch of road modeled by the Lighthill-Whitham-Richards (LWR) model. In the second part of this study we present the application of this algorithm to two traffic optimization problems involving trucks in urban environment: a joint coordination of traffic lights and trucks departures strategy; and a real-time parking-loading curbside management strategy.

9:30 **Simulation Based Quantification of the Potential Impacts of Incidents on Connected Vehicle Applications**

Abdullah Kurkcu, Fan Zuo, Jingqin Gao, Kaan Ozbay*
New York University

In this study, five adjacent intersections in Brooklyn, NY are selected for the case study. Data sources used to calibrate the network include real-time travel time information from online mapping services, video recordings of the Jay Street and Fulton Street intersection on different days; the data collected by fixed road-side wireless sensors to track vehicles, and manually collected turning movement counts. Once the simulation network is calibrated and validated, CV messages can be generated using a software called the Trajectory Conversion Algorithm (TCA) built by NYU CitySMART Transportation group and Noblis. The fundamental contribution of this paper is to illustrate and quantify the effects of incidents on the performance of CV applications using a calibrated traffic simulation network. The impact of different type, severity and duration of incidents on critical CV applications and to understand the effect of incidents on the accuracy of on and off line performance measures with various market penetration levels will be investigated, and the results will be reported in the final version of this paper.

10:00 **An Efficient Sampling Method for Stochastic Simulation-based Transportation Optimization**

Timothy Tay, Carolina Osorio*
Massachusetts Institute of Technology

In simulation-based transportation optimization problems, simulator evaluations are often associated with high computational costs, especially high-dimensional problems. For simulation-based optimization (SO) with a limited computational budget, it becomes important to sample points efficiently. This paper proposes an efficient sampling method using the analytical approximation of the SO objective function as a sampling distribution, so as to increase the chances of sampling in regions with good objective function values. An inverse transform method is used to derive a sampling point from the approximation of the SO objective function. The proposed sampling method is validated by combining it with several SO algorithms and comparing the speed of convergence when using a uniform sampling method. The algorithms are tested under a tight computational budget (maximum of 150 simulation runs) using a microscopic traffic simulation model of Lausanne, Switzerland and a mesoscopic simulation model of Lyon, France. The

Lausanne model consists of 99 signal phases to be controlled, while the Lyon model contains 800 signal phases to be controlled.

10:30 A Within-Day Microscopic Dynamical Model of Route Choice and Responsive Traffic Signal Control

[1]Ronghui Liu, [2]Mike Smith*
[1]University of Leeds, [2]University of York

In this paper, we explore the dynamical system of route choice and responsive signal control in a simulated real-life environment, where (a) the route costs are observed directly from a microsimulation model, and (b) drivers' pre-trip route choices respond to current traffic conditions and signal green-times respond to current traffic flow. Queues are explicitly modelled, as with queue spill back. We show that the dynamical systems, if well designed, can significantly improve network capacity and reduce vehicle delays, as well as lead to desirable route choices.

Traffic & Mobility
SB2: Traffic Data Analysis
Saturday 11:15 – 12:45 PM Schreiber 806
Session Chair: Jiwon Kim

11:15 Opportunities for Floating Car Data in Integrated Traffic Management: The Case of Queue Estimation

[1]Serge Hoogendoorn, [2]Erik-Sander Smits, [2]Jaap Van Kooten*
[1]Delft University of Technology, [2]Arane

Integrated Network Management (INM) entails the coordinated deployment of traffic management measures (traffic control, ramp metering, VMS, in-car systems) for the sake of improving the effectiveness of local traffic control and management measures. Recent pilots in The Netherlands have shown the potential of INM, but also have highlighted that for successful deployment, several issues need to be resolved. One of these is that we need to be able to determine the length of queues on urban arterials with sufficient accuracy. This paper focusses on queue estimation, which turns out to be a difficult problem to tackle due to several reasons most of which related to measurement error. None of the methods proposed in literature and tested during an elaborate INM pilot in The Netherlands provided satisfactory and generic results. The main research objective is to use the added value of floating car data in increasing the accuracy and reliability of queue estimates, where we will only consider current of-the-shelf FCD products (in this case from the company TomTom) that will be described in more detail in the remainder of the abstract. This in contrast to many other studies that use vehicle trajectory data that often are collected for the sake of the study, but not being broadly available. To this end, we will develop three different queue estimation approaches to fuse the FCD with loop data. We will show that the data driven approach provides the most accurate estimates.

11:45 A Data-Driven and Integrated Evaluation of Area-Wide Impacts of Double Parking Using Macroscopic and Microscopic Models

[1]Jingqin Gao, [1]Kaan Ozbay, [2]Michael Marsico*
[1]New York University, [2]New York City Department of Transportation

Double parking that often negatively affects traffic operations and safety is not a new phenomenon on urban streets. This study proposes a novel data-driven integrated framework for estimating the actual frequency of double parking so that both microscopic and macroscopic models can be utilized to quantify area-wide impacts in the presence of double parking. The findings of the study can provide transportation agencies with useful insights on identifying locations that will experience the greatest benefits by removing problematic double parking. As a result, various parking enforcement and management strategies can be planned more effectively.

12:15 Urban Trajectory Analytics: Day-Of-Week Movement Pattern Mining Using Tensor Factorization

Jiwon Kim, Kianoosh Soltani Naveh*
The University of Queensland

Urban traffic arises from population movement and interaction between different regions of a city. Understanding movement patterns of various users in a traffic network is a key to designing and operating effective transport systems. Movements of individual travelers can be captured by various sensors such as GPS devices, Bluetooth detectors or public transit smart card systems. Recently, movement trajectory data have been collected at massive scales in many cities, providing the opportunity to gain insight into network-wide traffic dynamics and understand how the urban network is used and what changes can be made to improve the overall performance of traffic in the system. An important aspect of movement pattern mining is to discover regularity or periodicity in human mobility patterns. A particular research question addressed

in this paper is whether there exist specific weekly patterns in network-wide movement data and whether we could learn and build knowledge of typical movement patterns for different days of the week from historical data. Such knowledge can be applied in predicting future movements and detecting anomalies, enabling better decision support systems for network planning, fleet management, and real-time traffic and incident management. To answer this question, this paper proposes a dynamic graph method that converts trajectory data for a given day into a time series of graph snapshots and represents aggregated flows between different regions using a compact graph structure. Using tensor decomposition on dynamic graphs, we obtain spatio-temporal patterns underlying population movement for any given day. By learning patterns from data that span over six months, we characterize day-of-week movement patterns and demonstrate that the resulting patterns can be distinguished by a classifier.

Vehicle Routing Models & Applications

TA3: EV Charging Logistics

Thursday 8:30 – 10:30 AM Schreiber 901

Session Chair: Halit Uster

8:30 **Locating Refueling Points on Lines and Comb-Trees**

*Pitu Mirchandani, Yazhu Song**
Arizona State University

Since the associated refueling infrastructure of alternative fuel vehicles is sparse and is gradually being built, the distance between refueling points becomes a crucial attribute in attracting drivers to use such vehicles. Optimally locating refueling points (RPs) will both increase demand and help in developing a refueling infrastructure. This paper introduces a new set of location problems related to locating refueling points on lines and tree networks. It first deals with the simplest case of locating refueling points on a line, where origins can be anywhere on the line and destinations can be anywhere on the line. First, problems of feasibility are studied. Given there are feasible locations, then the location problem becomes "where should RPs be located to minimize a given fuel-related objective". For example the objective of minimizing the maximum distance between RPs minimizes the anxiety for the drivers. Scenarios include single one-way Origin-Destination (O-D) pair, multiple one way O-D pairs, round trips, etc. Extensions to tree networks are discussed.

9:00 **Modeling Electric Vehicle Charging Demand**

*[1]Guus Berkelmans, [1]Wouter Berkelmans, [2]Nanda Piersma, [1]Rob van der Mei, [1]Elenna Dugundji**
[1]CWI, [2]HvA

In the past 5 years, electric car use has grown rapidly, almost doubling each year. To provide adequate charging infrastructure it is necessary to model the demand. In this paper we model the distribution of charging demand in the city of Amsterdam using a cross-nested logit model and sociodemographic statistics of neighborhoods.

9:30 **Electric Vehicle Routing with Uncertain Charging Station Availability & Dynamic Decision Making**

[1]Nicholas Kullman, [2]Justin Goodson, [1]Jorge Mendoza*
[1]Polytech Tours, [2]Saint Louis University

We consider the problem of routing a single electric vehicle (EV) to a set of customers and allow the EV to perform mid-route recharging at charging stations which have uncertain availability. The uncertainty in charging station availability complicates the planning of mid-route recharging, which is necessitated by EVs' restricted driving ranges; longer recharging times for EVs compound this difficulty. We present a stochastic dynamic programming approach to route planning that hedges against these uncertainties, and we present our preliminary results. We claim to advance the current electric vehicle routing literature through more realistic modeling of uncertainty and queuing behavior at charging stations.

10:00 **Network Design for In-Motion Wireless Charging of Electric Vehicles in Urban Traffic Networks**

Mamdouh Mubarak, Halit Uster, Khaled Abdelghany, Mohammad Khodayar*
Southern Methodist University

We address a network design problem arising in the deployment of wireless charging stations (WCSs) in an urban transportation network. Despite the availability of EV conventional charging facilities, relatively short driving range of EVs (due to low energy density of the batteries) and the long battery charging times (collectively leading to a phenomenon known as "range anxiety"') remain to be the major factors that hamper EV adoption. Thus, in our approach, we study cost-effective WCS deployment network design that facilitates EV adoption by alleviating these two major anti-adoption factors. In doing so, we aim not to disturb drivers' usual driving habits by adopting the current user-equilibrium (UE) travel pattern as an input and determine the optimal design that best serves this pattern. We consider the problem from the perspective of a city as the decision maker whose aim, for societal benefits, is to satisfy the charging demands of all EVs in its urban traffic network at the minimum investment cost. For this purpose, we suggest a new mathematical model to strategically deploy WCSs in the network in such a way that no EV runs out of energy before reaching its destination. To solve the proposed model, we devise a combined combinatorial-classical Benders Decomposition approach and enhance its efficiency further via surrogate constraints and an upper bound heuristic. We present computational results illustrating the algorithmic efficiency of our approach as well as an analysis of the effects of varying system and technology related parameters on the resulting network design based on a case study with urban network data from Chicago, IL.

Vehicle Routing Models & Applications

TB3: VRP Exact Methods

Thursday 1:00 – 2:30 PM Schreiber 901

Session Chair: Michel Gendreau

1:00 **An Integer Programming Approach for the Time-Dependent Traveling Salesman Problem with Time Windows**

*[1]Agustin Montero, [2]Isabel Mendez-Diaz, [3]Juan Jose Miranda Bront**
[1]FCEyN-Universidad de Buenos Aires, [2]Universidad de Buenos Aires, [3]Universidad Torcuato Di Tella/Consejo Nacional de Investigaciones Científicas y Técnicas

Congestion in large cities and populated areas is one of the major challenges in urban logistics, and should be addressed at different planning and operational levels. The Time-Dependent Travelling Salesman Problem (TDTSP) is a generalization of the well-known Traveling Salesman Problem (TSP) where the travel times are not assumed to be constant along the day. The motivation to consider the time dependency factor is that it enables to have better approximations to many problems arising from practice. In this paper, we consider the Time-Dependent Traveling Salesman Problem with Time Windows (TDTSP-TW), where the time dependence is captured by considering variable average travel speeds. We propose an Integer Linear Programming model for the problem and develop an exact algorithm, which is compared on benchmark instances with another approach from the related literature. The results show that the approach is able to solve instances with up to 40 customers.

1:30 **A Mixed-Integer Linear Program for the Traveling Salesman Problem with Structured Time Windows**

*[1]Philipp Hungerlaender, [2]Christian Truden**
[1]Laboratory for Information & Decision Systems-MIT, [2]Alpen-Adria Universität Klagenfurt, Austria

In this extended abstract we introduce the Traveling Salesman Problem with structured Time Windows (TSPsTW) that is motivated by an online shopping application of an international supermarket chain. We suggest an efficient and easy to implement mixed-integer linear program (MILP) of the TSPsTW and in a computational study compare it to related MILPs from the literature. Finally we analyze the relation of TSPsTW, TSPTW and TSP with the help of dependency graphs and give an outlook on further planned extensions of the applicability of our MILP.

2:00 **A Branch-and-Price Algorithms for a Multi-Attribute Technician Routing and Scheduling Problem**

[1]Michel Gendreau, [2]Ines Mathlouthi, [2]Jean-Yves Potvin*
[1]CIRRELT and MAGI-École Polytechnique de Montréal, [2]CIRRELT and DIRO-Université de Montréal

We present an exact algorithm based on column generation for the multi-attribute technician routing and scheduling problem. The TRSP is formulated as a set-packing problem. The pricing problem used for column (route) generation is solved as an Elementary Shortest-Path Problem with Resource constraints (ESPPRC). A Decremental State-Space Relaxation procedure is used to speed up its solution. A key feature of the overall solution approach is the use of a specialized branching strategy based on the assignment of tasks to technicians. Computational results show that the proposed branch-and-price algorithm performs well in term of solution quality and computational efficiency.

Vehicle Routing Models & Applications

TC3: VRP Extensions

Thursday 2:45 – 4:15 PM Schreiber 901

Session Chair: Daniele Vigo

2:45 **Multi-Modal Variations of the Vehicle Routing Problem**

[1]Marc-Antoine Coindreau, [1]Olivier Gallay, [2]Nicolas Zufferey*
[1]University of Lausanne, [2]University of Geneva

In this work, we extend the Vehicle Routing Problem formulation by proposing multi-modal variations of this well-established problem. For these new formulations, we empirically show that a streamline metaheuristic is able to highlight the potential benefit offered by the introduction of multi-modality.

3:15 **Multi-Commodity Two-Echelon Vehicle Routing Problem with Time Windows**

*Tom Van Woensel**
Eindhoven University of Technology

Short abstract is not available.

3:45 **The Vehicle Routing Problem with Private Fleet and Common Carrier: Extension and Exact Algorithm**

*[1]Said Dabia, [1]David Lai, [2]Daniele Vigo**
[1]Dept. of Information, Logistics and Innovation-VU Amsterdam, [2]D.E.I. - Universita' di Bologna

The Vehicle Routing Problem with Private Fleet and Common Carrier (VRPPC) is a generalization of the classical Vehicle Routing Problem where the owner of a private fleet can either visit a customer with one of his vehicles or assign the customer to a common carrier. The latter case occurs if the demand exceeds the total capacity of the private fleet or if it is more economically convenient to do so. The owner's objective is to minimize the variable and fixed costs for operating his fleet plus the total costs charged by the common carrier. This family of problems has many practical applications, particularly in the design of last mile distribution services, and has received some attention in the literature, where some heuristics were proposed. We present an exact approach based on a branch-and-cut-and-price algorithm for the VRPPC and for a more general and practical case where the cost charged by the external common carrier is based on cost structures inspired from practice.

Vehicle Routing Models & Applications

TD3: Dynamic Routing

Thursday 4:30 – 6:00 PM <Room>

Session Chair: Barrett Thomas

4:30 **Route-Based Markov Decision Processes for Dynamic Vehicle Routing Problems**

[1]Justin Goodson, [2]Marlin Ulmer, [2]Dirk Mattfeld, [3]Barrett Thomas*
[1]Saint Louis University, [2]Technische Universität Braunschweig, [3]Department of Management Sciences-University of Iowa

We propose a new modeling framework for dynamic routing problems (DRPs). DRPs are problems in which a set of geographically dispersed customers is visited by one or more travelers or vehicles, information changes stochastically over the problem horizon, and there exist opportunities to make decisions in response to new information. Acknowledging the disconnect between model and method in DRP research, our framework extends the conventional Markov decision process (MDP) model for dynamic and stochastic optimization problems to more closely align with route-based solution methodologies predominate in the DRP literature. We construct route-based MDPs by redefining the conventional MDP action space to operate on sets of planned routes. The modification leads to a generalization of the conventional MDP state (and post-decision state) to include route plans and to a definition of the current-period reward or cost to be the marginal change in value associated with a route plan update. In addition to joining the model with both application and method, route-based MDPs are positioned to facilitate more scientific rigor in DRP studies. We anticipate route-based MDPs will provide researchers with a common language, allow for better inquiry, and improve classification and description of solution methods. Under an easily satisfiable condition, we show route-based MDPs are equivalent to the conventional MDP model, thus providing a formal means to model the evolution of routes in a sequential decision-making environment. Via an example from the literature, we illustrate the value of connecting model and solution methodology.

5:00 **Scalable Anticipatory Policies for the Dynamic and Stochastic Pickup and Delivery Problem**

Gianpaolo Ghiani, Emanuele Manni, Alessandro Romano*
Department of Engineering - University of Salento

Real-time vehicle routing problems arise in a number of applications spanning from couriers to emergency services. In this article, we present new anticipatory dispatching policies for the dynamic and stochastic pickup and delivery problem, in which a fleet of vehicles must service a set of dynamically occurring customers' requests that are partitioned in several classes (according to their priority). Our policies are parameterized and the optimal parameter settings are determined by solving an off-line training problem on a sample of the instance population. The quality of our policies is assessed by comparing them with two policies already proposed in the literature, namely a reactive and an anticipatory procedure. Computational results on randomly-generated instances indicate that our procedures can often match the quality of an anticipatory algorithm with a computational effort comparable to that of a reactive approach. Moreover, the results show that the policies are scalable, i.e., they are able to easily handle instances of growing size.

5:30 **Enough Waiting for the Cable Guy - Estimating Arrival Times for Service Vehicle Routing**

[1]Barrett Thomas, [2]Marlin Ulmer*
[1]Department of Management Sciences-University of Iowa, [2]Business Information Systems-Technische Universitat Braunschweig

Everyone hates waiting for the cable guy. In fact, people dislike "waiting for the cable guy" so much that it has spawned its own meme with over two million Google search results. More generally, customers dislike the wide time windows (TWs), the earliest and latest times at which a service will begin, that service providers and home-attended delivery companies provide customers. While customers are willing to tolerate some amount of wait, these wide TWs are frustrating for customers who often must take at least a part of a day off work to stay at home and wait for the technician. Ideally, companies would offer narrower TWs, but these TWs must often be communicated at the time that the customer makes the service request, before all of the requests that will be served on that day are known. In this work, we seek to improve the customer experience by improving the width of the TWs that are offered without sacrificing reliability. The key to the problem is to estimate a state-dependent arrival time of a technician at the time of the service request when we do not know all of the requests that the technician will be asked to serve on that day. This work makes several important contributions to the literature. First, we introduce a new model and method valid for a number of applications related to completion time estimation in both dynamic routing and scheduling. Second, we introduce a temporal-aggregation scheme for the state space. This aggregation allows us to develop high-quality state-dependent estimates of the arrival times for a given request and thus provide high quality state-dependent TWs. Given the challenges associated with estimating the median of the arrival-time distributions in the case of a large state space, we instead estimate mean arrival times and show that our estimates of the mean lead to superior TWs. We present an offline approach for developing these estimates, giving us the ability to communicate TWs in real time. An extensive computational study demonstrates that the proposed method significantly outperforms the benchmarks.

Vehicle Routing Models & Applications

FA3: Dynamic Pick Up and Delivery

Friday 8:30 – 10:30 AM Schreiber 901

Session Chair: Martin Savelsbergh

8:30 Dynamic Pickup and Delivery Problems with Transfers

[1]Afonso Sampaio, [2]Martin Savelsbergh, [3]Lucas Veelenturf, [4]Tom Van Woensel*
[1]Eindhoven University of Technology, [2]Georgia Institute of Technology, [3]Eindhoven University of Technology, [4]Technische Universiteit Eindhoven

In this research we focus on dynamic pickup and delivery systems (in which each transportation request has an origin and a destination and associated time windows). We include transfer opportunities to facilitate constructing and maintaining more cost-effective and robust transportation plans. Transfer points are locations in the network where requests can be transferred between vehicles and temporarily stored. Hence, more than one vehicle (type) can be used to serve a request, e.g., a request may be picked up at its origin by one vehicle, then dropped off at a transfer point where another vehicle (with other characteristics) will pick it up and drop it of at its destination. The introduction of transfer opportunities allows serving more requests with a given set of vehicles and/or serving a given set of requests with fewer vehicles. As transfers require time synchronization, developing decision technology that effectively exploits transfer opportunities is challenging, more so in a dynamic setting where future requests need to be anticipated and the time to make decisions is limited.

9:00 How Many Vehicles Do We Need? Pickup and Delivery Problem with Synchronized Tasks and Transfers

[1]Monirehalsadat Mahmoudi, [2]Junhua Chen, [1]Xuesong Zhou*
[1]Arizona State University, [2]Beijing Jiaotong University

Short abstract is not available.

9:30 Order Acceptance Mechanisms for Same-Day Delivery

[1]Mathias Klapp, [2]Alan Erera, [2]Alejandro Toriello*
[1]Pontificia Universdad Catolica de Chile, [2]Georgia Institute of Technology

We study same-day delivery systems by formulating the Dynamic Dispatch Waves Problem with Immediate Acceptance (DDWP-IA) that models integrated request management and order distribution decision-making where delivery requests arise dynamically throughout the day. When a delivery request arises, a decision is made immediately to accept (offer service) or reject (with a penalty). All accepted delivery requests are included in dynamically-updated dispatch plans that serve each request by the end of the operating day. This research considers the special case of dispatching a single vehicle, on potentially multiple trips from a single distribution center to deliver requests to customer locations. The objective is to make decisions that minimize total penalties for rejected delivery requests and total vehicle travel costs for deliveries. We develop a framework for dynamic decision policies for such systems, where a system state is maintained that includes a feasible dispatch plan (with potentially multiple planned trips) serving all accepted delivery requests along with a set of potential future delivery requests that have not yet realized. This dispatch plan is used to guide order acceptance decisions, and it is updated dynamically when new information is available. We develop and test methods for determining an initial optimal a priori dispatch plan, and for updating the plan via a roll-out procedure that includes heuristic approaches designed to speed up the update step. Our methods are compared against two common-sense myopic benchmarks and a perfect information lower bound in a computational study. We show via experiments that the cost-per-request of the best benchmark is 9.7% higher than our proposed best dynamic policy, which has a gap of 21% over the perfect information bound. We also estimate that a cost increase of 4.4%

results when imposing immediate order acceptance on same-day delivery systems, and we study cost sensitivity to different assumptions on request processing times within the facility.

10:00 Optimization Algorithms for Meal Delivery Operations

Damian Reyes, Alan Erera, Martin Savelsbergh*
Georgia Institute of Technology

On-demand meal delivery platforms are becoming increasingly popular. Their success depends critically on the solution to dynamic pick-up and delivery problems with high degrees urgency and dynamism in order arrival patterns. Industry adoption of an independent-contractor model to perform deliveries increases the flexibility of the system, but adds a new source of uncertainty that must be controlled during the operations. In this paper we introduce optimization algorithms for the driver assignment (vehicle routing) and capacity management (shift scheduling) problems in meal delivery. Preliminary experiments using real-world data suggest that our algorithmic ideas can be valuable in practical implementations.

Vehicle Routing Models & Applications

FB3: Stochastic Routing

Friday 1:00 – 2:30 PM Schreiber 901

Session Chair: Stefan Minner

1:00 **Vehicle Routing with Space- and Time-Dependent Stochastic Travel Times**

[1]Stein W. Wallace, [2]Zhaoxia Guo, [3]Michal Kaut*
[1]Norwegian School of Economic, [2]Sichuan University, [3]Norwegian University of Science and Technology

We study how to model and handle stochastic travel times in two-stage stochastic vehicle routing problems. Contrary to existing literature, we allow these travel times to be dependent in time and space, that is, the travel time on one link in one period will be correlated to travel times on the same link in nearby time periods, as well as travel times on neighboring links in the same, and nearby, time period. Hence we are handling a very high dimensional dependent random vector (the number of time periods times the number of road links). We shall discuss how such vehicle routing problems should be modeled in time and space, how the random vector can be represented, and how scenarios (discretization) can meaningfully be generated to be used in a stochastic program. We assume the setting is to solve the stochastic vehicle routing problem by a heuristic, and focus on the objective function evaluation for any given solution. Numerical procedures are given and tested.

1:30 **A Two-Phase Safe Vehicle Routing and Scheduling Problem: Formulations and Solution Algorithms**

[1]Aschkan Omidvar, [2]Eren Ozguven, [2]Arda Vanli, [3]Reza Tavakkoli-Moghaddam*
[1]Department of Civil and Coastal Engineering-University of Florida, [2]Florida State University, [3]University of Tehran

We propose a two phase time dependent vehicle routing and scheduling optimization model that identifies the safest routes, through (1) avoiding recurring congestions, and (2) selecting routes that have a lower probability of crash occurrences and non-recurring congestion caused by those crashes. In the first phase, we formulate a mixed-integer programming which takes the dynamic speed variations into account on a graph of roadway networks, according to the time of day and identifies the routing of a fleet and sequence of nodes on the safest feasible paths. Second phase considers each route as an independent transit path (fixed route with fixed node sequences), and tries to avoid congestion by rescheduling the departure times of each vehicle from each node and by adjusting the optimal speed on each arc. Unlike the most researches in this area, which assume the speed on arcs a fixed value or a time dependent step function, in our research the speed (and travel time) variation with respect to the hour of the day is calculated via queuing models (i.e., M/G/1) to capture the stochasticity of travel times more accurately. Models are applied on a small real-world case in Miami City for different objective functions. Results suggest that in some cases, both the traveled distance and travel time increases in return for a safer route, however, the advantages of safer route outweigh this slight increase.

2:00 **Optimal A-Priori Tour and Restocking Policies for the Vehicle Routing Problem with Stochastic Demands**

*[1]Alexandre Florio, [1]Richard F. Hartl, [2]Stefan Minner**
[1]University of Vienna, [2]Technische Universität München

We present an exact mixed-integer programming approach to the stochastic demand vehicle routing problem with a-priory routing and dynamic restocking. The approach combines a mixed-integer programming formulation for the vehicle routing problem with a linear programming model for solving the stochastic restocking problem. Numerical results highlight the benefits of the unified approach over sequential planning of routing and restocking and over using the common detour-to-depot restocking policy.

Vehicle Routing Models & Applications

FC3: Statistical Data Analysis for Routing and Location

Friday 2:45 – 4:15 PM Schreiber 901

Session Chair: Bruce Golden

2:45 **A Novel Statistical Algorithm for Very Large-scale Vehicle Routing Problems with Time Windows**

Mayank Baranwal, Lavanya Marla, Srinivasa Salapaka, Carolyn Beck*
University of Illinois at Urbana-Champaign

The purpose of this paper is to introduce our novel modeling approach inspired from the field of information theory, to the VRPTW, and to demonstrate its significant advantage in achieving cost effective solutions with highly competitive solution times. Our approach, termed Deterministic Annealing (not to be confused with the deterministic variant of simulated annealing) is based on a statistical technique used commonly in data compression and model aggregation. Our approach is a unified approach that is applicable to vehicle routing problems of varying complexity. In this paper, we address the basic VRP, the CVRP, and the VRPTW using our approach. In our Routing-enhanced DA approach, scheduling and routing are not viewed as different problems, but are viewed as forms of clustering problems in a larger dimensional space. The free energy function is written as a Lagrangian, therefore constraints in the problem are not treated as `hard' constraints but violations are penalized. The approach is modeled as a continuous problem in terms of the free energy function, which is minimized using an annealing approach at successively reduced temperatures. We present computational results in which we show that our approach provides competitive results in high efficient solution times, rendering large-scale solutions of the VRPTW possible in a few minutes.

3:15 **Facility Location and Design Decisions from Public Data**

*[1]Kalyan Talluri, [2]Muge Tekin**
[1]Imperial College Business School, [2]Universitat Pompeu Fabra

There has been a tremendous increase in the size, scope and availability of public data, yet it is not clear how a firm might effectively use it. Analytical studies rarely seem to go beyond summary statistics and attractive visualizations. In this paper, we present an application based only on publicly available data in which a restaurant chain makes location and design decisions (e.g. cuisine type, price point, size, capability to serve groups) for a new restaurant so as to maximize its profit. We assume customers patronize restaurants based on review ratings and proximity to the restaurant. We combine Yelp review data sets with demographic and geographic data to build a model of demand and use it to formulate an optimization problem that recommends the top k alternatives.

3:45 **Addressing Uncertainty in Meter Reading for Utility Companies Using RFID Technology**

[1]Debdatta Sinha Roy, [1]Bruce Golden, [2]Edward Wasil*
[1]Robert H. Smith School of Business-University of Maryland, [2]Kogod School of Business-American University

Utility companies collect usage data from meters on a regular basis. The data are collected automatically by a vehicle that uses radio-frequency identification (RFID) technology. Each meter has a signal transmitter that is read by a receiver within a specified distance. Routing the vehicles can be modeled by a Close Enough Vehicle Routing Problem (CEVRP) on a street network. In practice, there is uncertainty while reading meters. The signal transmitted by an RFID tag is discontinuous and each meter differs with respect to the specified distance. These factors can lead to missed reads. We address this uncertainty using Bayesian statistics and data analytics in an attempt to design improved routes for the vehicles.

Vehicle Routing Models & Applications

FD3: Routing Applications

Friday 4:30 – 6:00 PM Schreiber 901

Session Chair: Burcu Keskin

4:30 Heuristics and Lower Bounds for Robust Heterogeneous Vehicle Routing Problems Under Demand Uncertainty

[1]Anirudh Subramanyam, [2]Panagiotis Repoussis, [1]Chrysanthos Gounaris*
[1]Carnegie Mellon University, [2]Stevens Institute of Technology

We study the Robust Heterogeneous Vehicle Routing Problem (HVRP) under Demand Uncertainty. The HVRP is a generalization of the CVRP where one must additionally decide the fleet composition from a number of available vehicle types and the objective function includes a fixed cost component in addition to a variable component. Our approach is based on Robust Optimization and guarantees that the resulting fleet composition and transportation plan remains feasible for all anticipated customer demand realizations, for which only the corresponding support is assumed to be known. Our contribution is two-fold. First, we extend an Adaptive Memory Programming (AMP) metaheuristic algorithm developed for the deterministic HVRP to generate high quality solutions for the robust HVRP. Second, we develop a new integer programming (IP) formulation and a branch-and-cut solution framework that produces lower bounds on the optimal robust HVRP solution, thus allowing us to quantify the quality of the AMP heuristic solutions. In both upper and lower bounding approaches, we use known results from the robust CVRP to expedite the associated solution algorithms for two specially structured but broad classes of customer demand supports. Computational experiments conducted on a number of medium and large scale literature benchmark instances indicate that the AMP metaheuristic produces high quality solutions within short computational times. Our methods are readily generalizable to a number of routing models that are subsumed by the generic HVRP model, including the Fleet Size and Mix VRP, the Site Dependent VRP and the Multi-Depot CVRP.

5:00 Optimal Snow Plow Routing with Route Continuity Constraint

Luning Zhang, Jing Dong*
Iowa State University

Winter road maintenance includes the removal of snow and ice on roadways and spreading materials for anti-icing, de-icing or increasing friction. This paper formulates and solves an arc routing problem (ARP) to optimize snow plow routing considering route continuity constraint. Metaheuristic algorithm is used to find optimal solutions. The proposed algorithm is tested on benchmark instances. The main difference of the proposed ARP from the previous studies is the route continuity constraint. In snow plowing and material spreading operations, there are three possible situations when a truck is traveling on a road segment—plowing and spreading, traversing the segment when it has already been served, and traversing the segment when it has not been plowed. In practice, the third case where the truck has to drive on the snow covered road should be avoided. Thus, the route continuity constraint is introduced—a connected route may consist of alternated service road segments and deadhead road segment, but it will not allow trucks traversing the segment when it has not been plowed.

5:30 **Patrol Routing with Hybrid Electric Vehicles**

Mesut Yavuz, Burcu Keskin, Huseyin Ergin*
University of Alabama

In the field of law enforcement, many police departments have already adopted electric or other alternative-fuel vehicles. In this work, we focus on highway patrol operations performed by state troopers, which differs from police operations in regards to (i) geographical area coverage, (ii) number of miles traveled by a vehicle, and (iii) the higher probability of involvement in high-speed, long-distance chases. Specifically, for a given mixed patrol fleet consisting of traditional (gasoline or diesel) and hybrid electric vehicles, we investigate optimal patrol routes to visit time-critical hot spots. Our overall goal is to maximize the visibility of the state troopers while minimizing the costs associated with utilization of troopers via a bi-criteria optimization problem. We analyze mathematical properties and special cases of the problem that lend themselves to quick analytic solutions or transformations to polynomially solvable problems. We present a computational study using appropriate algorithms on real-life data obtained from the Alabama Law Enforcement Agency. Our solutions support data-driven enforcement efforts in developing strategic countermeasures and operational plans.

Vehicle Routing Models & Applications

SA3: VRP in Services

Saturday 9:00 – 11:00 AM Schreiber 901

Session Chair: Lei Zhao

9:00 **Self-Sustained Car-And-Ride Sharing Design and Optimization for Improving the Mobility of Underserved Communities**

[1]Miao Yu, [2]Siqian Shen*
[1]University of Michigan, [2]Industrial and Operations Engineering-University of Michigan

We focus on the design and optimization of an innovative self-sustained car-and-ride sharing system. We study one of its special applications in improving the mobility of underserved communities. In this system, we assume two types of demands: Type 1 demand arises from customers who rent shared cars for private use and Type 2 demand arises from customers who cannot drive but require ridesharing services that could be fulfilled by Type 1 drivers. We propose a two-phase approach for optimizing resource pooling, supply-demand matching, and service scheduling, to maximize the fulfillment of car/ride-sharing demand while maintaining the cost self-sustainability of running the system. In the first phase, we allocate shared vehicle fleet and maximize the total car/ride sharing requests to satisfy, while ensuring that enough Type 1 drivers are accepted to serve Type 2 non-driver users. In the second phase, we design routing and scheduling for both types of users. We provide preliminary computational results of our two-phase approach by testing diverse instances.

9:30 **The Multi-Period Service Planning and Routing Problem**

Albert H. Schrotenboer, Evrim Ursavas, Iris F.A. Vis*
University of Groningen

We study a multi-period multi-commodity pickup and delivery problem with a heterogeneous fleet inspired by the short-term planning of maintenance activities for offshore operations. In this Multi-Period Service Planning and Routing Problem, each maintenance service requires spare parts as well as different types of servicemen. This leads to a mix of one-to-one and many-to-many pickup and delivery structures for the construction of the daily vehicle routes. Travel times and costs are period dependent to model a wide variety of application dependent characteristics in a unified way. We propose a branch-and-price-and-cut algorithm to solve this problem. It relies on efficiently solving a new variant of the Resource Constrained Elementary Shortest Path Problem. Preliminary experiments show that the algorithm easily finds solutions to instances with 25 maintenance services, demanding three types of servicemen, over a five-period planning horizon.

10:00 **Covering Tour Problem with an Application to School Bus Routing: Analysis of Single Vehicle Tours on a Grid**

Liwei Zeng, Sunil Chopra, Karen Smilowitz*
Northwestern University

In the face of critical budget cuts, many school districts are looking to reduce transportation expenditures. This paper presents initial work on the School Bus Routing Problem (SBRP), motivated by a partnership between Evanston/Skokie District 65 (D65), a pre-K - 8 public school district north of Chicago, and Northwestern University focused on bus transportation. The SBRP has been studied by the operations research community for fifty years, identifying creative routing and scheduling approaches for school districts. The SBRP itself is a composite of five decision subproblems: data preparation, bus stop selection, bus route generation, school bell time adjustment, and route scheduling. In our work, we take a new approach to the joint problem of bus stop selection and bus route generation, exploiting the underlying

grid-like structure of the road network present in the D65 service region to obtain robust, easy-to-implement solutions. We model the joint bus stop selection and bus route generation as a covering tour problem (CTP). In developing solution approaches for the CTP, we exploit characteristics of urban bus routing, most notably the underlying grid structure. We show in our analysis that the grid structure greatly reduces the complexity of the problem. We first establish results for stylized settings and then generalize to more complex settings.

10:30 Coordinated Delivery to Nanostores in Megacities

[1]Ruidian Song, [1]Lei Zhao, [2]Jan C. Fransoo, [2]Tom Van Woensel*
[1]Tsinghua University, [2]Technische Universiteit Eindhoven

In megacities in emerging economies, tens of thousands of traditional mom-and-pop grocery stores (nanostores) play an important role in city residents' daily lives and aggregately remain a major retail channel. However, these independently operated stores create a large amount of high frequency, small size, and uncoordinated replenishment orders, which results in inefficient delivery operations in practice. From a wholesaler's perspective, we study two (passive and proactive) coordination strategies in the delivery to the nanostores in a multi-period setting. We develop an integer programming based heuristics to solve the resulting problems and perform systematic numerical study to verify the performance of the solution algorithm and to derive managerial insights on the impact of delivery coordination in traditional retailing in emerging economies.

Vehicle Routing Models & Applications

SB3: VRP in Health and Food Delivery

Saturday 11:15 – 12:45 PM Schreiber 901

Session Chair: Ann Campbell

11:15 An ALNS For a Rich Home Health Care Routing and Scheduling Problem

Florian Grenouilleau, Antoine Legrain, Nadia Lahrichi, Louis-Martin Rousseau*
CIRRELT-Montréal, Canada

In Canada, as in many other developed countries, home health care services are expanding. Such care provides support or medical services to people in their own homes. In this work, we propose a specialized version of the ALNS for the home health care routing and scheduling problem using a mix of classical and new operators. The tests done on real-life instances show that the ALNS permits to reduce by more than 31% the total travel time and to increase by more than 6% the continuity of care.

11:45 Team Orienteering with Uncertain Rewards and Service Times with an Application to Phlebotomist Intra-Hospital Routing

[1]Huan Jin, [2]Barrett Thomas*
[1]Ningbo Supply Chain Innovation Institute Center, [2]University of Iowa

This study focuses on the intra-hospital routing of phlebotomists at the University of Iowa Hospitals and Clinics (UIHC). Phlebotomists are responsible for drawing specimens from patients based on doctors' orders. The results of the analysis of these specimens play an important role in determining patient treatment. However, the demand for phlebotomists is likely to outpace supply over the next few years. Therefore, it is important to improve the efficiency of phlebotomists. In this study, we formulate the phlebotomist intra-hospital routing problem as a team orienteering problem with stochastic rewards and service times. The rewards and service times are particularly interesting as they are the result of a queueing process. We present an a priori solution approach and derive a method for efficiently sampling the value of a solution, a value that cannot be determined analytically. Finally, we demonstrate that our proposed approach outperforms the current practice at UIHC.

12:15 The Restaurant Delivery Problem

[1]Marlin Ulmer, [2]Barrett Thomas, [2]Ann Campbell, [2]Nicholas Woyak*
[1]Technische Universität Braunschweig, [2]Department of Management Sciences-University of Iowa

We consider a stochastic dynamic pickup and delivery problem. A fleet of drivers delivers food from a set of restaurant to spontaneously ordering customers. The objective is to dynamically assign and route drivers in a way that avoids delays with respect to customers' deadlines. The sources of stochasticity for this problem are twofold. First, the customers are unknown until they place an order. Second, the time at which the food is ready at the restaurants is unknown. To address these challenges, we present a policy function approximation (PFA). To account for the stochasticity in customer requests, the PFA postpones the assignment decisions for selected customers allowing more flexibility in the response to new requests. Further, the PFA introduces parameterized time buffers to account for the uncertainty in the ready times of the food. Based on data derived from an existing restaurant delivery company, we show how our PFA is able to improve customer service significantly compared to the company's current practice. We further show how the parametrization of the PFA allows the consideration of additional objectives such as the freshness of the food or the average delivery time.

Supply Chain Logistics & Methods

TA4: Humanitarian Logistics

Thursday 8:30 – 10:30 AM Schreiber 1001

Session Chair: Lavanya Marla

8:30 **Using Drones to Minimize Latency in Distribution Systems**

Mohammad Moshref-Javadi, Seokcheon Lee*
Purdue University

Use of drones for the purpose of delivery of service and goods has recently gained considerable attention. Drones are specifically suitable for the delivery of small, urgent, and light packages, for example, blood and medicine in emergency situations and disaster relief. In this research, we consider a combined delivery system of drones and trucks for more efficient delivery of products. It is assumed that a single truck carries both goods and drones and launches the drones at some points in its route. At each stop point, the truck waits until all drones come back to the truck and then it can move to the next customer. We also extend this system and assume that the drones may be launched multiple times when the truck stops. The results show that using drones can considerably improve the waiting time of recipients. Comparison of the single-trip with multi-trip drone systems shows that having multiple trips of drones at each truck's stop is very effective in reducing the latency at customers.

9:00 **A Novel Formulation and a Column Generation Technique for a Rich Humanitarian Logistic Problem**

*Ohad Eisenhandler, Michal Tzur**
Tel Aviv University

We provide a novel formulation to a logistic problem motivated by the daily challenges of food banks. The problem is to simultaneously determine vehicle routes and allocation of limited amounts of food to welfare agencies. The new formulation can be shown to be tighter than the "classical" site-based formulation. However, since it includes an exponential number of decision variables, we use a column generation technique as part of the solution method.

9:30 **Humanitarian Medical Supply Chain in Disaster Response: Role and Challenges**

[1]Irina Dolinskaya, +2Maria Besiou, [2]Sara Guerrero-Garcia*
[1]Northwestern University, [2]Kühne Logistics University

Following a large scale disaster, medical assistance is a critical component of the emergency response. While the existing academic literature discusses distribution of various supplies needed by the affected population, limited research focuses specifically on studying the humanitarian medical supply chain aspect of the response. In this paper we close this gap by (1) describing the humanitarian medical supply chain in the case of disaster response, and (2) identifying the factors affecting its effectiveness, especially focusing on the factors that are unique to the medical aspect of the humanitarian supply chain. A theoretical framework is developed based on academic and practitioner literature, including the reports of the logistical challenges encountered during the response to the Ebola outbreak in 2014. We then validate the factors identified from the existing literature by conducting interviews with experts in the field of humanitarian and medical logistics and expand the list. Finally, we integrate additional factors affecting the humanitarian medical supply chain by looking at a serious humanitarian medical crisis (Ebola outbreak in 2014), which pushed the humanitarian medical supply chain to its limits.

10:00 Cooperative Humanitarian Logistics Models for Highly Resource-Constrained Settings

*Lavanya Marla**
University of Illinois at Urbana-Champaign

In this work, we focus on operational and policy issues related to resource management and operational interventions in extremely resource constrained settings occurring in these systems. Specifically, we focus on ultra-resource constrained scenarios and settings arising in emergency medical systems (EMS) that necessitate multiple, possibly competing, operators and agencies to cooperate in order to ensure service and public health. In this work we design the operational underpinnings of such cooperative-competitive frameworks, which can be enabled by well-designed information systems, and sensing-enabled smart cities that are designed to explicitly take advantage of such systems. Our two-tiered approach incorporates both static and dynamic elements, embedded with the game-theoretic framework of cooperative-competitive decomposition. Our approach models for cooperation between multiple EMS responding agencies such that technology-enabled information sharing, and resource sharing can be done, to meet the needs of the multiple agencies and end-users when ultra-resource constraints occur.

Supply Chain Logistics & Methods

TB4: Games and Collaboration

Thursday 1:00 – 2:30 PM Schreiber 1001

Session Chair: Nicole Adler

1:00 **Multi-Round Combinatorial Auctions for Carrier Collaboration**

[1]Margaretha Gansterer, [1]Richard Hartl, [2]Martin Savelsbergh*
[1]University of Vienna, [2]Georgia Institute of Technology

In horizontal collaborations, carriers form coalitions in order to perform parts of their logistics operations jointly. By exchanging transportation requests among each other, they can operate more efficiently and in a more sustainable way. Through the means of combinatorial auctions, carriers can exchange transportation requests without revealing information about their other tours. They submit part of their requests to a common pool. They are then combined to a set of bundles by a central authority and offered back to all participating carriers. From a practical point of view, offering all possible bundles is not manageable, since the number of bundles grows exponentially with the number of requests that are in the pool. Thus, an attractive subset of bundles has to be generated. In this study we investigate how the concept of multi-round auctions can be adopted in order to contribute to the evaluation of bundle attractiveness. By this we can significantly reduce the number of offered bundles while maintaining solution quality. Three different multi-round auction procedures are developed and assessed. We show how information from a single additional bidding phase can be successfully used, such that the number of offered bundles can be reduced by 60%, while solution quality is maintained. In the proposed preliminary phase, carriers only have to give their bids on the traded single requests. They do not have to reveal any additional information. We show that this procedure even dominates an approach, where carriers disclose aggregate information on their current tours.

1:30 **Collaborative Vehicle Routing with Excess Vehicle Capacity in Urban Last-Mile Deliveries**

[1]Joydeep Paul, [1]Niels Agatz, [2]Remy Spliet, [1]René De Koster*
[1]Rotterdam School of Management-Erasmus Univeristy Rotterdam, [2]Erasmus School of Economics-Erasmus Univeristy Rotterdam

The Consolidation of transport flows in logistics is a promising way to improve the sustainability of urban transportation. In this paper, we introduce a novel dynamic collaborative strategy where one carrier (focal) has the possibility to piggyback on the routes of the other (external) by utilizing the unused capacity. We develop different heuristics to efficiently decide which customers to visit and which customers to redirect to an external route. There is a trade-off between the cost savings achieved by redirecting the loads of certain customer locations to the external routes and the additional cost incurred in transporting the items between the warehouses of the carriers. Our experiments show potential savings generated using this collaborative strategy under different scenarios.

2:00 Competition in Congested Service Networks: The Case of Air Traffic Control Provision in Europe

[1]Nicole Adler, [2]Eran Hanany, [3]Stef Proost*
[1]Hebrew University of Jerusalem, [2]Tel Aviv University, [3]KU Leuven

A two-stage network congestion game, assuming oligopolistic competition in both stages is developed, whereby regulators, service providers and customers interact. Heterogeneous customers with market power are served across multiple origin-destination pairs in a general network. The congestion game with pricing is analyzed across multiple market design scenarios, considering different forms of regulation, ownership form, co-operation between players and the implementation potential of new technologies. The model is subsequently applied to a case study of air traffic control provision in Western Europe, in which it is shown that changes in the regulation are required in order to create a more cost efficient sector with increased capacity.

Supply Chain Logistics & Methods

TC4: Delivery Service Network

Thursday 2:45 – 4:15 PM Schreiber 1001

Session Chair: Niels Agatz

2:45 An On-Demand Same-Day Delivery Service Using Direct Peer-to-Peer Transshipment Strategies

*[1]Wei Zhou, [2]Jane Lin**
[1]CH Robinson, [2]University of Illinois at Chicago

As the same-day delivery service becomes increasingly popular among e-commerce customers, it demands fast, cheap, and flexible on-demand delivery service. This paper proposes, formulates, and evaluates a new on-demand, same-day delivery (ODSD) strategy using direct peer-to-peer transshipment (P2PT). P2PT involves package relays among multiple couriers to extend beyond the normal service range of a single courier; this is done directly via effective collaboration and coordination among couriers. Three P2PT variants are investigated in this paper: P2PT-1 with one single inter-zonal ODSD service request (pickup and delivery in two different service zones), P2PT-M with multiple inter-zonal ODSD requests, and P2PT-RT with real-time inter-zonal demand. An adaptive boundary relaxation (ABR) heuristic algorithm is proposed and evaluated for its solution performance. The P2PT delivery paradigm is also compared with the most responsive and naive ODSD strategy of direct shipping. It is found that while P2PT tends to incur longer travel time than direct shipping, it provides the ODSD service without having to expand and maintain a larger fleet of vehicles (and thus drivers) or incurring extra labor cost. As the economy of scale of ODSD demand increases, those advantages of P2PT will only become more prominent. Our investigations have also found that the efficiency of P2PT, measured by the additional travel time incurred per ODSD service request, improves initially with the economy of scale, and then seems to flatten out in the static demand scenario or worsen in the real-time demand scenario as the number of service requests increases.

3:15 Balancing Availability and Profitability in E-Fulfillment with Revenue Management and Predictive Routing

[1]Catherine Cleophas, [2]Jan Fabian Ehmke, [2]Charlotte Köhler, [1]Magdalena Lang*
[1]RWTH Aachen University, [2]European University Viadrina

To enable attended deliveries, customers and e-grocers must agree on a delivery time window. On the one hand, customers look for a tight delivery time window in the very near future, and they are not willing to pay significantly more for a better choice of delivery time windows. On the other hand, e-grocers' profit margins are small, and the offered delivery time windows strongly affect the costs for order delivery. We present an iterative approach to e-fulfillment for attended deliveries that focuses on profitability, but also ensures a sufficient availability of delivery time windows per delivery area and customer segment.

3:45 Heuristic Approaches to the Same-Day Delivery Problem

[1]Alp Arslan, [2]Niels Agatz, [2]Rob Zuidwijk*
[1]Rotterdam School of Management, [2]Rotterdam School of Management Erasmus University

With the rise of e-commerce, consumer preferences have been shifting significantly towards to the same-day delivery services. However, the design of these type services often requires high investment and operational costs. We study the same day problem in a setting in which a delivery is guaranteed in a pre-specified time after the delivery order is placed. In this context, order announcement time is considered as release time of the task. Furthermore, we relax the single trip limitation of the vehicle routing problems by allowing vehicles can make multiple trips in a service period. We develop a heuristic to solve the static version of the same day delivery problem in which all delivery tasks are assumed to be known in advance.

Supply Chain Logistics & Methods

TD4: Service Network Design

Thursday 4:30 – 6:00 PM Schreiber 1001

Session Chair: Mark Hewitt

4:30 A Benders' Decomposition Approach for Airline Timetable Development and Fleet Assignment

Keji Wei, Vikrant Vaze*
Thayer School of Engineering-Dartmouth College

In this paper, we describe a model that integrates timetable development and fleet assignment steps from the airline planning process to maximize airline profits. We attempt to select the optimal set of flight departure times and the optimal fleet type for every flight leg. The optimal solution captures a large market share by explicitly incorporating passengers' itinerary choice, while ensuring that the operating cost stays low. We design a novel way to apply Benders' decomposition to solve this challenging mixed-integer optimization problem to near-optimality. Computational results using data from two real-world airline networks demonstrate the efficacy of the proposed modeling and solution techniques.

5:00 Service Network Design of Bike Sharing Systems: Formulation and Solution Method

[1]Bruno Albert Neumann Saavedra, [1]Dirk Mattfeld, [2]Teodor Gabriel Crainic, [3]Bernard Gendron, [4]Michael Römer*
[1]Technische Universität Braunschweig, [2]ESG, UQAM & CIRRELT, [3]UniversitÃ© de MontrÃ©al, [4]Martin Luther University Halle-Wittenberg

In this work, we present a modeling framework and solution method for the service network design of bike sharing systems. Bike redistribution is necessary to ensure both bikes and free racks at stations when requested. Our service network design formulation produces a redistribution plan ensuring a reliable level of service taking limited redistribution resources into account. Our formulation explicitly represents the necessary bike handling time at stations to produce suitable vehicle tours. We next present a matheuristic solution method where redistribution decisions are hierarchically made. In the first step, a dynamic transportation problem produces time-of-day fill level at stations by means of transportation services. Transportation services neglect the schedule of vehicle tours in a first instance. In the second step, a pick-up and delivery problem with time windows is derived from the transportation services in order to produce vehicle tours. These two steps are repeated several times obtaining a pool of vehicle tours. Finally, this pool is used as a warm start for a standard solver when the original service network design problem is addressed. The proposed solution method is tested on instances generated from online available bike sharing data.

5:30 Enhanced Dynamic Discretization Discovery Algorithms for Service Network Design Problems

*Mike Hewitt**
Loyola University Chicago

Consolidation carriers transport shipments that are small relative to trailer capacity and participate in both the the less-than-truckload (LTL) freight and small package/parcel transportation sectors. Both sectors are important, as both LTL and small package carriers play a prominent role in the fulfillment of orders placed online (as well as other channels) and the supply chains that produce those goods. Fast shipping times (and low cost) are critical to the success of the online sales channel, with e-tailers such as Amazon.com continuously pushing the boundary, aiming for next-day and even same-day delivery. To plan their transportation operations, consolidation carriers have long relied on solving the Service Network Design (SND) problem. Recently, researchers have proposed a Dynamic Discretization Discovery (DDD) algorithm for solving Service Network Design problems that recognize that fast shipping times necessitate

optimization models that represent time precisely. This talk will present enhancements to DDD that make it more relevant to practice in multiple ways. First, we will show how to improve its performance, so that it can solve more instances of the SND for a fine discretization of time, and in less time. Second, we will show how DDD can be applied to variants of the SND that represent a wide array of operational realities.

Supply Chain Logistics & Methods

FA4: Location Routing

Friday 8:30 – 10:30 AM Schreiber 1001

Session Chair: Francesco Viti

8:30 Finding Optimal Park-and-Ride Facility Locations in an Urban Network

Pramesh Kumar, Alireza Khani*
University of Minnesota

Park-and-ride facilities are becoming more popular nowadays as these facilities encourage people to switch to public transit in order to access congested areas like central business district (CBD). Driving to park-and-ride locations also acts as feeder service to light rail, commuter rail or other types of public transit. In order to make transit effective, it's very important to locate the park-and-ride facilities at appropriate locations. So, finding optimal park and ride facility locations has become one of crucial tasks for planners as inappropriate locations may force people to drive and result in more congestion. This study proposes a mixed integer nonlinear programming (MINLP) problem to find the optimal location of park-and-ride facilities in an urban network. The objective is to minimize the total system travel time while satisfying stochastic user equilibrium. The decision variables in this model are binary variables corresponding to candidate park-and-ride locations which take value 1 if the park-and-ride location is selected and 0 otherwise. Finally, the optimization problem is constrained by maximum number of park-and-ride locations to be built among candidate locations and also budget constraints. To solve the given optimization problem a solution algorithm is proposed which consists of a stochastic traffic assignment to calculate the flow variables and a branch & bound algorithm to solve the relaxed integer programming problem. Finally, a hypothetical example is solved using the developed solution algorithm and results are presented.

9:00 Reliable Facility Location Design with Imperfect Information: Continuum and Discrete Models

*Lifen Yun, Hongqiang Fan, Xiaopeng Li**
University of South Florida

Short abstract is not available.

9:30 Location-Routing Problems with Economies of Scale

James Bookbinder, Xiaoyang Pi*
University of Waterloo

The location-routing problem aims to select the sites at which facilities (Distribution Centers) will be open, assign customers to those facilities, and design vehicle routes from there to respective customers. The objective is minimal total cost. For the "standard" location-routing problem that total cost includes (just) the fixed costs to open DCs plus the transportation costs from facilities to customers. In this paper, we also consider the variable cost of facilities' operations. Two forms of variable cost are proposed. One is a linear cost function with a constant operating cost per unit; the other employs a concave function of total throughput at each DC. The latter is studied because larger facilities may permit the use of enhanced technology, hence possible achievement of economies of scale. Following preliminary tests of several metaheuristic solution methods, we employed a genetic algorithm with ant colony optimization. Computational experiments of the model without variable cost are performed on two published data sets. Then extensive testing is done on modified data sets: for cases with operating cost but without economies of scale, and for other cases when scale economies are present. We analyze the influence of economies of scale, and study how parameter values affect those economies. Then we carefully exhibit the trade-offs between facility operating costs and transportation costs. Conclusions are drawn and further research is suggested.

10:00 Exact and Approximate Optimal Route Set Generation in Sensor Location Problems

Marco Rinaldi, Francesco Viti*
University of Luxembourg

Sensor positioning is a fundamental problem in transportation networks, as the location of sensors strongly determines how traffic flows are observable and hence manageable. This paper studies the impact of choosing the route set in route-based link flow inference problems and formulates a methodology for identifying the optimal route sets such that additional routes do not add any relevant information for optimal full observability. This is an important contribution to sensor location problems as route-based link flow inference problems suffer of the curse of dimensionality and hence solutions are strongly depending on the link-route information used. We first classify route sets in terms of degree of information redundancy, and then formulate an optimization problem where information redundancy is minimized. Then we propose a hypergraph approach, which allows reformulating the optimization problem in graph theoretical terms. This reformulation guarantees exact solutions to be found. The properties of the new methodology are analyzed and illustrated by small toy networks. Thanks to the route sets found by our approach, we are able to find full observability solutions with a smaller number of sensors, yet being very efficient also in terms of partial observability.

Supply Chain Logistics & Methods

FB4: Freight Transportation

Friday 1:00 – 2:30 PM Schreiber 1001

Session Chair: Ronald Askin

1:00 **Scheduled Service Network Design and Revenue Management with an Intermodal Barge Transportation Illustration**

[1]Teodor Gabriel Crainic, [2]Ioana Bilegan, [3]Yunfei Wang*
[1]ESG, UQAM & CIRRELT, [2]LAMIH, University of Valenciennes, [3]University of Valenciennes

Scheduled service network design (SSND) is generally used to build the tactical plan for consolidation-based transportation, selecting the services and schedule to be repeatedly operated over the next season. SSND with resource management also allocates and routes the main resources supporting the selected services. Most freight SSND models consider a unique class of customers making up the regular demand. We take a different view and consider several categories of customers, tariffs and operation classes, and the maximization of the net revenue. We aim to study the incorporation of revenue management considerations, usually tackled at the operational-planning level, into tactical planning models for intermodal consolidation-based freight transportation carriers. Our interest goes beyond the modeling and algorithmic challenges, to exploring the impact of this integration on the structure of the service network and the selection of customer demands to service. We perform this study within the context of intermodal barge transportation, a field relatively neglected in the literature. Our contributions include a new SSND with resource and revenue management model, a novel meta-heuristic for this problem, and the results and insights provided by an extensive experimentation campaign.

1:30 **Load Commitment Policies for the Stochastic Advance Booking Problem for Truckload Trucking**

Juliana Nascimento, Hugo Simao, Warren Powell*
Princeton University

Considerable research has focused on the management of vehicles (trucks, containers) over time under uncertainty, but virtually no attention has been directed to the optimization of the load acceptance process, a major issue in truckload trucking. We build on prior work on the optimizing of drivers in the truckload industry, but extend this to model both the call-in process of loads, and the acceptance process, recognizing that fifty percent of loads are called in four or more days into the future. We use a stochastic look-ahead model to estimate the probability that a load will be accepted. We then propose a parametric policy function approximation (PFA) controlled by two tunable parameters. Search algorithms are proposed for both offline and online learning settings. This policy is then optimized in a stochastic base model that has been calibrated using the data of a major motor carrier.

2:00 **Logistic Network Design for Daily Cyclic Truck Routes**

[1]Ronald Askin, +2Zhengyang Hu, [2]Guiping Hu*
[1]Arizona State University, [2]Iowa State University

Hub or relay based logistics networks for long haul trucking have been proposed for improving trucker work-life balance and other efficiencies. Recent discussion of the Physical Internet has renewed interest in such systems. In this paper a formulation is proposed for hub network design and routing to support driver residency. The model determines the location and capacity of hub locations for the network to meet a set of source to destination shipping demands. The model minimizes fixed operating costs, loaded and deadheading travel cost and penalties for driver routes that exceed a daily tour. Experiments on a grid and a case study based on the highway grid for the Western United States are used to demonstrate the model and operational practice.

Supply Chain Logistics & Methods

FC4: Movement and Materials Control in Supply Chains

Friday 2:45 – 4:15 PM Schreiber 1001

Session Chair: Rajan Batta

2:45 **Dynamic Capacity Logistics and Inventory Control**

Satya Malladi, Alan Erera, Chelsea White III*
Georgia Institute of Technology

We investigate the problem of planning the logistics of a production system characterized by multiple compact transportable production units called modules. This problem deals with the sharing of mobile modular capacity across multiple locations and managing location-wise inventory in tandem. We model the problem as an MDP and present intuitive upper and lower bounds. We explore the value of mobile modular operations over using fixed capacity systems under stationary demands and propose two well performing heuristics viz., a rollout of the shift-now-or-never strategy and a simulation-based value function approximation scheme.

3:15 **Planning the Fuel Supply to Gas Stations According to the Concept of Carrier-Managed Inventory - an Optimization Approach**

*Paweł Hanczar**
Wroclaw University of Economics

The vendor managed inventory (VMI) concept has many different variants in business practice. In the case of fuel distribution to the gas station network, VMI cooperation is often referred to as carried managed inventories (CMI), as the transportation company takes the responsibilities over the shipment planning and delivery dates. Distribution companies expect the carrier not only to deliver specialized transport services, but also to develop end-to-end delivery plans to achieve key performance indicators (KPIs). On the one hand, companies that own a network of gas stations impose transport companies to operate in accordance with CMI as a prerequisite for cooperation. On the other hand, transport companies accept this approach, realizing that taking over additional responsibilities will result in higher utilization of the transport fleet and will in the future make it difficult for the distribution company to change the provider of transport services. In this paper was discussed the problem of determining the routes of inventory that occurs in the process of planning fuel supplies to the gas station network. The most commonly encountered KPIs were studied, which are used in the cooperation between the carrier and its contractor. The main part of the paper contains the proposal of a decision model for supply planning in the 7-day time horizon. The work finishes the assessment of the use of the presented formulation to find the delivery plans in practice.

3:45 **Exploration of Strategies to Form Convoys to Facilitate Effective Movement of Items**

Rajan Batta, Azar Sadeghnejad Barkousaraie, Moises Sudit*
University at Buffalo, The State University of New York

We introduce and analyze the convoy formation problem for multiple origins and destinations. The goal of this problem is to define feasible vehicle configurations for convoys, i.e. convoy formations that lead to superior route choices for the convoy movement problem. We start by using hypothetical staircase paths for each pair of origin and destination and then sequentially solve the demand satisfaction and vehicle assignment problem to find an initial feasible solution. To improve the quality of the initial feasible solution, a column generation based algorithm is presented. The efficiency of the proposed method is tested and experimental results are provided.

Supply Chain Logistics & Methods

FD4: Risk Analysis in Network Transportation

Friday 4:30 – 6:00 PM Schreiber 1001

Session Chair: Laura Wynter

4:30 **Hazardous-Materials Network Design Problem with Behavioral Conditional Value-at-Risk**

Liu Su, Changhyun Kwon*
University of South Florida

In this paper, we consider a network design problem to minimize the risk of hazmat accidents by selecting a set of road segments to be closed so that hazmat trucks cannot travel, i.e., road bans for hazmat traffic. While modeling probabilistic route-choice of hazmat carriers by the random utility model (RUM), we consider an averse risk measure called the conditional value-at-risk (CVaR), instead of the widely used expected risk measure. Using RUM and CVaR, we quantify the risk of having hazmat accidents and large consequences, and design the network policy for road bans accordingly. While CVaR has been used in determining a route for hazmat transportation, it has not been considered in the context of route-choice in hazmat network design problems. By applying CVaR to the route-choice behavior of hazmat carriers, we protect the road network from undesirable route-choices that may lead to severe consequences. We present a case study in the real road network of Ravenna, Italy.

5:00 **A Value-at-Risk (VaR)/Conditional Value-at-Risk (CVaR) Approach to Optimal Train Configuration and Routing of Hazmat Shipments**

S. Davod Hosseini, Manish Verma*
McMaster University

Hazardous materials (hazmat) incidents are rare though the consequences could be catastrophic. The low probability-high consequence nature of such events mandate that a risk-averse plan be implemented for routing hazmat shipments. We propose a value-at-risk (VaR) and conditional value-at-risk (CVaR) methodology for routing rail hazmat shipments, using the best train configuration, over a given railroad network using the pre-defined train services such that the transport risk as measured by VaR and CVaR is minimized. Freight train derailment records of the Federal Railroad Administration (FRA) were analyzed to model the behavior of railroad accidents, and to estimate their conditional probabilities. The proposed methodologies were used to study several problem instances generated using the realistic network of a railroad operator in Midwest United States, and to demonstrate that the proposed methodologies are superior to other measures for risk-averse routing of hazmat shipments and versatile enough to yield various routes based on risk preferences of the decision makers.

5:30 **Entity Resolution and Vessel Modeling for Maritime Situational Awareness**

Shiau Hong Lim, Yeow Khiang Chia, Laura Wynter*
IBM Research

We present methods for two challenging problems in the maritime domain, namely entity resolution and vessel activity modeling.

Supply Chain Logistics & Methods

SA4: Behavioral Data and Demand Estimation

Saturday 9:00 – 11:00 AM Schreiber 1001

Session Chair: Yueyue Fan

9:00 **Household Use of Autonomous Vehicles: Modeling Framework and Traveler Adaptation**

Yashar Khayati, Jee Eun Kang, Mark Karwan, Chase Murray*
University at Buffalo

With recent developments in vehicle automation, the idea and advantages of sharing public roads with Autonomous Vehicles (AV) or self-driving vehicles has been accepted. Many aspects of today's transportation system will be transformed with the introduction of AVs. These changes are attributed broadly to two properties of AVs: automated control and driverless operations. (Pinjari, 2013), and similarly (Litman, 2014), argue that potential impacts include (1) increased safety, (2) better use of traveler travel time, (3) independent mobility for the elderly and disabled populations, (4) reduced fuel consumption and emissions and (5) increased road capacity. It can be categorized that (1), (4), (5) come from automated control, and (2), (3) come from driverless operations. In the longer term, driverless operations may also affect individuals' home location choice, vehicle ownership choice, etc., resulting in reshaping of land-use characteristics and the transportation system. Three areas which are expected to be greatly transformed are vehicle use, travel behavior and subsequently vehicle ownership from driverless operations. Ever since the introduction of personal automobiles in the United States, per capita ownership grew during most of the 20th century and it has been the norm that a licensed driver operates his/her own vehicle. In 2011, there were 0.75 vehicles per person and 1.10 vehicles per licensed driver, and 1.95 vehicles per household in the US (Sivak, 2013; Litman, 2014). With AVs, this travel behavior is expected to change significantly. It is likely that travelers in a household can share one vehicle with its driverless operations. On the other hand, it is also possible that travelers without a license (e.g. children, disabled or elderly) could own a personal AV. Another prediction is that travelers will utilize autonomous taxis, or shared-mobility systems, as the cost of these systems will be greatly reduced with no driver involved (Pinjari, 2013). In this paper, we define a framework to model and evaluate potential household-level use of AVs, to understand advantages, potential issues and negative external effects. Since there are no data readily available in this field, we introduce a new formulation; the Household Activity Pattern Problem for Autonomous Vehicles (HAPP-AV) to simulate the travel patterns of people using AVs. The Household Activity Pattern Problem (HAPP) is a constraint-based full-day activity scheduling problem and can be used to simulate potential use of policies or adoption of new vehicles (Recker and Parimi, 1999; Kang and Recker, 2014). Based on the framework of HAPP, HAPP-AV additionally includes the self-driving capabilities of AVs. Using AVs in a household vehicle stable leads to significant differences between HAPP and HAPP-AV. Since no driver needs to be assigned to vehicles, AVs can be more effectively utilized, serving more trips during the day. The key modeling challenge is to include modeling capabilities of ride sharing, driverless operation, parking, pickup and dropoff as well as waiting during travelers' engagement in activities. Computationally, these new features make AV routing significantly more complicated than the original HAPP. We developed different solution approaches to solve this NP-hard problem. Using this model, we plan to conduct a scenario analysis to draw insights on changes in travel behavior and vehicle use, including vehicle-miles-traveled (VMT) and emissions, among other metrics.

9:30 **Estimating Primary Demand of One-Way Vehicle Sharing Systems**

Chiwei Yan, Chong Yang Goh*
Massachusetts Institute of Technology

Observed trip data for one-way vehicle sharing systems do not always correspond to true demands for the service due to varying vehicle and parking availability. For example, in bike sharing systems, passengers arriving at an empty pickup station may either leave the system or spill over to nearby stations. We propose efficient methods to estimate the true origin-destination demands in a one-way vehicle sharing system using observed trip data and station status data. Our approach models a user's station substitution behavior based on a ranking-based choice model. We demonstrate the effectiveness of our approach using data from a bike-sharing system in Boston.

10:00 **Modeling the Acceptability of Crowdsourced Goods Deliveries**

*Aymeric Punel, Alireza Ermagun, Amanda Stathopoulos**
Northwestern University

Development of new technologies in the shipment industry is redefining the public's needs and expectations for deliveries. Innovative shipment methods have emerged in response to technological innovation, increasing performance demand and a changing retail landscape. Among them, crowdshipping is built on the idea that citizens can connect via online platforms and deliver goods to each other along planned travel routes. While crowdshipping companies highlight the potentials for saving money, optimizing delivery operations, creating social connections, and reducing the energy footprint, uptake is still limited. The goal of this paper is to highlight the factors that influence the acceptability and preferences for crowdshipping. Through a survey using stated choice scenarios, disseminated to an on-line panel, discrete choice models with the introduction of error components and random parameters are specified. The estimation results suggest that distinct preference patterns exist for distance classes of the shipment. In the urban setting, senders value transparency of driver performance monitoring along with speed, while longer shipment distances lower these requirements. The model developed in this paper provides first key insights into the factors affecting preferences for goods delivery with occasional drivers.

10:30 **Travel Demand Estimation Using Heterogeneous Data Pieces: Addressing Stochasticity and Observability Issues**

Yudi Yang, Yueyue Fan, Roger Wets*
University of California, Davis

Travel demand is a critical input to many transportation systems analyses. There remains to be theoretical barriers to overcome especially with respect to the stochastic and observability issues. In this paper, we introduce a new stochastic demand estimation framework that enables more effective utilization of data and domain knowledge to mitigate identifiability issues. We provide both theoretical analyses and numerical results to demonstrate the effectiveness of our approach. In addition, this new framework does not rely on any special probability or behavior assumptions, thus providing a flexible platform to incorporate a large variety of data/information types and user behaviors, which is especially valuable considering the potential technological and behavior transformation faced by our transportation system.

Supply Chain Logistics & Methods

SB4: City Logistics and Inventory Control

Saturday 11:15 – 12:45 PM Schreiber 1001

Session Chair: Teodor Gabriel Crainic

11:15 **Value Function Approximation-based Dynamic Look-ahead Policies for Stochastic-Dynamic Inventory Routing in Bike Sharing Systems**

*Jan Brinkmann, Marlin Ulmer, Dirk Mattfeld**
Technische Universität Braunschweig

We consider a station-based bike sharing system (BSS), where user can rent and return bikes spontaneously. Rental and return requests are uncertain and subject to spatial-temporal pattern. Service providers dynamically dispatch transport vehicles to relocate bikes between stations. The challenge is to balance the number of bikes and free bike racks at every station to satisfy as many requests as possible. The considered problem is a stochastic-dynamic inventory routing problem (SDIRP). We model the SDIRP as a Markov decision process. The objective is to identify an optimal policy, minimizing the expected number of failed requests. To solve the SDIRP, we draw on policies by means of approximate dynamic programming. We present dynamic look-ahead policies (DLA) to anticipate potentially failing requests in online simulations. The DLA simulates a limited time of the horizon to evaluate feasible inventory and routing decisions. Due to the spatio-temporal request pattern, the suitable simulation horizons differ in the course of the day. To select suitable horizons for every hour of the day, we apply value function approximation (VFA). VFA carries out offline simulations and returns a sequence of suitable simulation horizons. Due to the small number of 24 hours, we apply Boltzman exploration. Our computational studies on real-world data by the BSS of Minneapolis (Minnesota, USA) point out, that the VFA-based DLA outperforms look-ahead policies with static simulation horizons as well as conventional policies from literature.

11:45 **Synchronizing City Logistics with Sliding Time Windows**

Saijun Shao, Gangyan Xu, Ming Li, George Q. Huang*
The University of Hong Kong

Short abstract is not available.

12:15 **Multi-Modal Scheduled Service Network Design for Two-Tier City Logistics System with Resource Management**

[1]Pirmin Fontaine, [1]Teodor Gabriel Crainic, [2]Ola Jabali, [1]Walter Rei*
[1]ESG, UQAM & CIRRELT, [2]DEIB, Politecnico di Milano

We build on the service network design problem of a two-tier city logistics system where the goods are transported from distribution centers at the border of a city to satellites in the city from where the final distribution is done. Besides inbound demand, we further include the demand out of the city. Moreover, we consider not only trucks but also scheduled services like trams as transportation modes and explicitly model resources in the model. We define a service-based formulation for the resulting multi-mode service network design problem with resource management. As efficient solution methods do not exist in the literature, we are developing an exact solution method based on decomposition techniques to solve the problem efficiently. Besides the efficiency of our method, we show the value of considering outbound demand as well as different transportation modes and the management of resources in such a system.

TSL Cross-Region Dissertation Grant Winner

Saturday 1:00 – 1:30 PM Schreiber 901

Session Chair: Maciek Nowak

1:00 **Multi-objective stochastic optimization models for managing a bike sharing system**

[1]Rossana Cavagnini, [2]Luca Bertazzi, [1]Francesca Maggioni, [3]Mike Hewitt*
[1]University of Bergamo, [2]University of Brescia, [3]Loyola University Chicago

In this talk, we present stochastic optimization-based approaches for managing a bike sharing system. Specifically, we focus on the daily allocation of bikes to stations and the subsequent rebalancing of bikes amongst stations at a point later in the day. We present both a stochastic programming-based approach as well as heuristics based on a Newsvendor model-type analysis for making these decisions. Finally, with an extensive computational study based on data derived from a bike sharing system in San Francisco, we study the comparative benefits of these two approaches, as well as the benefits associated with modeling uncertainty in this decision-making context.

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