Transportation and Logistics
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feasible snow truck routing plan to maximize snow removal efficiency. Formulated into a multi-depot traveling salesman problem. The model generates a single depot, two-vehicle cases. Some examples are presented to illustrate the method.

1 - A Multi-commodity Capacitated Pickup and Delivery Problem: The Single and Two-vehicle Cases
Harlaos N Psaraftis, National Technical University of Athens, Athens, 10682, Greece, hnpasar@mail.ntua.gr
We consider a multi-commodity capacitated pickup and delivery problem with cargo flows among all node pairs given by a general 0/1 matrix. Objective is to minimize the combination of vehicle trip costs and cargo delay/inventory costs. This problem is a generalization of several problems that have appeared in the literature. Dynamic programming approaches are developed for the single-vehicle and two-vehicle cases. Some examples are presented to illustrate the method.

2 - Multi-scenario Heuristics for a Dynamic Traveling Salesman Problem with Fixed Appointment Times
Yu-Shiu Lin, Georgia Institute of Technology, 15 Habersham Rd., Unit G66, Atlanta, GA, 30305, United States of America, phil.lin82@gmail.com, Ashlea Bennett, Alan Erera
This paper emphasizes a dynamic single vehicle, single depot routing problem with fixed appointment times. First, we introduce an exact algorithm for the static problem to maximize number of customer served with customers on the real line. For the dynamic problem, we present a multi-scenario heuristic. Our computation studies show that our heuristic can efficiently provide a high quality solution for 1) customers on the real line and 2) customers in two-dimensional space.

3 - A Bidding Advisory Model for Combinatorial Auctions Incorporating Less-than-Truckload Schemes
Rodrigo Mesa Arango, Purdue University, 550 Stadium Mall Drive, West Lafayette, IN, 47907, United States of America, rmesaa@gmail.com, Satish Ukkusuri
In this paper we present a bidding technique that can be used by a Less-than-Truckload (LTL) company in order to submit optimal quotes in a combinatorial auction. The objective is to minimize the unused capacity per-mile. This problem is solved using a Branch-and-Price technique. Numerical results show the implications of using LTL strategies over the usual Truck-Load (TL) strategies reported in previous literature.

4 - Employee Scheduling at Maritime Container Terminals
F. Jourdain, The University of British Columbia, P.O. Box 11-036, Riad El-Solh, Beirut, 1107 2020, Lebanon, fjjourdain@gmail.com, George Turkyyi, Omar Rafai, Francisco Franco
While numerous references exist on the topics of terminal design, container logistics, and vessel scheduling, only a limited number of papers address the need for a workforce management system tailored to the highly dynamic container terminal environment. Our research, motivated by the Beirut Container Terminal Consortium (BCTC), seeks to design and test a system for producing yard staff schedules that minimize costs while also promoting fairness across employees in the scheduling of overtime.

5 - Vehicle Routing for Snow Plowing Operations
Hang Li, University of Illinois Urbana-Champaign, Department Civil & Enviro Engineering, Urbana, IL, United States of America, hangli@illinois.edu
The paper develops a mathematical programming model for the routing of snow plowing vehicles, and the goal is to minimize the total service time needed to serve all road segments while satisfying a set of operational constraints. The problem is formulated into a multi-depot traveling salesman problem. The model generates a feasible snow truck routing plan to maximize snow removal efficiency.
Transportation: Real-life Applications

Vehicle Routing: Real-life Applications
Sponsor: Transportation Science and Logistics
Sponsored Session
Chair: Tom Van Woensel, Professor of Freight Transport and Logistics, Eindhoven University of Technology, School of Industrial Engineering, Eindhoven, BR, Netherlands, t.v.woensel@tue.nl

1 - The Dynamic Shortest Path Problem: Hybrid Routing Policies with Disruptions at the Network
Derya Sever, Technical University of Eindhoven, 5600 MB, Eindhoven, Netherlands, d.sever@tue.nl, Ton de Kok, Tom Van Woensel, Nico Dellaert
Travel time disruptions lead to significant increases in transportation costs. We develop hybrid routing policies to respond to the stochasticity in networks. Hybrid routing policies are developed off-line where the actual policy is selected according to real-time information. The hybrid routing policies use different levels of network knowledge and disruption information. Furthermore, we investigate the conditions under which the various routing strategies perform better under various network data.

2 - Vehicle Routing and Scheduling for Blood Collection
Ali Ekiç, Assistant Professor, University of Houston, Department of Industrial Engineering, Houston, TX, 77204, United States of America, aekici@central.uh.edu, Orsan Ozener
In many countries, people still die because of inadequate supply of blood products. Blood is needed for several types of treatments including organ transplants, cancer and anemia treatments. In blood supply management, an important step is processing donated blood within a certain amount of time after donation. In this research, motivated by the practices in blood supply management, we study a variant of the Vehicle Routing Problem and develop heuristic algorithms to find good solutions.

3 - Vehicle Routing Problem with Stochastic Travel Times and Time Windows
Duygu Tas, Doctoral Candidate, Eindhoven University of Technology, School of Industrial Engineering, PO Box 513 5600 MB, Eindhoven, Netherlands, d.tas@tue.nl, Nico Dellaert, Ton Van Woensel, Ton de Kok
Consider a vehicle routing problem with soft time windows and stochastic travel times with a known probability distribution leading to stochastic arrival times. We propose a model constructing efficient routes to service the different customers as reliable as possible in their delivery time windows. We describe our model and solution methods, and present our results based on well-known problem instances.

4 - A Parallel GRASP for the Therapist Routing and Scheduling Problem
Jonathan Bard, Professor, The University of Texas, Operations Research Group, Austin, TX, 78712, United States of America, jbard@mail.utexas.edu, Ahmad Jarrahi, Yufen Shao
This talk presents a parallel GRASP for solving a weekly routing and scheduling problem for therapists. The problem contains both fixed and flexible patients with respect to appointment times, and two grades of therapists. In Phase I, feasible solutions are constructed day by day by solving a series of assignment problems. In Phase II, a high-level neighborhood search is proposed to obtain local optima. Performance is demonstrated using real and randomly generated data sets.

5 - An Exact Approach to the VRPTW and Break Scheduling
Tom Van Woensel, Professor of Freight Transport and Logistics, Eindhoven University of Technology, School of Industrial Engineering, Eindhoven, BR, Netherlands, t.v.woensel@tue.nl, Said Babia, Ton de Kok, Nico Dellaert, Anna Fraceschetti
We consider restrictions such as driving hours regulations in the VRPTW. We demonstrate a Branch and Bound and Cut approach to the proposed problem. Numerical results are given for realistic settings and benchmarked to previous work in the literature.

INFORMS Charlotte – 2011

1 - Workforce Management in Periodic Routing: Modeling and Practice
Karen Smilowitz, Associate Professor, Northwestern University, 2145 Sheridan Road, Evanston, IL, 60208, United States of America, ksmilow@northwestern.edu, Maciek Nowak
Service quality and driver efficiency in delivery operations may be enhanced by increasing the regularity with which drivers visit customers. However, such consideration can increase travel distance. In this talk, we review the treatment of workforce management in routing models from the academic literature and industry practice. We evaluate several related models and assess the alignment of each model with industry characteristics.

2 - Routing Courier Delivery Services with Urgent Demand
Maged Dessouky, University of Southern California, 3715 McClintock Avenue, Department of Industrial & Systems Eng., Los Angeles, CA, 90089, United States of America, maged@usc.edu, Chen Wang, Fernando Ordonez
The objective of this research is to develop better vehicle routing solutions that are not only able to efficiently satisfy a random demand over time, but that in doing so take into account the presence of sporadic, tightly constrained, urgent or emergency requests. Routing solutions capable of providing better customer service by satisfying more urgent requests, reducing operational costs, or both, are essential in some industries.

3 - The Use of Telemetry to Improve Routing Costs
Amit Verma, PhD Student, The University of Iowa, Pappajohn Business Building, Iowa City, IA, 52242, United States of America, amit-verma@uiowa.edu, Ann Campbell
Telemetry units can be used to transmit inventory levels of many products to vendors. Having more frequent readings can be helpful to prevent stockouts and prevent making costly deliveries too early. Our work, inspired by a project with carbon dioxide provider NuCO2, looks at the question of where to put telemetry units when they cannot be placed at all customers. We will introduce a model for this problem, describe a heuristic to solve it, and summarize our insights.

4 - Robust Partitioning for Stochastic Multi-vehicle Routing
John Carlsson, University of Minnesota, 111 Church St SE, Minneapolis, MN, 55455, United States of America, jgc@isye.umn.edu
The problem of coordinating a fleet of vehicles so that workloads are most evenly distributed is a hard one. In this paper, we consider an assignment problem in which client locations are unknown at the time of service and that each of them will be drawn identically and independently according to a distribution that is also “unknown”. Simulations of a parcel delivery problem demonstrate that a data-driven partitioning approach makes better use of historical data as it becomes available.

Urban Logistics
Sponsor: Transportation Science and Logistics
Sponsored Session
Chair: Chi Xie, Research Associate, University of Texas at Austin, 1 University Station, C1761, Austin, TX, 78713, United States of America, chi.xie@mail.utexas.edu

1 - Addressing Demand Uncertainty in City Logistics
Todor Gabriel Crainic, Professor, CIRRELT and ESG UQAM, 2920 Chemin de la Tour, Montréal, QC, H3T 1J4, Canada, TodorGabriel.Crainic@cirrelt.ca, Fausto Errico, Nicolette Ricciardi, Walter Rei
We are interested in building the tactical plan of a two-tiered City Logistics system while explicitly accounting for the uncertainty in demand. We describe the problem, propose a two-stage stochastic formulation, and discuss three recourse strategies. Algorithmic challenges are discussed and a promising solution methodology is proposed.

MA47

1 University Station, C1761, Austin, TX, 78759, United States of America, aekici@central.uh.edu, Orsan Ozener

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2 - Intelligent Dynamic Signal Timing Optimization Program
Ali Hajibabaie, Graduate Research Assistant, University Of Illinois at Urbana Champaign, 205 N Mathwes Avenue, Room 3150, Urbana, IL, 61801, United States of America, ahaab2@illinois.edu, Rahim Benekohal

In this study, we introduce Intelligent Dynamic Signal Timing Optimization Program (IDSTOP). IDSTOP incorporates Genetic Algorithm with microscopic traffic simulation to find near optimal signal timing parameters in an oversaturated urban transportation network under time-variant demand. IDSTOP's formulation and solution technique as well as different heuristics that are developed to reduce its run time are explained. In addition, IDSTOP's performance on a realistic case study network is tested.

3 - Which Policy Works Better for Signal Coordination? Common, or Variable Cycle Length
All Hajibabaie, Graduate Research Assistant, University Of Illinois at Urbana Champaign, 205 N Mathwes Avenue, Room 3150, Urbana, IL, 61801, United States of America, ahaab2@illinois.edu, Rahim Benekohal

In this study, we compare the effects of using a common cycle strategy, to the effects of using a variable cycle length strategy on signal coordination in an urban transportation network. For this purpose, a Genetic Algorithm based method is developed to find optimal signal timing parameters when a common cycle is used and when the cycles can be different. Several network performance measures such as delay, throughput, and fuel consumption are used for the comparison.

4 - Evaluating City Logistics Alternatives
Qian An, University of Southern California, 2637 Ellendale Place, Los Angeles, CA, United States of America, qan@usc.edu. Maged Dessouky, James Moore

City logistics is a relatively new research area that focuses on strategies for increasing the efficiency of goods movement in urban areas, reducing noise and vehicle emissions, and improving safety in residential areas. Our objective is to formulate a location routing model that gives a very good strategic design for such a two-level distribution network, and also to estimate the benefits from this approach by exercising the Southern California Planning Model.

5 - Traveling Salesman Problem with Stochastic Demands in Stochastic-state Networks
David Fajardo, The University of Texas at Austin, Earnest Cockrell Jr. Hall, 6.202, Austin, TX, 78712, United States of America, davidfajardo2@gmail.com, Travis Waller

We formulate a Traveling Salesman Problem in which the subset of customers that must be visited is stochastic and represented through a finite set of possible network-states, each corresponding to a specific realization of the demand vector. An exact solution method based on a Markovian Decision Process formulation is presented. We develop rollout policies based on fixed routes that can be used for future networks as well as to possible future scenarios.

3 - Vehicle-routing Problems with Min-Max Objective and Stochastic Travel Times
Tim Urban, Professor, The University of Tulsa, Operations Management, 800 South Tucker Drive, Tulsa, OK, 74104, United States of America, timothy-urban@utulsa.edu

A familiar variant of the vehicle-routing problem is one with an objective of minimizing the time to complete the longest route. Stochastic travel times add substantial complexity, as the use of extreme-value theory becomes necessary to identify the minimum of several random variables; the correlation of travel times further complicates the analysis. We examine the effect of correlated stochastic travel times on the min-max objective and solution of VRPs and other node- and arc-routing problems.

4 - Dynamic Routing in the Vehicle Routing Problem with Stochastic Demands
Lei Zhao, Associate Professor, Tsinghua University, Department of Industrial Engineering, Beijing, China, lzhao@tsinghua.edu.cn, Yue Tong, Chen Zhang, Tom Van Woensel, Jan C. Fransoo

With the last development in the accessibility of geographic and traffic information, communication, and computing power, dynamic re-routing of vehicles during the delivery or pickup process becomes possible. We study the application of approximate dynamic programming in dynamic routing in the vehicle routing problem with stochastic demands and analyze the value of information.

MC47

H - Dunn Room - 3rd Floor
Anticipatory Optimization for Dynamic Vehicle Routing
Sponsor: Transportation Science and Logistics
Sponsored Session
Chair: Stephan Meisel, University of Braunschweig, Mühlenfeldstr. 23, Braunschweig, 38106, Germany, stephan.meisel@tu-bs.de

1 - Inventory Routing for Dynamic Waste Collection from underground Containers
Martijn Mes, Assistant Professor, University of Twente, P.O. Box 217, Enschede, 7500 AE, Netherlands, m.r.k.mes@utwente.nl, Marco Schutten

We study the use of dynamic policies for the collection of waste from underground containers. The problem is a reverse inventory routing problem which involves decisions regarding routing and container selection. We show that in more dense networks more emphasis should be put on the latter. Given the huge variation in deposits, we need an anticipatory policy that balances the workload. We propose such a policy and tune the parameters of this policy using simulation optimization.

2 - Adaptive Waiting Strategies for Dynamic Vehicle Routing with Service Agreements
Uli Suppa, University of Braunschweig, Mühlenfeldstr. 23, Braunschweig, Germany, u.suppa@tu-bs.de, Dirk C. Mattfeld, Stephan Meisel

We consider a dynamic vehicle routing problem with a fleet of vehicles, stochastic customer requests and two types of service agreements. The problem typically occurs in businesses providing after sales services. In order to minimize the total distance traveled for serving every request, future requests are anticipated by means of an adaptive waiting strategy. The strategy adapts to the current states of the vehicles as well as to possible future scenarios.

3 - Rollout Policies for Dynamic Vehicle Routing with Stochastic Demand, Duration Limits, and Waiting
Justin Goodson, Saint Louis University, 3674 Lindell Blvd., St. Louis, MO, 63108, United States of America, goodson@slu.edu, Jeff Ohihmann, Barrett Thomas

We consider a dynamic vehicle routing problem where demand is known only in distribution prior to arrival at customers, vehicle routes are limited in duration, and the objective is to maximize expected demand served. We formulate the problem as a Markov decision process and develop rollout policies based on fixed routes that dynamically adjust an initial routing plan as demand is observed. We study the benefit of allowing vehicles to wait, rather than requiring them to continue on their routes.

4 - Inventory Routing for Dynamic Waste Collection from underground Containers
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2 - The Split Delivery Capacitated Team Orienteering Problem
Grazia Speranza, University of Brescia, C.da S.Chiara 50, Brescia, Italy, speranza@eco.unibs.it, Claudia Archetti, Nicola Bianchessi, Alain Hertz

In the Capacitated Team Orienteering Problem (CTOP) a set of customers has to be identified to maximize the profit, with constraints on route duration and vehicle capacity. We study the Split Delivery Capacitated Team Orienteering Problem (SDCTOP). We show that the profit collected in the SDCTOP may be as large as twice the profit collected in the CTOP. We present a branch-and-price algorithm and two heuristics and computational results.

2 - The Driver Routing Problem
Johan Oppen, Associate Professor, Molde University College, PO Box 2110, Molde, 6402, Norway, johan.oppen@hi Molde.no

A transportation service is offered to bring people home in their own vehicles. The company uses several modes of transportation between locations. The associated planning problem can be modelled as a dynamic and stochastic Vehicle Routing Problem with multiple transportation modes. We present a mathematical model and discuss solution methods for the simplified version where all demand is known in advance.
- Anticipatory Routing of a Vehicle with Stochastic Customer Requests

Stephan Meisel, University of Braunschweig, Muehlenpfordstr. 23, Braunschweig, 38106, Germany, stephan.meisel@tu-bs.de

We consider different policies for anticipatory routing of a vehicle with stochastic customer requests. The number of requests served within the time horizon must be maximized. To this end we apply both purely heuristic policies and policies derived by approximate dynamic programming. The solution quality of the latter critically depends on the used type of value function approximation. We derive policies from different approximations and compare them with the purely heuristic approaches.

MD47
H - Dunn Room - 3rd Floor

Topics in Transportation

Sponsor: Transportation Science and Logistics

Sponsored Session

Chair: Ronald Askin, Professor and Director, Arizona State University, 699 S. Mill Avenue, Sch Compt Infor & Dec Sys Engr, Tempe, AZ, 85287-8809, United States of America, ron.askin@asu.edu

1 - Integrated Inventory Replenishment and Vehicle Routing

Ronald Askin, Professor and Director, Arizona State University, 699 S. Mill Avenue, Sch Compt Infor & Dec Sys Engr, Tempe, AZ, 85287-8809, United States of America, ron.askin@asu.edu, Mingjun Xia

We consider selecting the optimal order frequency and delivery routes for supplying multiple retailers from a single distribution center. Several VR heuristics are adapted to consider delivery frequency considerations and compared to metaheuristic approaches and a lower bound on total cost of inventory and shipping subject to customer service, vehicle capacity and tour length constraints. A modified sweep heuristic is found to provide good solutions with minimal computational requirement.

2 - A Nuclear Medicine Production and Routing Problem

Byung-In Kim, Associate Professor, POSTECH (Pohang University of Science & Technology), San 31, Hojyo-Dong, Pohang, Kyungbuk, 790-784, Korea, Republic of, bkim@postech.ac.kr, Seongbge Kim

This talk presents a nuclear medicine production and routing problem. Nuclear medicine is used in PET (Position emission tomography) scans for diagnosis, staging, and monitoring treatment of cancers. The unique characteristic of the medicine is its two-hour half-life. After production, its strength is reduced to a half in every two hours and hence production and delivery of orders should be carefully scheduled. A MIP model and a heuristic algorithm are developed for the problem.

3 - Safety Investment and Airline Accidents

Zuo zheng Wang, University of Maryland, College Park, MD, United States of America, zuowang@rhsmith.umd.edu, Martin Dresner, Christian Hofer

This study investigated how airlines choose their level of safety investment with tradeoffs between safety and economic efficiency. On one hand, airlines increase safety investment to reduce accident risk. On the other hand, the higher the cost of safety investment, the less the incentive for an airline to implement such risk mitigation. Therefore, in this research, we employ a structural model to estimate the bidirectional influence between safety investment and safety performance. Our results show that if an airline's safety expenses (i.e. total maintenance and training expenditure) per mile increase by 10%, this will decrease by 8.39% its average accident rate. For the purpose of risk analysis, the need for a proper understanding of the tradeoffs between safety and economic efficiency is demonstrated.

4 - Valuing Flexibility in the Operation of Assets in the LNG Value Chain

Peter Schütz, SINTEF Applied Economics, P.O. Box 4760 Sluppen, Trondheim, 7465, Norway, peter.schuetz@sintef.no, Ruud Eggink

We present a multi-stage stochastic programming model for planning the operations of a liquefied Natural Gas value chain. The goal is to examine the effect and monetary value of having flexibility in the system (e.g. in storage capacity or routing of vessels). We study a value chain consisting of 2 liquefiers and 3 regasifiers over a planning horizon of 3 months. We include capacity constraints and other operational characteristics combined with uncertainty in LNG and local spot market prices.
**TC47**

**H - Dunn Room - 3rd Floor**

**Ocean and Hinterland Intermodal Container Transportation**

**Sponsor:** Transportation Science and Logistics

**Sponsored Session**

**Chair:** Jan C. Fransoo, Professor, Eindhoven University of Technology, School of Industrial Engineering, P.O. Box 513, Pav F4, Eindhoven, 5600 MB, Netherlands, j.c.fransoo@tue.nl

1 - Inbound Container Storage Price Competition between the Container Terminal and Remote Container Yard

Mingzhu Yu, Hong Kong University of Science and Technology, Department of IELM, HKUST, Clear Water Bay, Kowloon, Hong Kong - PRC, julieyu@ust.hk, Chung-Yee Lee

This paper proposes inbound container storage pricing game models between the container terminal and a remote container yard. Two cases are considered: (1) the inbound container's dwell time is random and independent of the storage prices; (2) the inbound container's dwell time is sensitive to the storage prices. The primary objective is to analyze the storage pricing behavior and competition outcomes of the two players. A number of insights and analysis are provided.

2 - An Empirical Investigation of Transit Time Performance in Global Ocean Transportation

Basak Kalkanci, Postdoctoral Associate, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA, 02139, United States of America, kalkanci@mit.edu, Bruce Arntzen, Chris Caplice, Jan C. Fransoo

Due to decentralization of the supply chains across different locations, ocean transportation is merging as an extremely important component of global operations. In this study, we investigate transit time performance in ocean transportation using an empirical approach: we analyze a detailed data set on global shipment transactions of ocean carriers working with a major US company. We examine the variability in the transit times across different legs and regions and identify underlying factors.

3 - Impact of Business Models on Intermodal Network Service Design

Rob Zuidwijk, Erasmus University, Department of Decision and Information S, Rotterdam, Netherlands, r.zuidwijk@erasmus.nl

In ongoing research, we study the impact of business models on network service design for intermodal container transport. In particular, we study pricing of intermodal services in conjunction with network service design, various levels of information services, and the offering of premium services to market segments as opposed to providing a commodity service.

4 - Coordination and Analysis of Barge Container Hinterland Networks

Kristina Sharpyova, Eindhoven University of Technology, School of Industrial Engineering, P.O. 513, Eindhoven, 5600 MB, Netherlands, k.sharpyova@tue.nl, Tom Van Woensel, Jan C. Fransoo

We analyze the container hinterland supply chain from the joint perspective of the inland terminal operator and of the shipper. In the hinterland supply chain, the interests of capital-intensive terminal operators and the interests of the shippers do not coincide. Therefore, we investigate the influence of joint decision making on the total relevant costs of the parties of the hinterland supply chain. We consider the direct and the tour coordination policies.

**TD47**

**H - Dunn Room - 3rd Floor**

**Intermodal Issues in Transportation**

**Sponsor:** Transportation Science and Logistics

**Sponsored Session**

**Chair:** Srinivas Peeta, Purdue University, Nextrans Center, 3000 Kent Avenue, West Lafayette, IN, 47906, United States of America, pecta@purdue.edu

1 - Integrated Framework to Study High-Speed Rail with the Consideration of Existing Transportation Infrastructure

Jeffrey Peters, Research Assistant, Nextrans Center, 3000 Kent Avenue, West Lafayette, IN, 47906, United States of America, peters83@purdue.edu, Dan Delaurentis, Srinivas Peeta, Datu Agusdinata, En-Pei Han

This study provides a framework to study various investment, pricing, and performance characteristics of high-speed rail in the context of the existing intercity transportation infrastructure. The existing system includes highway, commercial air, and rail systems. Results will consist of sensitivity analysis based on several variables and constraints in the problem.

2 - The One Commodity Pickup-and-Delivery Traveling Salesman Problem: Feasibility and Algorithms

Binh Luong, Purdue University, 530 Stadium Mall Drive, West Lafayette, IN, 47907, United States of America, bluong@purdue.edu, Lanshan Han, Satish Ukkusuri, Michael Petri

In this paper we study the one commodity pickup-and-delivery traveling salesman problem (1-PDTSP), which is a recently proposed variant of the classic traveling sales problem (TSP). We first introduce a polynomial size integer programming formulation for the problem and then study the feasibility issue which is NP-complete by itself. In particular, we prove sufficient conditions for the feasibility of the problem and provide a polynomial algorithm to find a feasible solution. We also present a bound of the cost of the 1-PDTSP solution in terms of the cost of the TSP solution. Based on this bound, we provide approximation and heuristic algorithms for the 1-PDTSP. Extensive numerical experiments are performed to evaluate the efficiency of both the exact and approximation algorithms.

3 - Policy Analysis for Interdependent Infrastructure Systems

Jeffrey Peters, Research Assistant, Nextrans Center, 3000 Kent Avenue, West Lafayette, IN, 47906, United States of America, peters83@purdue.edu, Srinivas Peeta

Most policies which are directed at an individual infrastructure system have impacts on other infrastructure systems as well. This study introduces potential methods to evaluate and develop policy packages to address strategic goals across several infrastructure systems with interdependencies.

**WA47**

**H - Dunn Room - 3rd Floor**

**Reverse Logistics and Supply Chain I**

**Sponsor:** Transportation Science and Logistics

**Sponsored Session**

**Chair:** Ron Lembke, Associate Professor, Supply Chain Management, University of Nevada, MGRS / 0028, Reno, NV, 89557, United States of America, ronlembke@unr.edu

Co-Chair: Theresa Barker, Affiliate Assistant Professor, University of Washington, Box 352650, Seattle, WA, 98115, United States of America, barkettj@uw.edu

1 - Reverse Logistics and Carbon Footprints

Ron Lembke, Associate Professor, Supply Chain Management, University of Nevada, MGRS / 0028, Reno, NV, 89557, United States of America, ronlembke@unr.edu, Dale Rogers

Most carbon footprints metrics focus on the production and distribution aspects of the product and do not include important portions of the process such as reverse logistics and end-of-life management. In this research the authors describe several ways in which Reverse Logistics and end-of-life must be considered in computing a carbon footprint, and ways that good RL practices can actually reduce carbon usage within the firms and its supply chains.

2 - Closed-loop Supply Chain Network Configuration by Stochastic Goal Programming Approach

Saman Hassanazadeh Amin, Ph.D. candidate, University of Windsor, Department of Industrial Engineering, 401 Sunset Avenue, Windsor, ON, N9B 3P4, Canada, hassansaz@uwindsor.ca, Guojing Zhang

In this research, a generic closed-loop supply chain network is investigated which includes multiple plants, distribution centers, demand markets, collection centers, and products. To this aim, a goal programming model is proposed. Besides, the model is developed by stochastic programming (scenario-based) to consider uncertainty in goals, demands, and returns. Results of the numerical example indicate that the model can handle different sources of uncertainty, simultaneously.

3 - Reverse Logistics and Recall and Outdate Management in Healthcare Supply Chain

Vijith Malayil Varghese, University of Arkansas, 4207 Bell Engineering Center, Fayetteville, AR, 72701, United States of America, vvarge@uark.edu, Ronald Rardin, Nebil Buyurgan, Raja Jayaraman, Angelica Burbano, Nabil Lehliou, Paiman Farrokhiyar, Eghbal Rashidi

In this presentation we describe recall and outdate management practices widely adopted in healthcare supply chain and how returns are managed. We compare these practices to some of the best practices in other industries. Efficiencies gained in recall and outdate management through data standards adoption are also discussed.
Transportation Logistics and Supply Chain II

Sponsored Session

Chair: Guoging Zhang, Professor, University of Windsor, Department of Industrial Engineering, 401 Sunset Avenue, Windsor, ON, N9B3P4, Canada, gzh@guwindsor.ca
Co-Chair: Theresa Barker, Affiliate Assistant Professor, University of Washington, Box 352650, Seattle, WA, 98115, United States of America, Barker7J@uw.edu

1 - Optimal Supply Planning for a Closed Loop System with Uncertain Demand and Return

Guoging Zhang, Professor, University of Windsor, Department of Industrial Engineering, 401 Sunset Avenue, Windsor, ON, N9B3P4, Canada, gzh@guwindsor.ca, Jianmni Shi

We study the production planning problem for a closed loop system, in which the manufacturer has two channels for supplying products: producing brand-new products and remanufacturing returns into as-new ones. A mathematical model is presented to formulate the problem and a Lagrangian relaxation based approach is developed to solve the problem. Numerical examples are presented to illustrate the model and test the solution approach.

2 - Design of Integrated Forward and Reverse Logistics Networks with Time Periods

Hyangsook Lee, Rutgers University, 100 Brett Road, Piscataway, NJ, 08854, United States of America, lee.hyangsook@gmail.com, Maria Boile, Sotiris Theofanidis, Georgios Saharidis, Ti Zhang

The paper presents a facility location problem of the integrated logistics network aiming to improve the efficiency of both forward and reverse logistics. Three types of facilities are identified: warehouse (forward), collection center (reverse) and hybrid center (both). The paper proposes a nonlinear mixed integer model addressing the dynamic integrated distribution network design problem. A bi-objective model is developed to minimize the total shipping cost and time simultaneously.

3 - On the Study of Reverse Logistics Channels and Incentives in a Closed-loop Supply Chain

Dennis Z Yu, Assistant Professor, Clarkson University, 8 Clarkson Avenue, Potsdam, NY, 13699, United States of America, dyu@clarkson.edu, Chester Xiang

We study impacts of reverse logistics channel structures and incentives in a closed-loop supply chain. The business and individual demand segments show heterogeneous responses to the used-product return incentives. A third party may be used as an agent to collect used-products and exploit economies of scale. Three reverse logistics channel structures are investigated for the optimal incentive schemes, reverse logistics channel strategies, and resulting financial and social impacts.

4 - Coordinating the Discount for Purchase Quantity and Transportation in a Three-party Supply Chain

Ginger Y. Ke, University of Waterloo, 200 University Avenue West, Waterloo, ON, N2L 3G1, Canada, y3ke-engmail.uwaterloo.ca, James H. Bookbinder

This research studies the coordination of the quantity and transportation discount decisions in a supply chain system involving the buyer, supplier and carrier. More specifically, the discount decisions are analyzed from the perspectives of the parties who offer the discount, rather than the one that takes them. The improvements of system performance obtained from several different models are observed and compared to achieve further understandings of the coordination.

Applications of Location Routing Problems

Sponsor: Transportation Science and Logistics

Chair: Shirley Rong Li, PhD Candidate, The University of Alabama, 803, 12th Avenue, RM 10, Tuscaloosa, AL, 35401, United States of America, rl4@crimson.ua.edu

1 - Analysis of a Complex Location Routing Problem

Stephen Hill, Assistant Professor, Weber State University, 3802 University Circle, Ogden, UT, 84408-3802, United States of America, stephenhill@weber.edu, John Mittenhal

In this work we consider a complex product distribution problem that features facility location decisions. This problem is inspired by a real-world problem instance faced by a magazine publisher located in the southeastern United States. We present a heuristic solution approach and demonstrate the effectiveness of the heuristic via a set of computational experiments. Opportunities for future work are identified and discussed.

2 - Minimizing Redeployment in Ambulance Location Models

Cem Saydam, Professor, UNC Charlotte, 9201 Univ City Blvd., Charlotte, NC, 28223, United States of America, saydam@uncw.edu, Hari Rajagopalan, Elizabeth Sharer, Kay Lawrimore

Demand for ambulances fluctuates spatially and temporally. Recent advances in computing enabled IEMS managers to practice dynamic redeployment plans. In this paper we address the issue of redeployment and minimal fleet sizes by explicitly considering the number of redeployment trips to be made while meeting the coverage requirements and develop fast heuristics.

3 - Bi-criteria Dynamic Location-Routing Problem for Patrol Coverage

Shirley Rong Li, PhD Candidate, The University of Alabama, 803, 12th Avenue, RM 10, Tuscaloosa, AL, 35401, United States of America, rl4@crimson.ua.edu, Burcu Keskin

This paper addresses a multi-period dynamic location-routing problem. Specifically, we design patrol routes for a fixed number of state trooper cars. The routes start from a subset of given potential stations (PS) and cover critical locations with high crash frequencies. Furthermore, the selected PS may change from one period to the other. The objective is to maximize coverage benefit while minimizing costs. For this problem, we develop a MILP solve it using heuristics, and provide insights.

4 - Near-optimal Heuristics and Managerial Insights for the Storage Constrained, Inbound Inventory Routing

Malini Natarajarathinam, Assistant Professor, Texas A&M University, 3367 TAMU, College Station, TX, 77843, United States of America, malini@enr.tamu.edu, Jennifer Stacey, Charles Sox

We develop efficient heuristics for determining the route design and inventory management of inbound parts which are delivered for manufacturing, assembly, or distribution operations that have limited storage space for these parts. The shipment frequencies and quantities are coordinated with the available storage space and the vehicle capacities.

5 - Hybrid Heuristic Algorithm for the Capacitated Multi-Echelon Shipping Network Scheduling Problem with Delivery Deadlines

Gang Gabriel Wang, Rutgers, The State University of New Jersey, 1 Washington Park, Newark, NJ, 07102, United States of America, gangwang@pegasus.rutgers.edu, Lei Lei

We study the problem of scheduling a capacitated supply chain network with delivery deadlines. This problem is computationally difficult since it contains generalized assignment problem as a sub problem. We introduce a hybrid heuristic algorithm based on first-fit decreasing, our proposed special case and LP relaxation. This heuristic allows us to avoid dealing with the generalized knapsack problem directly. Empirical observations from over 500 randomly generated test cases are also reported.

Integrated Models for Supply Chain and Logistics Planning

Sponsor: Transportation Science and Logistics

Chair: Aly Megahed, PhD Student, Research and Teaching Assistant, H. Milton Stewart School of Industrial and Systems Engineering, Georgia Institute of Technology, 765 Frist Drive, NW, Atlanta, GA, 30332, United States of America, aly@gatech.edu

1 - A Comprehensive Tactical Supply Chain Planning Model Using Backorder Penalties

Aly Megahed, PhD Student, Research and Teaching Assistant, H. Milton Stewart School of Industrial and Systems Engineering, Georgia Institute of Technology, 765 Frist Drive, NW, Atlanta, GA, 30332, United States of America, aly@gatech.edu, Marc Goetschalckx

We present a comprehensive model for the tactical planning of multi-echelon, multi-commodity supply chains. The model includes production, transportation, inventory, and sourcing considerations as well as a fully recursive bill of materials for the products and backorder penalties for delay deliveries. Numerical experience with solving this model for various cases including a real-world problem instance, is shared. The impact of various cost functions for the backorder penalties is illustrated.
2 - Metaheuristic Solution Algorithms for a Four-layer Location-routing Problem
Mohsen Hamidi, North Dakota State University, Industrial & Manufacturing Engineering, NDSU Department 2485, Fargo, ND, 58108-6090, United States of America, mohsen.hamidi@ndsu.edu, Kambiz Farahmand, S. Reza Sajjadi, Kendall Nygard
The location-routing problem (LRP) simultaneously considers location, allocation, and vehicle routing decisions to design optimal distribution networks. In this research, metaheuristic solution algorithms for solving a complex four-layer LRP are developed. The four-layer LRP represents a multi-product distribution network consisting of plants, central depots, regional depots, and customers. The LRP integrates location, allocation, vehicle routing, and transshipment problems.

3 - A Capacitated One Warehouse Multi-Retailer Lot-Sizing Problem
Burcu Keskin, University of Alabama, 361 Stadium Dr., Tuscaloosa, AL, 35406, United States of America, bkeskin@ua.edu, John Mittenhal
In this paper, we study a capacitated lot sizing problem (CLSP) for a one warehouse multi-retailer system. Even though the CLSP has been studied in the production context, it has limited coverage in a distribution context. We present a formulation of this problem and investigate the structural properties of the optimal solution. We also develop mathematical programming-based and greedy heuristics. Numerical analysis demonstrates the effectiveness of the solutions in different settings.

4 - A Two-stage Stochastic Programming Model for Transportation Infrastructure Design and Retrofit
Shahrzad Azizzadeh, PhD Candidate, North Carolina State University, 346 Daniels Hall, Raleigh, NC, 27695, United States of America, sazizza@ncsu.edu, Ranji Ranjithan
Natural hazards often disrupt critical lifeline services supported by the transportation infrastructure. A two-stage stochastic programming model is presented to optimize system capacity and recourse decisions considering service demands and many failure scenarios. Two mixed-integer formulations are discussed and an L-shaped decomposition solution approach is presented.

WE47
Policy Analyses for Freight Transportation and Logistics
Sponsor: Transportation Science and Logistics
Sponsored Session
Chair: Ahmad Jarrah, Associate Professor, The George Washington University, Department of Decision Sciences, Washington, DC, United States of America, jarrah@gwu.edu
1 - Operational Changes versus External Policies for Cost and Emissions Reductions
Anne Goodchild, Assistant Professor, Washington University, Civil and Environmental Engineering, Seattle, WA, United States of America, anngood@washington.edu, Felipe Sandoval
Two pick-up and delivery companies are used as case studies to examine the relative impact of operational changes versus external policies on cost, emissions, and service quality. It is found that both cost and emissions can be reduced through internal changes, whereas external policies do not simultaneously improve cost and emissions.

2 - A Statistical Process Control System for Infrastructure Performance Monitoring
Pablo Durango-Cohen, Associate Professor, Northwestern University, 2145 Sheridan Road, A332, Evanston, IL, 60208, United States of America, pdc@northwestern.edu, Yukai Chen, David Corr
Statistical process control has been widely used to monitor the performance of manufacturing and financial systems. Such systems alert decision makers of systematic, temporary or permanent changes. In this presentation we discuss the development of a framework to monitor transportation infrastructure, and present results from an implementation on The Hurley Bridge (Wisconsin Structure B-26-7).

3 - Shipment Consolidation Policy Analysis with Stepwise Freight Costs
Dincer Konur, Industrial and Systems Engineering, University of Florida, Gainesville, FL, United States of America, dincer@ufl.edu, Joseph Geunes
We analyze shipment consolidation policies that explicitly account for transportation costs, including per-truck capacity and variable costs. We use a set partitioning formulation, where each element of the partition corresponds to the subset of consolidated items. We apply a branch-and-price approach and propose heuristic methods for solving the resulting nonlinear set partitioning problem.

SB48
Innovations in Pricing and Financing of Transportation Systems: I
Sponsor: Transportation Science and Logistics
Sponsored Session
Chair: Yaleng Yin, University of Florida, 365 Weil Hall, Gainesville, FL, 32611, United States of America, yaleng@ufl.edu
1 - Urban Delivery Industry Response to Pricing and Incentives: The NYC Off-Hour Delivery Project
Jose Holguin-Veras, Rensselaer Polytechnic Institute, 110 8th St Room JEC 4030, Troy, NY, 12180, United States of America, jhv@rpi.edu
This presentation discusses the analytical formulations developed to analyze the urban delivery industry response to pricing and financial incentives. In the second part of the presentation, the author presents the key results of a path breaking pilot test conducted in NYC that confirmed the results anticipated by theory.

2 - Robust and Dynamic Congestion Pricing
Tao Yao, Assistant Professor, The Pennsylvania State University, 349 Leonhard Building, University Park, PA, 16802, United States of America, tyy1@engr.psu.edu, Byung Do Chung, Terry Friesz
We formulate robust dynamic congestion pricing problem under demand uncertainty as a mathematical programming with equilibrium constraints (MPEC) and propose a new solution approach to solve the problem.

SB48
Innovations in Pricing and Financing of Transportation Systems: II
Sponsor: Transportation Science and Logistics
Sponsored Session
Chair: Siriphong (Toi) Lawphongpanich, University of Florida, Industrial & Systems Engineering, 303 Weil Hall, Gainesville, FL, 32611, United States of America, lawphong@ise.ufl.edu
1 - Transaction Cost and Tradable Mobility Rights
Yu (Marco) Nie, Northwestern University, Civil and Environmental Engineering, 2145 Sheridan Road, Evanston, IL, 60208-3109, United States of America, y-nie@northwestern.edu
Artificial markets for tradable mobility rights have been proposed as an alternative to conventional congestion pricing schemes. This paper examines the effects of transaction costs on two types of markets: a centralized market which is created by the government to simply auction off mobility rights; and a more decentralized market in which users trade with each other their initial endowment of mobility rights initially distributed by the government.

2 - Self-financed Optimal Incentive for Staggered Work Hours
Jeff Ban, Rensselaer Polytechnic Institute, 110 8th Street, Troy, NY, United States of America, banx@rpi.edu, Wilfredo Yushimoto, Jose Holguin-Veras
We present a multi-level formulation for finding the optimal incentive to induce firms to assign workers outside of the regular peak-hour. The model requires the transportation planner to be at the highest level seeking to reduce the system travel time and financing the incentive with the tolls collected in the network. Team behavior and Dynamic User’s Equilibrium are at the lower levels. In addition, a solution approach is presented and some initial results are discussed.
3 - Welfare Analysis of Vehicle Ownership-use Rationing and Congestion Pricing Policies
Shanjiang Zhu, Assistant Research Scientist, University of Maryland, Department of Civil & Environmental Engineering, 1173 Glenn Martin Hall, College Park, MD, United States of America, zhunx120@umd.edu, Longyuang Du, Lei Zhang
Vehicle ownership and/or use rationing, recently implemented in cities such as Beijing, Shanghai, and Mexico City as a travel demand and congestion management tool, has not been adequately studied. This research develops an analytical model and applies welfare analysis methods to evaluate vehicle ownership rationing and vehicle use rationing policies. The effectiveness of these rationing policies is also compared to that of congestion pricing.

4 - Optimal Selection of Build-operate-transfer Projects on Transportation Networks
Di Wu, University of Florida, 518C Well Hall, University of Florida, Gainesville, FL, 32611, United States of America, wudi@ufl.edu, Yafeng Yin, Siriphong (Toi) Lawphongpanich
This paper considers the problem of how to select highway projects for the build-operate-transfer development with the objective of improving the social benefit while ensuring the marketability of those selected. The problem can be viewed as a tri-level leader-follower game and is formulated as a mixed integer program with equilibrium constraints. By investigating its unique property, we develop an efficient heuristic algorithm for solving the project selection problem.

SC48 H - Graham Room - 3rd Floor
Advances in Traffic Equilibrium
Sponsor: Transportation Science and Logistics
Sponsored Session
Chair: N. Nezamuddin, University of Texas at Austin, 1 University Station C1761, ECJ 6.512, Austin, TX, 78712, United States of America, nezam@mail.utexas.edu
1 - Investigating the Performance of Path-based Algorithms for the Static User Equilibrium Traffic Assignment Problem
Amit Kumar, Graduate Research Assistant, Purdue University, Nextran Center, 3000 Kent Avenue, West Lafayette, IN, 47906, United States of America, kumar44@purdue.edu, Srinivas Peeta, Yu (Marco) Nie
This study investigates the relative performance of path-based algorithms for the static user equilibrium problem for networks of different size using three approaches: simultaneous approach, one origin to all destinations approach, and the sequential approach. Computational experiments are performed to compare the noise in the solution at the same level of convergence using the three approaches for each algorithm.
2 - A Combinatorial Algorithm and Warm Start Method for Multi-destination Dynamic User Optimal Problem
N. Nezamuddin, University of Texas at Austin, 1 University Station C1761, ECJ 6.512, Austin, TX, 78712, United States of America, nezam@mail.utexas.edu, Travis Waller
A polynomial combinatorial algorithm for multi-destination dynamic user optimal problem is developed. The algorithm is stated on a time-expanded cell transmission model (CTM) network; CTM ensures that traffic dynamics are adequately captured. Output of the combinatorial model is used to warm start a simulation-based dynamic traffic assignment (DTA) model. The combinatorial model complements simulation-based DTA models in implementing various policy measures and active traffic control strategies.
3 - Shipment Dispatching on Capacitated Networks
Chinmoy Mohapatra, University of Texas at Austin, 1 University Station, Austin, TX, 78712, United States of America, chinmoym@mail.utexas.edu, Anantaram Balakrishnan, Brian Roth
Motivated by shipment dispatching decisions in transportation, we address the problem of assigning shipments to scheduled transport services that share common capacitated resources so as to minimize total transit time. At each node, shipments that use the same outbound service are dispatched in first-in-first-out order. We discuss modeling and algorithmic enhancements to effectively solve this large-scale integer program, and present computational results for actual problem instances.
4 - Road Network Privatization: Alternative Approaches and a Hybrid Modeling System
Lei Zhang, Assistant Professor, University of Maryland, 1173 Glenn Martin Hall, College Park, MD, 20742, United States of America, leiz5@umd.edu, Shanjiang Zhu, Dilya Yusufzyanova
This research develops a hybrid modeling system to analyze alternative approaches for road network privatization. The hybrid method synergizes the strengths of mathematical programming models in representing optimizing behavior and the advantages of rule/agent-based techniques in simulating dynamic interactions on dissimilar time scales in large complex systems. Two popular road privatization schemes, namely private-sector takeover of existing roads and new private toll roads, are analyzed.

SD48 H - Graham Room - 3rd Floor
Advances in Dynamic Network Modeling
Sponsor: Transportation Science and Logistics
Sponsored Session
Chair: Carolina Osorio, Assistant Professor, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Office 1-232, Cambridge, MA, 02139, United States of America, osorioc@mit.edu
1 - Dynamic Network Loading: A Differentiable Approach that Yields Queue-length Probability Distributions
Carolina Osorio, Assistant Professor, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Office 1-232, Cambridge, MA, 02139, United States of America, osorioc@mit.edu, Gunnar Flottneröd, Michel Bierlaire
We present a dynamic network loading model based on transient finite capacity queueing theory. This differentiable model yields queue length distributions, accounts for spillover effects and captures the spatial correlation of all queues adjacent to a node. We compare the model to the kinematic wave model considering several congestion regimes. The model correctly represents the dynamic build-up, spillover, and dissipation of queues, and generates a plausible fundamental diagram.
2 - Price of Anarchy in Dynamic Network Equilibrium: Numerical Analysis
Kien Doan, Graduate Student, Purdue University, 550 Stadium Mall, West Lafayette, IN, 47907, United States of America, kdoan@purdue.edu, Satish Ukkusuri, Lanshan Han
In this study, we explore the price of anarchy in dynamic network assignment models. The inefficiency of the system is measured by the total cost difference between the system optimal assignment and the user equilibrium solution. We examine the worst case of inefficiency by testing various scenarios for single O-D and multiple O-D networks under different traffic patterns. Insights into the worst case inefficiencies and possible mechanism designs to minimize the price of anarchy will be discussed.
3 - Trajectory-adaptive Routing in Dynamic Networks with Dependent Random Link Travel Times
Song Gao, Assistant Professor, University of Massachusetts Amherst, 130 Natural Resources Road, 214C Marston Hall, Amherst, MA, 01003, United States of America, songgao@ecs.umass.edu, He Huang
Trajectory information is the least amount of information one can collect en route. This study addresses the optimal adaptive routing problem in a stochastic time-dependent network, where all link travel time random variables are correlated and the routing decisions are adaptive to trajectory information. Bellman’s principle is shown invalid for optimality and non-dominance. An exact algorithm is designed based on a new property termed purity, for which Bellman’s principle holds.
4 - Disequilibrium to Equilibrium for Transportation Networks with Fixed Demand and Representation of Day-to-Day Dynamics
Amit Kumar, Graduate Research Assistant, Purdue University, Nextran Center, 3000 Kent Avenue, West Lafayette, IN, 47906, United States of America, kumar44@purdue.edu, Srinivas Peeta
We develop a mathematical formulation to represent the change in path flows resulting from the day-to-day dynamics in the state of disequilibrium of transportation network. A flow update technique is presented to obtain the equilibrium flows from disequilibrium flows. The solution methodology is discussed and computational results are presented for a test network.
5 - Bi-directional Car-following Models for Microscopic Control between Connected Vehicles
Jing Jin, University of Wisconsin-Madison, 1415 Engineering Drive, Madison, WI, United States of America, jjin2@wisc.edu

This paper explores the bi-directional car-following models, which consider the impact from both preceding and following vehicles. These models can be used for microscopic speed coordination between vehicles under the connected vehicle environment. Seven bi-directional models are developed based on existing car-following models. Field trajectory data are used to calibrate and evaluate the control characteristics of the proposed models.

3 - Equity Effect of Tradable Driving Credit Scheme
Di Wu, University of Florida, 518C Weil Hall, University of Florida, Gainesville, FL, 32611, United States of America, wdul@ufl.edu, Yafeng Yin, Hai Yang

This paper analyzes the equity effect of a tradable driving credit scheme in a general multimodal transportation network. Under the scheme, the transportation authority distributes credits to travellers and then charges certain credits for driving. The credits can be traded freely among travelers at a market-determined price. By optimally designing the initial credit distribution and a credit charging scheme, this paper attempts to reduce congestion and simultaneously improve social equity.

4 - Differentiated Congestion Pricing of Urban Transportation Networks
Mahmood Zangui, PhD Student, University of Florida, 518-B Weil Hall, Gainesville, FL, 32608, United States of America, mzungui@ufl.edu, Yafeng Yin, Siriiphong (Toi) Lawphongpanich

In the literature, the focus on congestion pricing has been on anonymous schemes, i.e., one that charge every user the same amount of toll regardless of his or her travel or social characteristics. This paper explores a new type of non-anonymous scheme that differentiates users with respect to their travel characteristics and charges them different amount of toll accordingly. The scheme can reduce the financial burden of travelers or lead to more substantial reduction of traffic congestion.

H - Graham Room - 3rd Floor
Advances in Traffic Networks
Sponsor: Transportation Science and Logistics
Sponsored Session
Chair: Yi-Chang Chiu, Associate Professor, Department of Civil Engineering and Engineering Mechanics, 1209 E 2nd Street, Tucson, AZ, 85721, United States of America, ylou@u.arizona.edu, Yi-Chang Chiu, Hong Zheng

1 - Optimization of Work-zone Scheduling with Traffic Equilibrium
Hong Zheng, Postdoc Researcher, University of Arizona, 1209 E. Second Street, Tucson, AZ, 85721-0072, United States of America, hzheng@email.arizona.edu, Yi-Chang Chiu, Chengdong Cai, Vinayak V. Dixit, Eric Nava, Essam Radwan

In this research, we present an optimization model of work zone scheduling to minimize traffic delay (user costs) considering traffic divergence. The developed method considers day and night effects as well as agency costs. We use an approximation approach to estimate the new user equilibrium (UE) travel time under divergence to calculate the traffic delay, instead of solving UE from scratch to speed up computational time. A numerical example is presented.

2 - A Routing Behavior Model for Vacant Taxi Cabs in Urban Traffic Networks
Song Gao, Assistant Professor, University of Massachusetts Amherst, 130 Natural Resources Road, 214C Marston Hall, Amherst, MA 01003, United States of America, songgao@ecs.umass.edu, Yi-Chang Chiu, Dung-Ying Lin, Xianbiao Hu

In this research, we propose a vacant taxi routing model that is conceived based on the above behavior propositions, where taxi drivers are assumed to minimize expected search time for customers when making routing decisions at intersections. A probabilistic dynamic programming formulation of the problem and the solution algorithm are presented. We conduct numerical analysis on a hypothetical network inspired by the traffic network structure in the City of Taipei. The outcome of this study has shed light on routing decisions of taxi drivers, which will directly support area-wide traffic management. Further research on how to incorporate ITS technologies such as taxi fleet GPS data to effectively collect vehicle position, action, and behaviour data for model calibration is also discussed.

3 - Modeling Within-day Activity Rescheduling Decisions Considering Time-varying Network Conditions
Yunemi Jang, University of Arizona, Tucson, AZ, United States of America, Yunemi@gmail.com, Yi-Chang Chiu, Hong Zheng

In this talk, we present a utility maximization activity schedule adjustment decision approach to estimate the new user equilibrium (UE) travel time under divergence to calculate the traffic delay, instead of solving UE from scratch to speed up computational time. A numerical example is presented.

4 - On the Solution of the Boundedly Rational User Equilibrium (BRUE)
Henry Liu, Associate Professor, University of Minnesota, Minneapolis, MN, United States of America, henryliu@umn.edu, Xuan Di, Jong-Shi Pang, Jeff Ban

This study proposes an enhanced stochastic user equilibrium model where drivers' perceptions of travel times are considered bounded. Closed-form expressions of the route choice probability functions are derived for multiple types of distributions of perceived travel times. The resulting flow pattern and its implications in the context of transportation planning are examined. The relationship between the proposed model and several other traffic assignment models is also explored.

MB48
H - Graham Room - 3rd Floor
Advances in Traffic Networks
Sponsor: Transportation Science and Logistics
Sponsored Session
Chair: Yi-Chang Chiu, Associate Professor, Department of Civil Engineering and Engineering Mechanics, 1209 E 2nd Street, Tucson, AZ, 85721, United States of America, ylou@u.arizona.edu, Yi-Chang Chiu, Hong Zheng

1 - Optimization of Work-zone Scheduling with Traffic Equilibrium
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This paper presents an integrated travel demand modeling problem, which is the fixed-point equilibrium travel demand model over multimodal transportation networks. The model is characterized by random noise terms to deterministic equations, which could lead to negative traffic densities and mean dynamics that are inconsistent with the original deterministic dynamics. To address these issues, we will present a new stochastic model of traffic flow that accounts for the variability of travel demand.

1 - Numerical Analysis of Dynamic Traffic Information under Vehicle to Vehicle Communications
Yong Hoon Kim, Purdue University, 3000 Kent Avenue, West Lafayette, IN, United States of America, kim523@purdue.edu

We analyze the characteristics of dynamic traffic information in V2V Communications with different physical network, demand, and market penetrations. An efficient searching algorithm in V2V Communication Information Map is used to identify the dynamic traffic information. Numerical experiments are used to test the data quality and spatio-temporal coverage. Insights will be illustrated by comparing the data obtained through the V2V Communications and the field data.

2 - Modeling Individual Activity Patterns Using Online Social Media Data
Samiul Hasan, PhD Student, Purdue University, 505 Stadium Mall Drive, West Lafayette, IN, 47906, United States of America, hassan1@purdue.edu, Satish Ukkusuri

Individual mobility is a fundamental need of all societies to participate in a wide variety of activities including work and leisure. Geo-locations shared by the users of social media offer us access to patterns of human activity choices and locations at a level unimaginable before. In this work we seek to develop models inferring individual activity patterns from geo-location data shared by the users of online social media.

3 - Graph Theoretical Modeling for the Dynamic Traffic Information Update Problem under Vehicle-to-Vehicle Communications
Yong Hoon Kim, Purdue University, 3000 Kent Avenue, West Lafayette, IN, United States of America, kim523@purdue.edu, Satish Ukkusuri

This study proposes a graph theoretical approach to identify the dynamic traffic information update under V2V Communications. We represent comprehensive descriptions of the structural and functional organization of V2V Communication Information Map, which provides important implications of relationships with traffic network. Illustrative numerical examples are presented to demonstrate the proposed approach, as well as the data structures of V2V Communication Information Map.

4 - A Stochastic Model of Traffic Flow
Henry Liu, Associate Professor, University of Minnesota, Minneapolis, MN, United States of America, henryliu@umn.edu, Saif Jabari

In a variety of applications of traffic flow, one requires a probabilistic model of traffic flow. The usual approach to constructing such models involves the addition of random noise terms to deterministic equations, which could lead to negative traffic densities and mean dynamics that are inconsistent with the original deterministic dynamics. In this talk, we will present a new stochastic model of traffic flow that addresses these issues.
3 - Robust Control for Traffic Networks: The Near Bayes Near Minimax Strategy
Nathan H. Gartner, Professor, University of Massachusetts Lowell, Department of Civil and Environmental Eng., One University Avenue, Lowell, MA, 01854, United States of America, Nathan.Gartner@uml.edu, Lee Jones, Rahul Deshpande, Chronis Stamatiadis, Pei Zou
This paper addresses the problem of determining robust signal controls in a traffic network which (a) consider the interdependency of signal controls and flow patterns and (b) account for the variability or uncertainty in the origin-destination demands. The approach taken is to consider the uncertainty in the origin-destination demands concurrently with the design changes to produce a “best” control strategy that readily accounts for this uncertainty.

4 - Vehicle Queue Location Estimation of Signalized Intersections Using Sample Travel Times from Mobile Sensors
Hao Peng, Rensselaer Polytechnic Institute, 110 Eighth Street, Troy, NY, 12180, United States of America, haop@rpi.edu, Jeff Ban
We discuss how sample intersection travel times can be used to estimate the location of a (queued) vehicle in the queue of a traffic signal. The method focuses on the queue discharging process when the signal turns green and thus does not impose any assumption on the vehicle arrival process at the intersection.

5 - Microscopic Traffic State Estimation Based on a Stochastic Three-detector Approach
Wen Deng, Visiting Student, University of Utah, 110 Central Campus Dr, Salt Lake City, UT, 84112, United States of America, wendengwen@gmail.com, Xuesong Zhou
We extend Newell’s deterministic three-detector model to a stochastic case through a novel use of Clark’s approximation method for Probit functions. Linear measurement equations are constructed to estimate evolution of cell-based microscopic traffic states by using data sources from point, AVI and mobile probe sensors.

■ TB48

H - Graham Room - 3rd Floor

IT and Sensors
Sponsor: Transportation Science and Logistics
Sponsored Session
Chair: Tao Xing, PhD Candidate, University of Utah, 110 Central Campus Dr, MCE 2000, Salt Lake City, UT, 84112, United States of America, tao.xing@utah.edu

1 - On a Two-stage Time-dependent OD Calibration Methodology for Matching Link Counts and Speed Profile
Xianbiao Hu, University of Arizona, Tucson AZ, Yi-Chang Chiu, Xianbiao Hu, University of Arizona, Tucson AZ, Yi-Chang Chiu
Adjusting time-varying OD matrices to match both observed link counts and speed profile has been a challenging problem for calibrating dynamic traffic assignment (DTA) models. The proposed two-stage approach integrates optimization and traffic flow theory for effective and efficient model calibration. Model formulation and numerical testing results are presented.

2 - Variable Time Discretization for Time-Dependent Shortest Path Algorithms
Ye Tian, University of Arizona, 1127 E. James E. Rogers Way, Tucson, AZ, 85721, United States of America, tianye0112@gmail.com, Yi-Chang Chiu, Yang Gao
This talk introduces a variable time discretization strategy for a time-dependent A* shortest path algorithm. The strategy is aimed at determining the optimal memory allocation for time-dependent travel times data in order to achieve a desirable compromise between accuracy and memory usage. The results show that with the same amount of computer memory usage, the proposed variable time discretization strategy achieves much higher accuracy than that of uniform time discretization.

3 - A Linear-Integer Programming Model for Sensor Location Flow-Estimation Problem
Ning Wang, Arizona State University, 1710 S. Jentilly Ln Apt26, Tempe, AZ, 85281, United States of America, twang14@asu.edu
In traffic network modeling, Origin-Destination (OD) matrix is usually estimated for the purpose of providing high-quality input for some decision making procedures. Since a lot of OD matrix estimation models depend on the link flow observations from counting sensors, which can only be located on limited number of links in the traffic network, a mixed integer programming model is proposed to find a location solution, which can provide good result in OD matrix estimation models.

4 - Designing Heterogeneous Sensor Networks for Estimating and Predicting Path Travel Time Dynamics: An Information-Theoretic Modeling Approach
Tao Xing, PhD Candidate, University of Utah, 110 Central Campus Dr, MCE 2000, Salt Lake City, UT, 84112, United States of America, tao.xing@utah.edu
We present an information-theoretic sensor location model that aims to maximize information gains from a set of point, point-to-point and probe sensors in a traffic network. The methods are developed and demonstrated within a Kalman filtering-based travel time estimation/prediction framework for both recurring and non-recurring traffic conditions.

■ TC48

H - Graham Room - 3rd Floor

ITS and Traffic Simulation
Sponsor: Transportation Science and Logistics
Sponsored Session
Chair: Kien Doan, Graduate Student, Purdue University, 550 Stadium Mall, West Lafayette, IN, 47907, United States of America, kdoan@purdue.edu

1 - Simulation Based Multi-Objective Optimization: An Application in Metal Casting
Cem Celal Tutum, Assistant Professor, Technical University of Denmark, Produktionstorvet 423, Kgs. Lyngby, 2800, Denmark, cctu@mek.dtu.dk, Himanshu Jain, Kalaynmyo Deb, Jesper Thorborg, Petr Kotas, Jesper Hattel
In this paper, a multi-objective optimization problem is defined for a steel cast part where the riser and the chill design is being optimized based on thermal simulations. The two objectives are maximization of the casting yield and minimization of the shrinkage porosity. Consequently, a postoptimality study is manually performed to find out some common design principles among multiple design solutions.

2 - Comparative Investigation of Novel Control Strategies with an Agent Based Model
Adbul Aziz, PhD Student, Purdue University, 150 Arnold Dr., Apt #15, West Lafayette, IN, 47906, United States of America, hass@purdue.edu, Satish Ukkusuri, Kien Doan
This work presents an implementation of adaptive signal control schemes in an agent based traffic flow model. Java based simulation tool Repast-S has been used to develop signal control framework within an agent based traffic flow model that considers approximate predictive dynamic user equilibrium. Different adaptive signal control algorithms are implemented with real world test networks and results are compared with other available simulators: Green-Light-District (agent based) and VISSIM.

3 - A RP/SP Combined Framework for Quantifying the Qualitative Benefits of Real-time Travel Information on Individual Travelers
Dong Yoon Song, Research Assistant, Purdue University (Nextrans Center), 3000 Kent Avenue, West Lafayette, IN, 47906, United States of America, song50@purdue.edu, Srinivas Peeta
In this study, we seek to identify and quantify the qualitative benefits of real-time travel information provided through Advanced Traveler Information Systems (ATIS) on individual drivers in addition to the commonly analyzed quantitative benefits (e.g., travel time savings). Stated and revealed preference data will be utilized in behavioral analysis to address psychological impacts on different groups of travelers as well as the corresponding quantitative impacts of information.

4 - A Heuristic Scheme for the Heterogeneous Vehicle Routing Problem on Trees based on Generalized Assignment and Bin-packing Upper Bounds
Roshen Kumar, University of Texas at Austin, Austin, TX, United States of America, roshen@mail.utexas.edu, Avinash Umkirishnan, Travis Waller
A heuristic method for solving the Heterogeneous Vehicle Routing Problem on Tree networks (HtVRP) is presented here. The Generalized assignment problem and the bin-packing problem are sub-problems of the HtVRP. A heuristic that exploits this relation and the tree structure of the problem is proposed. Numerical experiments are conducted to evaluate the efficiency of the proposed heuristic.
In this study we show how traffic metering in urban transportation networks can potentially improve network efficiency in oversaturated condition. A Genetic Algorithm based method has been developed to determine near optimal signal timing parameters for different metering strategies. Network performance measures such as delay, throughput, number of trips, and fuel consumption are determined for different metering strategies, and are compared to find the best strategy.
2 - A Newton-type Algorithm for Dynamic Traffic Assignment
Steve Boyles, University of Wyoming, 1000 E. University Avenue, Laramie, WY, 82071, United States of America, sboyles@uwyo.edu, Ruoyu Liu
Algorithms based on Newton-type flow shifts lead to rapid convergence for static traffic assignment; this project considers its application to dynamic traffic assignment based on the cell transmission model. Although a convex programming formulation is unavailable, path travel time derivatives can be used to generate shifts among paths. Properties of the cell transmission model are used to calculate these derivatives, and convergence properties are studied.

3 - Simulation-based Optimization for Urban Traffic Management
Carolina Osorio, Assistant Professor, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Office 1-232, Cambridge, MA, 02139, United States of America, osoricio@mit.edu, Michel Bierlaire
We present a simulation-based optimization framework that allows urban traffic simulators to be used in a tractable manner for optimization. The metamodel approach combines information from the simulator and an analytical network model. We resort to a derivative-free trust region algorithm. We evaluate the performance of the method with a signal control problem for the city of Lausanne. This method is computationally efficient and suitable for problems with tight computational budgets.

3 - Sustainable Public Transportation Systems
Maximilian M. Etschmaier, GME International Corporation, 2702 Berryland, Oakton, VA, 22114, United States of America, etschmaier@cox.net
This paper argues that the key to sustainability of public transportation systems is in the sustainment of the asset base. It will show that an approach that emanated from airlines many years ago, combined with object-based modeling, has been used to develop a new quantitative model that can lead to sustainable public transportation. Using object-based programming, this model is directly translated into systems for simulating, optimizing, and controlling public transportation systems, including airlines, public transit, and railroads.

4 - Energy Consumption Efficiency in Multimodal Transportation Networks
Lili Du, Research Associate, NEXTRANS, Purdue University, 3000 Kent Avenue, West Lafayette, IN, United States of America, ldu@purdue.edu, Srinivas Peeta, Dengfeng Sun, Peng Wei
This study proposes a bi-level mathematical model to optimize the operation of a multimodal transportation network by enhancing the system energy consumption efficiency. It captures the interactions between the multimodal transportation network (supply) and intermodal trips (demand). A customized branch-and-bound solution methodology and the sensitivity analysis for the key factors are discussed.

SA51
H - Caldwell Room - 3rd Floor
Shared Mobility Systems I
Sponsored Session
Chair: Tal Raviv, Tel Aviv University, Ramat Aviv, Tel Aviv, 69978, Israel, talraviv@eng.tau.ac.il
1 - Anticipating Usage Patterns in the Design of Bike-sharing Systems
Patrick Vogel, University of Braunschweig, Decision Support Group, Muehlenforststraße 23, Braunschweig, Germany, p.vogel@tu-bs.de, Dirk C. Mattfeld
A common issue observed in Bike-sharing systems is imbalances in the distribution of bikes. We refer to Data Mining to gain insight into typical usage patterns of Bike-sharing systems. Alleviating imbalances by means of bike repositioning is expensive. Our aim is to support design decisions with regards to the establishment of bike infrastructure, considering costs due to a certain service level. Operational usage patterns are anticipated and incorporated in a strategic location planning model.

2 - The Right Size of Bike Rental Stations
Tal Raviv, Tel Aviv University, Ramat Aviv, Tel Aviv, 69978, Israel, talraviv@eng.tau.ac.il, Edison Avraham, Ofer Kolka
A method to decide upon the size of a station in a bike sharing system based on forecasted demand pattern and assuming a static repositioning policy is presented. It can be used to determine the minimal number of stalls required so to meet some pre-specified service level or, alternately, to determine the optimal allocation of stalls among the stations in the system assuming a given budget. A case study that is based on data collected from Capital Bikeshare, Washington DC is reported.

3 - Bicycle-sharing System: Deployment, Utilization and the Value of Re-distribution
I-Lin Wang, Associate Professor, National Cheng Kung University, Dept. of Industrial & Information Management, Tainan 701, Taiwan - ROC, ilinwang@mail.ncku.edu.tw, Mabel Chou, Qizhang Liu, Jia Shu, Chung Piaow Teo
We develop practical OR models to support decision making in the design and management of bicycle sharing systems. Using estimates of demand for bicycles between stations in each time period, we develop a model to predict the bike flow, estimate the number of trips supported by the system given an initial allocation of bicycles at each station, the number of docks needed in each station; and also examine the viability of periodic re-distribution of bicycles in the network to support more flows.

4 - Sizing, Incentives and Regulations in Bike-sharing Systems
Christine Fricker, INRIA, Domaine de Voluceau, Rocquencourt, Le Chesnay, 78153, France, christine.fricker@inria.fr, Nicolas Gast
We model including the rental station size in homogeneous bike sharing systems is proposed. Closed form results are obtained for the large system behavior. The influence of the parameters and some load balancing strategies on the proportion of problematic stations is discussed. Simple incentives to choose the station to return the bike may improve dramatically the performance. An non-homogeneous scenario is also investigated, where incentives are insufficient and regulation mechanisms are needed.
The goal is to choose transit routes which are robust to potential disruptions both in
This research considers a stochastic transit network design problem, where certain
Parking is a significant component of urban transportation system, and searching for
Chair: Steve Boyles, University of Wyoming, 1000 E. University Avenue, Laramie, WY, 82071, United States of America, sboyles@uwyo.edu,
1 - Dynamic Repositioning in a Bike-Sharing System
Michal Tzur, Tel Aviv University, Industrial Engineering Department, Tel Aviv University, Tel Aviv, 69978, Israel, tzur@eng.tau.ac.il, Dana
Dynamic repositioning in a bike sharing system is the problem of routing trucks to
We describe a proposed Transportation Market, a distributed system based on
3 - Operating Self Service Transport Systems in Real Time
Frédéric Meunier, Ecole des Ponts, 6-8 avenue Blaise Pascal, Cité Descartes, France, frederic.meunier@enpc.fr, Daniel Chemla, Thomas
Motivated by the operation of self service bike hiring systems, we propose several
3 - Solving the Bus Rapid Transit (BRT) Route Design Problem with Multiple Corridors
Jaimie E. González, Instructor, Universidad de los Andes, Departamento de Ingeniería Industrial, COPA, Bogotá, Colombia, je.gonzalez30@uniandes.edu.co, Andrés L. Medaglia, Leonardo
The Bus Rapid Transit Route Design Problem (BRTRDP) consists of finding a set of
4 - A Stochastic Programming Approach for Robust Vehicle Scheduling in Public Bus Transport
Marc Naumann, DSNOR Lab - University of Paderborn, Warburger Strasse 100, Paderborn, 33098, Germany, naumann@dsor.de, Leena
Vehicle schedules in public transport are usually planned several weeks before their
5 - Modeling Transit in Regional Dynamic Travel Models: FAST-TrIps
Mark Hickman, Associate Professor, University of Arizona, 1209 E. Second Street, Bldg. 72, Tucson, AZ, 85721-0072, United States of America, mhickman@email.arizona.edu, Hyunsoo Noh, Neema
We have developed a model called FAST-TrIps (Flexible Assignment and Simulation Tool for Transit and Intermodal Passengers) that serves as an add-in to regional
dynamic traffic assignment (DTA) models. The model handles the assignment and simulation of transit passengers, as well as the assignment for intermodal (auto + transit) trips. This presentation emphasizes tools for intermodal assignment with
activity-based travel demand models.
Operations for Shared Mobility Systems
Sponsor: Transportation Science and Logistics
Sponsored Session
Chair: Robert Hampshire, Assistant Professor of Operations Research and Public Policy, Carnegie Mellon University, Heinz College, 4800 Forbes Avenue, 2102B Hamburg Hall, Pittsburgh, PA, 15217, United States of America, Hamp@andrew.cmu.edu
1 - An Empirical Analysis of Bike Sharing
Robert Hampshire, Assistant Professor of Operations Research and Public Policy, Carnegie Mellon University, Heinz College, 4800 Forbes Avenue, 2102B Hamburg Hall, Pittsburgh, PA, 15217, United States of America, Hamp@andrew.cmu.edu
Bike sharing programs are an emerging mobility mode that increases freedom of
choice in mobility. Currently, over 100 cities around the world have deployed or have plans to deploy a bike sharing system. In Paris alone, there are over 90,000 trips taken daily using bike sharing. We present a demand model using empirical observations from bike sharing programs from around the world. We also discuss one of the main cost drivers of the system, the rebalancing operations.
2 - Barcelona Bike Sharing System: Supervised Machine Learning for Capacity Prediction
Karthik Dinakar, Research Assistant, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA, 02139, United States of America, kdinakar@media.mit.edu,
Robert Hampshire, Carolyn Rose, Ryan Chin, Kent Larson
In this work, we use combination of temporal and static features for effective prediction of station capacity at a given instant in time. We find that MSP, which combines a conventional decision tree with linear regression functions perform better than sequential minimal optimization and ensemble methods. Our work shows that supervised machine learning methods can effectively used for capacity prediction.
3 - The Bike Sharing Repositioning Problem: The Montreal Case
Louis-Martin Rousseau, École Polytechnique de Montréal, C.P. 6079, succ. Centre-ville, Montréal, Canada, louis-martin.rousseau@polymtl.ca, Catherine Morency, Martin Trépanier
A bike sharing system of 405 stations and 5050 bikes is implemented in Montreal, Canada since 2009. The repositioning method is currently under review. We will discuss the operational constraints linked to supply characteristics and trip patterns and discuss an algorithmic approach to the problem. We also discuss the externalities that influence repositioning, like weather conditions, other modes availabilities, and seasonal mobility variation for short trips.

MA51
H - Caldwell Room - 3rd Floor
Public Transit: Operations and Design
Sponsor: Transportation Science and Logistics
Sponsored Session
Chair: Nicholas Lownes, Assistant Professor, University of Connecticut, 261 Glenbrook Rd, U-2037, Storrs, CT, 06269, United States of America, nlownes@engr.uconn.edu
1 - Incorporating Trip Chaining Into Transit Accessibility
Jeffrey LaMondia, Assistant Professor, Auburn University, 138 Harbert Engineering Center, Auburn, AL, 36849, United States of America, jlamondia@auburn.edu
Trip chaining is a critical component of selecting transit as a viable mode choice. However, this aspect of travel is often ignored in analyses of travel accessibility. This research develops transit accessibility measures based on trip chaining using fixed transit route data from CapMetro in Austin, Texas. Additionally, this research compares results of this new transit accessibility measure with those from traditional gravity-based accessibility measures.

2 - A Study on Holding and Boarding Limits Strategies to Improve Transit Performance
Ricardo Giesen, Assistant Professor, Universidad Catolica de Chile, Vicuna Mackenna 4860, Macul, Santiago, Chile, giesen@ing.puc.cl, Juan Carlos Munoz, Felipe Delgado
Bus bunching affects transit operations increasing passenger waiting times and its variability. We propose a multi-programming model that considers holding and boarding limits to control bus times, and can handle vehicle capacities. The results show that the proposed strategies outperform other control strategies, providing a more balanced load factor across vehicles, thus increasing users comfort. To operators the use of boarding limits reduces the average vehicle cycle time and its variability.

3 - Integrating Connectivity in Transit Network Design
Nicholas Lownes, Assistant Professor, University of Connecticut, 261 Glenbrook Rd, U-2037, Storrs, CT, 06269, United States of America, nlownes@engr.uconn.edu
The transit network design problem is addressed from a bi-level perspective, placing network coverage at odds with routing efficiency and connectivity. Each level represents a difficult problem - heuristic methods and new methods for integrating connectivity are explored along with a discussion of integrating multi-modal assignment.

4 - A Schedule-based Transit Assignment Using Gradient Projection
Mark Hickman, Associate Professor, University of Arizona, 1209 E. Second Street, Bldg. 72, Tucson, AZ, 85721-0072, United States of America, mhickman@email.arizona.edu, Hyunsoo Noh
We consider a schedule-based transit assignment method that includes capacity constraints. To do this, we propose a logit-based transit assignment model using gradient projection. Capacity constraints include a FIFO rule on transit vehicle boarding. In addition, we assume each path has an entropy term for stochastic behavior. The model is applied on a link-based transit schedule network.

5 - A Combined Optimization Problem for Public Transit Stop Locations and Service Coverage
Sha Mamun, Graduate Student, University of Connecticut, 261 Glenbrook Road, Unit 2037, Storrs, CT, 06269, United States of America, smm80814@engr.uconn.edu
A multivariate public transit accessibility model was formulated to minimize the number of transit stops located at fixed construction cost. This model minimizes the cost components weighted by different demand classes. Demand coverage distribution was estimated using access distance between the assigned transit stop and the demand point.
2 - Determining Coordinated and Reliable Pre-emergency Evacuation Routes under Uncertain Road Capacity
Lixing Yang, State Key Laboratory of Rail Traffic Control and Safety, Beijing Jiaotong University. Beijing, China, lxyang.utah@gmail.com, Xuesong Zhou

Focusing on a pre-earthquake evacuation route planning application, we present a system-wide least expected time optimization model for finding coordinated reliable evacuation routes for evacuees with multiple origins and destinations. A Lagrangian relaxation approach is proposed for seeking the high-quality solutions subject to stochastic and time-dependent road capacity constraints.

3 - Heuristic Algorithm for the Earliest Arrival Flow Problem with Multiple Sources
Zheng Zhong, Postdoc Researcher, University of Arizona, 1209 E. Second Street, Bldg. 72, Bldg. 72, Tucson, AZ, 85721-0072, United States of America, hzcheng@email.arizona.edu, Pitu Mirchandani, Yi-Chang Chiu

In this talk we present a new heuristic algorithm for the multi-source earliest arrival flow problem. The main body of the algorithm consists of a series of earliest arrival s-t flow computations, via solving the shortest paths repeatedly. As an application, the algorithm can be used to solve the CTM model based system optimal dynamic traffic assignment problem efficiently.

Network Evacuation and Dynamic Modeling
Sponsor: Transportation Science and Logistics
Sponsored Session
Chair: Tao Yao, Assistant Professor, The Pennsylvania State University, 349 Leonhard Building, University Park, PA, 16802, United States of America, ty1@engr.psu.edu

1 - An Agent Based Modeling Approach Integrating Household Level Behavior with Traffic Simulation
Samirial Hasan, PhD Student, Purdue University, 550 Stadium Mall Drive, West Lafayette, IN, 47906, United States of America, hasan1@purdue.edu, Satish Ukkusuri, Kien Doan, Rodrigo Mesa Arango

Current transportation evacuation models largely overlook the complexity of household decision making behavior and as a result, fail to model the complex interactions in evacuation decision making. In this work an agent-based simulation model is developed incorporating the behavior of individual household vehicle (agent) decision and its interaction with the environment during a hurricane.

2 - Robust and Dynamic Models for Evacuation
Tao Yao, Assistant Professor, The Pennsylvania State University, 349 Leonhard Building, University Park, PA, 16802, United States of America, ty1@engr.psu.edu, Byung Do Chung, Bo Zhang, Andreas Thorsen

In this talk, we discuss the difficulties of mathematical programming due to the inherent uncertain nature of disaster and propose a computationally tractable robust optimization approach based on dynamic traffic assignment (DTA) model. Computational results demonstrate the advantage of the proposed approach compared to the deterministic or stochastic methods.

3 - Congested Network Flows over Time for Evacuation Planning
Douglas Bish, Assistant Professor, Virginia Tech, Department of ISE, 250 Durham Hall, Blacksburg, VA, 24061-0118, United States of America, dbi1@vt.edu, Edward Chamberlayne, Hussein Tarhini

Optimal planning for automobile-based regional evacuations can be developed using network flows over time. This methodology allows for the exploration of various strategies (e.g., staging or staggering evacuee flows, routing flows, and contra-flow planning). These are difficult problems, especially as models that adequately describe traffic flow often have non-convex feasible regions. In this presentation we examine appropriate network models for this problem and discuss modeling issues.

4 - Spatial Risk Assessment and Its Implications in Demand Management for Evacuation Operations
Yu-Ting Hsu, Purdue University, Nextrans Center, 3000 Kent Avenue, West Lafayette, IN, 47906, United States of America, yhsu@purdue.edu, Srinivas Peeta

We propose a systematic approach to determine an Evacuation Risk Zone (ERZ), which encloses the population sustaining the highest risk under evacuation operations. The ERZ is derived based on the assessment of risk which spatially varies over the affected region, depending on disaster, demand pattern, and network structure. A stage-based operational framework of ERZ deployment is designed to account for network dynamics. Its effectiveness is illustrated and discussed using numerical experiments.

Emergency Rescue Location Planning under the Risk of Probabilistic Disruptions
Yanfeng Ouyang, Associate Professor, University of Illinois, Urbana-Champaign, Department of Civil Environmental Engineering, Urbana, IL, United States of America, yfouyang@illinois.edu

This paper presents a reliable rescue location problem to optimize rescue location planning, evacuate allocation, and rescue vehicle re-assignment in case the rescue locations are disabled by the disaster. A compact mixed-integer program model is proposed to minimize the total system cost for rescue location set-up, rescue vehicle operations, evacuate transportation and queuing delay.
1 - A Framework for Assessing Resilience of Networks
Reza Fatourechi, PhD. Candidate, University of Maryland, Department of Civil & Env. Engineering, 1173 Glenn L. Martin Hall, College Park, MD, 20742, United States of America, reza.fatourechi@gmail.com, Elise Miller-Hooks

A framework is proposed for conceptualizing resilience and its various facets, clarifying the interrelationships between these facets previously exposed as independent vulnerability measures in the literature, quantifying resilience and related measures congruously, and optimizing network performance in terms of these resilience concepts.

2 - Transit Vehicle Routing Methods for Large-Scale Evacuation
Mark Hickman, Associate Professor, University of Arizona, 1209 E. Second Street, Bldg. 72, Tucson, AZ, 85721-0072, United States of America, mhickman@email.arizona.edu, Moshe Dror

We consider a routing of public vehicles to evacuate persons during a large-scale emergency. To facilitate the evacuation, we consider a routing of vehicles along roadways to pick up people at their residences or other locations. We present an arc routing model for this case and illustrate the model on a large-scale case study.

3 - Efficient Dynamic Distribution of Security Assets in Transit Systems
Rahul Nair, University of Maryland, 1173 Glenn Martin Hall, University of Maryland, College Park, MD, 20742, United States of America, rahul@umd.edu, Elise Miller-Hooks, Jonathan Kumi, Kevin Denny

A mixed-integer, multi-stage program for the optimal deployment of security assets in transit systems is presented. The model considers a risk measure that depends on passenger volumes and fluctuates over time, as is shown for the Washington, D.C. metro system.

4 - Robust Shortest Path Problems with Two Uncertain Multiplicative Cost Coefficients
Changhyun Kwon, Assistant Professor, University at Buffalo, SUNY, 400 Bell Hall, Buffalo, NY, 14260, United States of America, ckwon@buffalo.edu, Paul Berglund, Taehan Lee

We consider a robust shortest path problem when the cost coefficient is a multiplication of two uncertain parameters. We first show that the robust problem can be solved by a line search with shortest path subproblems. We propose another enumeration-based solution approach using a K-shortest paths finding algorithm that may be efficient in many real cases. An application in hazardous materials transportation is discussed and the solution methods are illustrated by numerical examples.

2 - Locating Medical Supplies in Preparation for a Large-scale Emergency
Pavan Murali, Research Staff Member, IBM Research, 19 Skyline Dr, 4S-G54, Hawthorne, NY, 10532, United States of America, pmurali@uscs.edu, Fernando Ordazone, Maged Dessouky

We discuss a capacitated facility location problem to determine the points of dispensing medicines in a bioterrorist attack. We formulate a special case of the maximal covering location problem with loss function to account for the distance-dependent coverage and chance-constraints to model demand uncertainty. We solve this problem using a locate-allocate heuristic. We illustrate the use of the model in a case study of locating facilities to address an anthrax attack in Los Angeles County.

3 - Optimization-based Models for Hospital Evacuation Planning
Kevin Taaffe, Associate Professor, Clemson University, 130-A Freeman Hall, Clemson, SC, 29642, United States of America, taaffe@clemson.edu, Ashley Childers, Maria Mayorga

There is a lack of consensus about whether critical care or non-critical care patients should be transferred away from a healthcare facility first during an emergency evacuation. In this research, we formulate a dynamic programming model and discuss insights of the resulting patient prioritization strategies. We show that a greedy policy is not always optimal. We also compare the performance of several policy options through simulation analysis.

2 - Prioritizing Strategies for Healthcare Facility Evacuations
Kevin Taaffe, Associate Professor, Clemson University, 130-A, Freeman Hall, Clemson, SC, 29642, United States of America, taaffe@clemson.edu, Ashley Childers, Maria Mayorga

A hospital evacuation is a logistically complex process. To assist emergency planners in planning for and managing hospital evacuations, we study optimization-based planning models that minimizes the expected risk (from both the threat prompting the evacuation and the movement of patients), given limited resources and patients that have varying medical-logistical requirements. Results are illustrated using a realistic case study.

1 - Optimizing the Control Delay in High-rising Building Evacuation Plan
Jeongin Koo, POSTECH, San 31 Hyoja, Pohang, Korea, Republic of, jession@postech.ac.kr, Byung-In Kim, Yong Seog Kim

We take an agent-based simulation approach to develop optimal evacuation plans in a high-rise building considering people with disabilities, social dynamics among people, and the structural characteristics of the building. We use the information of congested floors and stair areas to determine the control delay that regulates the start of evacuation for all the people on different floors and people with various disabilities.

1 - Analysis of Alternate Layout Designs for Distribution of Bulk Relief Supplies
Ananth Krishnamurthy, University of Wisconsin-Madison, 1533 University Avenue, Madison, WI, United States of America, ananth@engr.wisc.edu, Dejbit Roy

At a disaster affected site, bulk distribution relief centers provide immediate supplies. In order to make the distribution centers feasible to be located at a variety of sites, the researchers develop queueing models to analyze alternate layouts and volunteer staffing levels with time-varying arrival rates.
1 - Algorithms and Optimization Models for Truckload Relay Network Design
Hector Vergara, University of Arkansas, 4207 Bell Engineering Center, Fayetteville, AR, 72701, United States of America, hvergara@uark.edu
Sponsored Session
Chair: Sarah Root, Assistant Professor, University of Arkansas, 4207 Bell Engineering Center, Fayetteville, AR, 72701, United States of America, seroot@uark.edu

2 - A Lagrangean Decomposition Approach for Capacitated Relay Network Design
Halit Uster, Texas A&M University, 241 Zachry, 3131 TAMU, College Station, TX, 77840, United States of America, uster@tamu.edu, Panjati Krkwaroowoong
Motivated by its applications in Less-than-Truckload (LTL) and Truckload (TL) transportation, we consider a relay network design problem with generalized capacity and load imbalance requirements. We develop an efficient solution approach based on Lagrangean decomposition and present computational results illustrating the performance of the algorithm.

3 - Decoupled and Integrated Planning Models for Divergent Supply Chain in an Oil Company
Martin Kylinger, PhD-student, Linköping University, 581 83, Linköping, 581 83, Sweden, martin.kylinger@liu.se, Mario Guajardo, Mikael Ronnqvist
We study an oil company with a divergent supply chain. The planning is decoupled into two separate problems. The first is concerned with sales and maximizing profit and the second is with planning production, transportation and inventory to minimize cost. In the real case an internal price system attempts to coordinate the solution of the two problems. We propose and discuss models for decoupled and integrated approaches, and show how they can be used to achieve a more efficient planning.

4 - Robust Planning of Production, Inventory and Ship Loading
Chair: Sarah Root, Assistant Professor, University of Arkansas, 4207 Bell Engineering Center, Fayetteville, AR, 72701, United States of America, seroot@uark.edu

1 - Robust Planning of Production, Inventory and Ship Loading
Jens Bengtsson, Norwegian School of Economics and Business Administration, Helleveien 30, Bergen, NO-5045, Norway, Mikael.Ronnqvist@nhh.no, Patrik Flisberg, Mikael Ronnqvist
We present a case study of inventory management of spare parts in a large supplier of oil and gas. Inventory of spare parts is held to assist the repair and replacement of equipments. The inventory includes a large number of items stored in several onshore and off-shore locations. The demand for these items is uncertain. We study how to determine inventory levels for each spare part and analyze the potential in how risk pooling between the inventory locations can be implemented.

2 - Inventory Management of Spare Parts in an Energy Company
Mario Guajardo, PhD-student, Norwegian School of Economics and Business Administration, Helleveien 30, Bergen, NO-5045, Norway, mario.guajardo@nhh.no, Jens Bengtsson, Mikael Ronnqvist
We present a case study of inventory management of spare parts in a large supplier of oil and gas. Inventory of spare parts is held to assist the repair and replacement of equipments. The inventory includes a large number of items stored in several onshore and off-shore locations. The demand for these items is uncertain. We study how to determine inventory levels for each spare part and analyze the potential in how risk pooling between the inventory locations can be implemented.

3 - Evaluation of Transportation Privacy Preserving Algorithms Using Traffic Knowledge Based Adversary Models
Zhanbo Sun, sim2rpi.edu, Bin Zan, Jeff Ban, Marco Gruteser, Peng Hao
Mobile traffic sensors have quickly emerged recently as an important data source for traffic applications. In this research, we develop traffic knowledge-based adversary models to attack privacy algorithms that have been proposed so far for protecting mobile data privacy. The results can hopefully provide some insight on how mobile data should be collected and processed in order to ensure both privacy and application data needs.

4 - Traffic Knowledge Based Adversary Models
Chair: Sarah Root, Assistant Professor, University of Arkansas, 4207 Bell Engineering Center, Fayetteville, AR, 72701, United States of America, seroot@uark.edu

1 - A Lagrangean Decomposition Approach for Capacitated Relay Network Design
Hector Vergara, University of Arkansas, 4207 Bell Engineering Center, Fayetteville, AR, 72701, United States of America, hvergara@uark.edu, Sarah Root
Scarcity of road capacity is a major issue for road transportation. To reduce operational constraints such as load curtailment and driver tour length within the variable definition, we develop a method to design a relay network that maximizes total profits.

2 - A Lagrangean Decomposition Approach for Capacitated Relay Network Design
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3 - Evaluation of Transportation Privacy Preserving Algorithms Using Traffic Knowledge Based Adversary Models
Zhanbo Sun, sim2rpi.edu, Bin Zan, Jeff Ban, Marco Gruteser, Peng Hao
Mobile traffic sensors have quickly emerged recently as an important data source for traffic applications. In this research, we develop traffic knowledge-based adversary models to attack privacy algorithms that have been proposed so far for protecting mobile data privacy. The results can hopefully provide some insight on how mobile data should be collected and processed in order to ensure both privacy and application data needs.

4 - Traffic Knowledge Based Adversary Models
Chair: Sarah Root, Assistant Professor, University of Arkansas, 4207 Bell Engineering Center, Fayetteville, AR, 72701, United States of America, seroot@uark.edu

1 - Decoupled and Integrated Planning Models for Divergent Supply Chain in an Oil Company
Martin Kylinger, PhD-student, Linköping University, 581 83, Linköping, 581 83, Sweden, martin.kylinger@liu.se, Mario Guajardo, Mikael Ronnqvist
We study an oil company with a divergent supply chain. The planning is decoupled into two separate problems. The first is concerned with sales and maximizing profit and the second is with planning production, transportation and inventory to minimize cost. In the real case an internal price system attempts to coordinate the solution of the two problems. We propose and discuss models for decoupled and integrated approaches, and show how they can be used to achieve a more efficient planning.
3 - Creative Dispatching in Truckload Trucking
Don Taylor, Gordon Professor and Department Head, Virginia Tech, Grado Department of ISE, 250 Durham Hall (0118), Blacksburg, VA, 24061, United States of America, don.taylor@vt.edu

In this presentation, the author presents several alternatives to traditional dispatching in truckload trucking. The goal of these various alternatives is to improve the quality of life for professional drivers while keeping the trucking company profitable and the customer happy. With improved dispatching systems in place, current research is focused on the achievement of higher profitability without degradation of the improved dispatch function.

4 - Load Plan Improvement through IP Based Local Search
Kathleen Lindsey, Georgia Institute of Technology, 765 Ferst Drive, NW, Atlanta, GA, 30332-0205, United States of America, kate.abercrombie@gatech.edu, Alan Erera, Martin Savelsbergh

We develop an integer programming based local search improvement method for a service network design problem faced by less-than-truckload (LTL) freight transportation carriers. The technique uses a time-space network to realistically model consolidation opportunities, while simultaneously evaluating loaded freight and empty trailers. This approach finds significant cost savings for large-scale LTL networks seen in practice.

■ TA52
H - North Carolina - 3rd Floor
Facility Logistics I
Sponsor: Transportation Science and Logistics/Facility Logistics
Sponsored Session
Chair: Sadan Kulturel-Konak, Associate Professor of MIS, Pennsylvania State University, Tulpehocken Road, P.O. Box 7009, Reading, PA, 19610, United States of America, sadan@psu.edu

1 - Reducing Extended Versions of the Facility Layout Model to the Standard Form
Stein W. Wallace, Professor, Lancaster University, Department of Management Science, Lancaster, LAI 4XJ, United Kingdom, stein.w.wallace@lancaster.ac.uk, Yifei Zhao

The standard facility layout model leads to the classical quadratic assignment problem - QAP. The QAP is very hard to solve, but also comes with very strong assumptions. We add several jobs, random demand, and multiple copies of each machine type, but are still able to reduce the model to the classical QAP, leading to very strong (but not optimal) solutions. So good solutions can be found to the extended versions whenever good or optimal solutions can be found for the classical QAP.

2 - Unequal Area Facility Layout with a New Flexible Bay Representation
Sadan Kulturel-Konak, Associate Professor of MIS, Pennsylvania State University, Tulpehocken Road, P.O. Box 7009, Reading, PA, 19610, United States of America, sadan@psu.edu, Abdullah Konak

In this paper, a hybrid particle swarm optimization (PSO) and local search approach is proposed to solve the facility layout problem (FLP) with unequal area departments. The flexible bay structure (FBS), which is a very common layout in manufacturing and retail facilities, is used and it is relaxed by allowing empty spaces in bays. The comparative results show that the hybrid PSO approach is very efficient in finding the previously known-optimal solutions and some new best solutions.

3 - An Optimization-based Planning Tool for the Selection of Piece-level Order-fulfillment Technologies
Jennifer Pazour, Assistant Professor, University of Central Florida, 4000 Central Florida Blvd, Orlando, FL, United States of America, jpa zou r@uark.edu, Russell Meller

We develop a mathematical-programming model that jointly determines the best combination of piece-level order-fulfillment technologies and the assignment of SKUs to these technologies. We validate our methodology with industry data and show that our model provides technology recommendations and SKU assignments that are consistent with successful implementations. We also provide insights into the application of different order-fulfillment technology strategies.
Simultaneously. We analyze the effect of lot splitting for the trade-off between the best mix of shorter lead time and also less frequent material movement.

We propose a new material handling rule, called time based rule, which can create a solution in a polynomial time.

This paper studies how to sequence storage and retrieval jobs for a two-depot multi-aisle Automated Storage/Retrieval System (AS/RS) in order to minimize the makespan of these jobs. We formulate the sequencing problem as a special case of the Traveling Salesman Problem (TSP). An algorithm is developed to find the optimal solution in a polynomial time.

This paper explores alternatives for slotting inbound containers in storage centers in a physical Internet (www.physicalinternetinitiative.org). It provides a slotting conceptual framework suited for this context and describes the alternatives and their differences. It then analyzes exploratory simulation-based empirical results showing the open duration-of-stay target strategy to be best in throughput and space performance for the studied cases.

Order picking systems differ in their organizational and technical configuration in order to meet specific performance and quality requirements. By analyzing existing types of implementation, similar concepts and general design principles can be identified. The paper describes standardized order picking modules, common fields of application, and relevant selection criteria to support a systematic and transparent design process with a top-down approach.

We propose a new material handling rule, called time based rule, which can create a best mix of shorter lead time and also less frequent material movement simultaneously. We analyze the effect of lot splitting for the trade-off between the material movement and lead time by the simulation experiment.
1 - Generalized Asymmetric Traveling Salesman Problem: Sequencing Storage and Retrieval Containers
Amir Hossein Gharehgozli, PhD Candidate, Rotterdam School of Management, P.O. Box 1738, Rotterdam, 3000 DR, Netherlands, AGharehgozli@rsm.nl, Yugang Yu, Rene de Koster

We study how to select storage locations for storage containers while a set of storage and retrieval containers are sequenced in a block by minimizing the travel time of an automated crane. Multiple input/output (I/O) points are located at each side of the block. Every I/O point has a set of storage containers each with a given set of storage locations. The problem is modeled as a generalized asymmetric traveling salesman problem (GATSP) and solved by transforming the GATSP to the ATSP.

2 - Decentralization and Trade-offs of Equity and Efficiency in Humanitarian Fleet Management Systems
Maria Besiou, Postdoctoral Fellow, INSEAD, Social Innovation Centre, Fontainebleau, France, Maria.Besiou@insead.edu, Alfonso J. Pedraza-Martinez, Luk Van Wassenhove

Humanitarian Organizations manage the fleets using three systems: Centralized: decisions are made by the fleet management unit (FMU). Decentralized: there is no global FMU, decisions are made at program level. Hybrid: combines features of centralized and decentralized. Using system dynamics, we model the three systems exploring trade-offs of equity and efficiency for relief and development programs. Our findings help understand which system should best satisfy a particular organization's needs.

3 - Reduction of CO2 & Energy Consumption in Logistics in Bulgaria by Development of Green Supply Chains
Vikenti Spassov, Professor, University of Transport, 158 Geo Milev Street, 16 en.B Hemus Street, Sofia, 1111, Bulgaria, vikenti.spassov@yahoo.com

The trend towards developing a green supply chain is now gaining popularity but most companies are still coming to terms with how this can be achieved. The paper presents results of projects for the decreasing of the power consumption in cold storage by optimization of the storage systems and the organization and using a fuel cell lift trucks. For minimizing of the space of storage by the optimization of storage systems we propose two alternatives and the mathematical models for them.

4 - Game Theoretic Models for Competition in Public Transit Services
Janny M.Y. Leung, The Chinese University of Hong Kong, Systems Engineering & Eng. Mgt. Department, Hong Kong, Hong Kong - PRC, janny@se.cuhk.edu.hk, Eddie Chan

As metropolitan areas grow, commuting needs increase the burden on public transport systems, leading to traffic congestion and pollution. We model the competitive situation when several service providers offer public transport services using potential games, and discuss mathematical programmes for finding their Nash equilibria. We investigate the relative merits and tradeoffs for different structures of transit networks, and the interplay between the services offered and system ridership.