Literature Report

张晨峰, 华东理工大学商学院

Abstract

Discrete-time day-to-day dynamic congestion pricing scheme considering multiple equilibria

- Transportation Research Part B: Methodological---2017---Linghui Han,David Z.W. Wang,Hong K. Lo,Chengjuan Zhu,Xingju Cai

In this study, we focus on the discrete-time day-to-day dynamic congestion pricing scheme which varies the toll on a day-to-day basis and aims to drive the traffic system to a given objective traffic equilibrium state. As is well known, due to the asymmetric nature of the travel cost functions, multiple equilibria exist. In this case, without external force, the traffic system cannot converge to the traffic equilibrium state as desired by traffic management through a day-to-day adjustment process if the initial traffic state does not fall into its attraction domain (Bie and Lo, 2010). Therefore, it is imperative for traffic management to propose a traffic control measure to ensure the desired traffic state can be achieved regardless of the initial traffic state. Previous studies on the day-to-day dynamic congestion pricing, either worked on continues-time day-to-day pricing scheme, or took the form of discrete-time day-to-day pricing scheme but did not guarantee the convergence to the desired objective traffic state for the cases when multiple traffic equilibria exist. Both are undesirable. This study aims to develop a discrete-time day-to-day pricing scheme so as to direct the traffic evolution to reach the desired equilibrium from any initial traffic state when multiple traffic equilibria exist. Based on the very general formulation of day-to-day traffic dynamics model, we present a general formulation of such day-to-day pricing schemes and propose a method to obtain one specific road pricing scheme. Moreover, we present rigorous proofs and numerical tests to verify the proposed pricing scheme.

Determining optimal locations for charging stations of electric car-sharing systems under stochastic demand

- Transportation Research Part B: Methodological---2017---Georg Brandstätter,Michael Kahr,Markus Leitner

In this article, we introduce and study a two-stage stochastic optimization problem suitable to solve strategic optimization problems of car-sharing systems that utilize electric cars. By combining the individual advantages of car-sharing and electric vehicles, such electric car-sharing systems may help to overcome future challenges related to pollution, congestion, or shortage of fossil fuels. A time-dependent integer linear program and a heuristic algorithm for solving the considered optimization problem are developed and tested

on real world instances from the city of Vienna, as well as on grid-graph-based instances. An analysis of the influence of different parameters on the overall performance and managerial insights are given. Results show that the developed exact approach is suitable for medium sized instances such as the ones obtained from the inner districts of Vienna. They also show that the heuristic can be used to tackle very-large-scale instances that cannot be approached successfully by the integer-programming-based method.

An agent-based day-to-day adjustment process for modeling ‘Mobility as a Service’ with a two-sided flexible transport market

- Transportation Research Part B: Methodological---2017---Shadi Djavadian,Joseph Y.J. Chow

Due to advances in communications technologies and social networks, flexible mobility systems such as taxi, carpool and demand responsive transit have gained interest among practitioners and researchers as a solution to address such problems as the “first/last mile problem". While recent research has modeled these systems using agent-based stochastic day-to-day processes, they assume only traveler adjustment under a one-sided market setting. What if such systems are naturally “two-sided markets" like Uber or AirBnB?In this study, we explore flexible transport services in the framework of two-sided markets, and extend an earlier day-to-day adjustment process to include day-to-day adjustment of the service operator(s) as the seller and the built environment as the platform of a two-sided market. We use the Ramsey pricing criterion for social optimum to show that a perfectly matched state from a day-to-day process is equivalent to a social optimum. A case study using real data from Oakville, Ontario, as a first/last mile problem example demonstrates the sensitivity of the day-to-day model to operating policies. Computational experiments confirm the existence of locally stable states. More importantly, the experiments show the existence of thresholds from which network externalities cause two-sided and one-sided market equilibria to diverge.

Investigation of the traffic congestion during public holiday and the impact of the toll-exemption policy

- Transportation Research Part B: Methodological---2017---Yue Bao,Feng Xiao,Zaihan Gao,Ziyou Gao

Traffic congestion has long been a noticeable issue worldwide. Besides congestion caused by the daily commuters, congestion during public holidays is also very typical. The traffic volume often has a sharp increase during public holidays, which puts a heavy burden on the road capacity and results in severe congestion. This is especially true for the beginning and ending of the holidays. The situation is even worse under some government policies designed initially to benefit people, e.g. the highway toll-exemption during public holidays in China. The focus of this paper is to model the evolution of traffic congestion caused by the demand from residential place to the famous resorts during public holidays. The research questions include: (1) how do tourists tradeoff between schedule delay, queuing time and the overcrowding of the resort? and (2) the impact of the toll-exemption policy during public holidays on tourists’ departure time choices and the social welfare. By adopting the bottleneck model, we obtain the cumulative departure curves of tourists during public holidays. Closed-form results of tourists’ departure time variation with the toll-exemption policy are obtained, as well as the resulting social efficiency loss, which is significant for the management of the traffic mobility during public holidays.

Resilient facility location against the risk of disruptions

- Transportation Research Part B: Methodological---2017---Guodong Yu,William B. Haskell,Yang Liu

In this paper, we consider an uncapacitated facility location problem (RUFL) with random facility disruptions. We develop risk-averse optimization formulations to compute resilient location and customer assignment solutions for two cases (i.e., under either independent or correlated disruptions), where the risks are expressed through a family of risk measures including conditional value-at-risk (CVaR) and absolute-semideviation (ASD). The risk-averse RUFL with independent facility disruptions is to control the risks at each individual customer and modeled as a mixed-integer nonlinear programming, which is challenging to be solved. In response, we develop a branch-and-cut algorithm combined with augmented Lagrangian decomposition for globally optimizing the problem. As for the risk-averse RUFL with correlated facility disruptions, we propose a scenario-based model to minimize the total fixed costs and risks across the entire customer set. The resulting formulation is a pure MILP and a Lagrangian decomposition scheme is proposed for computational aspects in large-scale cases. Our numerical results show that the risk-averse models outperform the classic risk-neutral models in improving the reliability. Experiments demonstrate that our proposed algorithms perform well. To conclude, we extract managerial insights that suggest important guidelines for controlling risk in the face of disruption.

Simultaneous estimation of states and parameters in Newell’s simplified kinematic wave model with Eulerian and Lagrangian traffic data

- Transportation Research Part B: Methodological---2017---Zhe Sun,Wen-Long Jin,Stephen G. Ritchie

The traffic state estimation process estimates various traffic states from available data in a road network and provides valuable information for travelers and decision makers to improve both travel experience and system performance. In many existing methods, model parameters and initial states have to be given in order to estimate traffic states, which limits the accuracy of the results as well as their transferability to different locations and times. In this paper, we propose a new framework to simultaneously estimate model parameters and traffic states for a congested road segment based on Newell’s simplified kinematic wave model (Newell, 1993). Given both Eulerian traffic count data and Lagrangian vehicle reidentification data, we formulate a single optimization problem in terms of the initial number of vehicles and model parameters. Then we decouple the optimization problem such that the initial number of vehicles can be analytically solved with a closed-form formula, and the model parameters, including the jam density and the shock wave speed in congested traffic, can be computed with the Gauss-Newton method. Based on Newell’s model, we can calculate individual vehicles’ trajectories as well as the average densities, speeds, and flow-rates inside the road segment. We also theoretically show that the optimization problem can have multiple solutions under absolutely steady traffic conditions. We apply the proposed method to the NGSIM datasets, verifying the validity of the method and showing that this method yields better results in the estimation of average densities than existing methods.

A predictive-control framework to address bus bunching

- Transportation Research Part B: Methodological---2017---Matthias Andres,Rahul Nair

Busy bus routes often suffer from buses not arriving at regular intervals but in bunches at bus stops. In this paper we study this bus bunching phenomenon and address it by a combination of data-driven headway prediction and dynamic holding strategies, which allow to modulate buses’ dwell times at stops to reduce the headway deviation. We formulate time headways as time series and compare several prediction methods by testing on data from a busy bus route in Dublin. Furthermore we review and extend an analytical model of an artificial bus route and discuss stability properties and dynamic holding strategies using both data available at the time and predicted headway data. In a numerical simulation we illustrate how the combination of two simple concepts lead to a promising strategy to reduce bus bunching.

Train timetabling by skip-stop planning in highly congested lines

- Transportation Research Part B: Methodological---2017---Feng Jiang,Valentina Cacchiani,Paolo Toth

We study the problem of scheduling passenger trains in a highly congested railway double-track line with the aim of increasing the number of scheduled trains. A feasible timetable of the trains currently scheduled in the network is given. Additional trains should be scheduled to meet the increasing passenger demand. To achieve this goal, we are allowed to increase the dwelling time of some trains at some stations, to let them stop at some additional stations and even to skip a few stops. Thereby, we need to take explicitly into account the deceleration and acceleration times that are needed by the train when it stops at a station. This problem integrates the choice of the train schedule with the choice of the train stops, the latter being usually made in the Line Planning process. To solve this problem, we propose a heuristic algorithm, extended from a previous method to include the new features of the studied application, and show its performance on real-world instances of the Chinese high-speed JingHu corridor (between Beijing and Shanghai) involving up to 387 trains.

Modelling bus bunching and holding control with vehicle overtaking and distributed passenger boarding behaviour

- Transportation Research Part B: Methodological---2017---Weitiao Wu,Ronghui Liu,Wenzhou Jin

Headway fluctuation and bus bunching are commonly observed in transit operations, while holding control is a proven strategy to reduce bus bunching and improve service reliability. A transit operator would benefit from an accurate forecast of bus propagation in order to effectively control the system. To this end, we propose an 'ad-hoc' bus propagation model taking into account vehicle overtaking and distributed passenger boarding (DPB) behaviour. The latter represents the dynamic passenger queue swapping among buses when bunching at bus stops occurs and where bus capacity constraints are explicitly considered. The enhanced bus propagation model is used to build the simulation environment where different holding control strategies are tested. A quasi first-depart-first-hold (FDFH) rule is applied to the design of schedule- and headway-based holding control allowing for overtaking, with the objective to minimise the deviation from the targeted headway. The effects of control strategies are tested in an idealised bus route under different operational setting and in a real bus route in Guangzhou. We show that when the combined overtaking and queue-swapping behaviour are considered, the control strategies can achieve better headway regularity, less waiting time and less on-board travel time than their respective versions without overtaking and DPB. The benefit is even greater when travel time variability is higher and headway is smaller, suggesting that the control strategies are preferably deployed in high-frequency service.

Speed optimization over a path with heterogeneous arc costs

- Transportation Research Part B: Methodological---2017---Qie He,Xiaochen Zhang,Kameng Nip

The speed optimization problem over a path aims to find a set of speeds over each arc of the given path to minimize the total cost, while respecting the time-window constraint at each node and speed limits over each arc. In maritime transportation, the cost represents fuel cost or air pollutant emissions, so study of this problem has significant economic and environmental impacts. To accommodate different fuel and emission models, we allow the dependence of the cost on the speed to be a general continuously differentiable and strictly convex function, and different across the arcs. We develop an efficient algorithm that is able to solve instances of 1000 nodes in less than a second. The algorithm is 20 to 100 times faster than a general convex optimization solver on test instances and requires much less memory. The solutions found at intermediate steps of our algorithm also provide some insights to ship planners on how to balance the operating cost and service quality.

Modeling the dynamics of congestion in large urban networks using the macroscopic fundamental diagram: User equilibrium, system optimum, and pricing strategies

- Transportation Research Part B: Methodological---2017---Mahyar Amirgholy,H. Oliver Gao

The macroscopic fundamental diagram (MFD) is introduced in recent studies to present the relationship between the flow and the density of the network in large urban regions (neighborhoods). The MFD can be also rescaled to approximate network outflow as a function of the vehicular accumulation of the system in the morning commute problem. In this research, we develop a bathtub model (macro-scale traffic congestion model) by combining Vickrey's (1969) model of dynamic congestion with the MFD to formulate the user equilibrium over the peak as an ordinary differential equation (ODE). This problem can be solved numerically to estimate the exact solution of the morning commute problem. Alternatively, the morning commute problem can be solved analytically by approximating the solution of the ODE using a well-behaved function. Here, we present a quadratic and also a linear approximation of the equilibrium solution for a semi-quadratic MFD, considering that the declining part of the MFD is shown to be well estimated by a quadratic function. To optimize the system, we present pricing strategies for network users (dynamic tolling) and employers inside the region (dynamic taxing) that can minimize the generalized cost of the system by keeping the outflow maximized over the peak. Finally, we compare the exact and the approximate solutions of the problem, and also the proposed pricing strategies of the region in a numerical example.

A fast simulation algorithm for multiple moving bottlenecks and applications in urban freight traffic management

- Transportation Research Part B: Methodological---2017---Michele D. Simoni,Christian G. Claudel

Moving bottlenecks are moving capacity restrictions that affect traffic flows, and they can be used to describe the effects of buses and trucks in transportation networks. The computation of solutions associated with the presence of moving bottlenecks is complex, since they both influence and are influenced by surrounding traffic. In this study, we propose a fast numerical scheme that can efficiently compute the solutions to an arbitrary number of moving (and fixed) bottlenecks, for a stretch of road modeled by the Lighthill–Whitham–Richards (LWR) model. Several different moving bottlenecks can be simulated endogenously all together by means of an algorithm based on a semi-analytic Lax–Hopf formula. Since the numerical scheme is semi-analytic and requires a very low number of operations, it can be employed for traffic estimation problems where fast and accurate solutions are required. We demonstrate the capabilities of the method by implementing two alternative traffic management strategies designed to minimize the negative impacts of trucks and buses in urban environments.

On the stochastic fundamental diagram for freeway traffic: Model development, analytical properties, validation, and extensive applications

- Transportation Research Part B: Methodological---2017---Xiaobo Qu,Jin Zhang,Shuaian Wang

In this research, we apply a new calibration approach to generate stochastic traffic flow fundamental diagrams. We first prove that the percentile based fundamental diagrams are obtainable based on the proposed model. We further prove the proposed model has continuity, differentiability and convexity properties so that it can be easily solved by Gauss–Newton method. By selecting different percentile values from 0 to 1, the speed distributions at any given densities can be derived. The model has been validated based on the GA400 data and the calibrated speed distributions perfectly fit the speed-density data. This proposed methodology has wide applications. First, new approaches can be proposed to evaluate the performance of calibrated fundamental diagrams by taking into account not only the residual but also ability to reflect the stochasticity of samples. Secondly, stochastic fundamental diagrams can be used to develop and evaluate traffic control strategies. In particular, the proposed stochastic fundamental diagram is applicable to model and optimize the connected and automated vehicles at the macroscopic level with an objective to reduce the stochasticity of traffic flow. Last but not the least, this proposed methodology can be applied to generate the stochastic models for most regression models with scattered samples.

Efficient and fair system states in dynamic transportation networks

- Transportation Research Part B: Methodological---2017---Feng Zhu,Satish V. Ukkusuri

This paper sets out to model an efficient and fair transportation system accounting for both departure time choice and route choice of a general multi-OD network within a dynamic traffic assignment environment. Firstly, a bi-level optimization formulation is introduced based on the link-based traffic flow model. The upper level of the formulation minimizes the total system travel time, whereas the lower level captures traffic flow propagation and the user equilibrium constraints. Then the bi-level formulation is relaxed to a linear programming formulation that produces a lower bound of an efficient and fair system state. An efficient iterative algorithm is proposed to obtain the exact solution. It only requires solving one linear program in one iteration. Further, it is shown that the number of iterations is bounded, and the output traffic flow pattern is efficient and fair. Finally, two numerical cases (including a single OD network and a multi-OD network) are conducted to demonstrate the performance of the algorithm. The results consistently show that the departure rate pattern generated from the algorithm leads to an efficient and fair system state, and the algorithm converges within two iterations across all test scenarios.

The decentralized field service routing problem

- Transportation Research Part B: Methodological---2017---Edison Avraham,Tal Raviv,Eugene Khmelnitsky

Companies that provide service at geographically dispersed locations face the problem of determining the technician that will serve each location as well as setting the best route for each technician. Such a scenario is known as the field service routing problem. Large companies often outsource their field service tasks to several contractors. Each contractor may serve several companies. Since the contractors cannot share the information about the tasks of their other clients, the most common practice involves allocating the tasks to the contractors heuristically based on geographical considerations. In this approach, the tasks for which the contractors have already been committed to other companies are not considered. As a result, the allocation of new tasks can be inefficient. This study develops 2-stage task allocation mechanisms that cope with the problem and result in nearly optimal allocations.

Strategic entry to regional air cargo market under joint competition of demand and promised delivery time

- Transportation Research Part B: Methodological---2017---Fan Wang,Xiaopo Zhuo,Baozhuang Niu

In air cargo industry, mainline carrying and regional carrying are complementary services that form an air cargo service supply chain. Recently, many mainline carriers (MCs) have strategically entered upstream regional carrying service market to offer "one-stop-delivery" service and hence, competed with incumbent regional carriers (RCs). Note that promised delivery time (PDT) competition is essential and common in this industry. We study a MC's entry decision using a joint demand and PDT competition model. We investigate the entry mode issue (fully-controlled or joint-venture), which influences the equilibrium profits and channel structure, and characterize the value of upstream competition and vertical cooperation between the MC and incumbent RC. Interestingly, we find that the MC's upstream entry can result in a win-win situation, or a lose-lose situation for the MC and the incumbent RC. Comparing parties' profits with and without PDT competition, we find that multi-dimensional competition may weaken the negative effect of upstream entry on the incumbent RC, resulting in a price advantage and PDT disadvantage for the MC. We also find that a fully-controlled entry mode is always a dominant strategy with or without PDT competition. Moreover, by assuming power distribution of the PDT, we find that the increase in service rate can result in a lower price and shorter PDT quotation for the MC. A(n) decrease (increase) of service rate strengthens (weakens) the PDT disadvantage, and this effect is strengthened with fully-controlled entry mode. We also examine Bertrand models and characterize the entry effects and the MC's entry decisions under joint price and PDT competition.

Effects of risk-aversion on competing shipping lines’ pricing strategies with uncertain demands

- Transportation Research Part B: Methodological--2017---Wei Zheng,Bo Li,Dong-Ping Song

Container shipping is facing severe overcapacity, fierce price-based competition and high demand uncertainty. It is natural that some shipping lines may adopt a risk-aversion attitude in their pricing strategies. This paper considers the pricing strategies of two competing ocean carriers facing uncertain demand. The first carrier is risk-neutral with sufficient capacity, whereas the second carrier is risk-averse with limited capacity. The conditional value at risk (CVaR) is used to measure the risk-averse attitude of the second carrier. A Nash game model is formulated to model the pricing decisions and the equilibrium solution is obtained. We find that the pricing solution takes two forms, which can be determined by a threshold value of carrier 2’s capacity. Under uniformly distributed demand, we show that as the second carrier becomes more risk-averse, both carriers’ optimal prices are decreasing, and the threshold value that determines the pricing strategy is also decreasing. We also analyze the impact of price sensitivity and competition intensity parameters on two carriers’ price decisions under more specific conditions. A necessary and sufficient condition is established to determine whether two carriers’ optimal prices would be positively or negatively affected by the competition intensity parameter. A range of numerical experiments are provided to illustrate the analytical results and explore their validity in more general cases. Moreover, it is shown that the main analytical results in this paper can carry over to the cases when both carriers are risk-averse.

Cruising for parking around a circle

- Transportation Research Part B: Methodological--2017---Richard Arnott,Parker Williams

Several recent papers have used the approximation that the number of curbside parking spaces searched before finding a vacant space equals the reciprocal of the expected curbside vacancy rate. The implied expected cruising-for-parking times are significantly lower than those that have been obtained through observation and simulation. Through computer simulation of cars cruising for parking around a circle in stochastic steady state, this paper shows that the approximation leads to underestimation of expected cruising-for-parking time and, at high occupancy rates, considerable underestimation. The paper also identifies several “effects” that contribute to the approximation being an increasingly poor one as the occupancy rate increases.

Group-based hierarchical adaptive traffic-signal control Part II: Implementation

- Transportation Research Part B: Methodological---2017---Seunghyeon Lee,S.C. Wong,Pravin Varaiya

In part I of this study (Lee et al., 2017), the formulation of a theoretical framework for a group-based adaptive traffic-control method for isolated signalized junctions is presented, which includes tactical and local levels of signal timing optimization. The global level control aims to determine the time-varying cycle structure, with a resolution of cycles, and the real-time adjustment of the green phase, with a resolution of seconds, based on longer-term traffic information observed by traffic detectors. Overall, the purpose of the study is to actualize a multi-resolution strategy for a group-based adaptive signal-control method and establish a microscopic simulation platform to implement the proposed methodology and test its effectiveness. To actualize the global proactive-optimization scheme, in this paper, a rolling-horizon approach to the temporal and spatial variables, signal structures for four-arm intersections, and discrete directional search methods is applied using the developed mathematical framework. The formulation of the group-based max-pressure policy is realized using the logical form of the local reactive-control policy at a typical directional three-lane, four-arm approach to an isolated intersection. The integrated group-based adaptive traffic-signal control is actualized using VISSIM, Fortran, and VBA based on the developed tactical and local levels of signal timing optimization. The results of the computer simulations and the case study presented in this paper show that the integrated group-based adaptive traffic-signal-control logic outperforms the other methods over a wide range of traffic conditions, from free-flowing traffic to extreme congestion. Moreover, the proposed models perform much better than the existing fixed-signal plan and the actuated signal-control in asymmetric traffic conditions.

Testing the slope model of scheduling preferences on stated preference data

- Transportation Research Part B: Methodological---2017---Dereje Abegaz,Katrine Hjorth,Jeppe Rich

The valuation of travel time variability is derived either from a structural model, given information on departure time, or directly from a reduced-form model where departure time is assumed to be optimally chosen. The two models are theoretically equivalent under certain assumptions, hence are expected to yield similar results. We use stated preference data to compare the valuation of travel time variability under a structural model where trip-timing preferences are defined in terms of time-dependent utility rates, the “slope model”, against its reduced-form model. Two choice experiments are used that are identical except one has a fixed departure time while the other allows respondents to choose departure time freely. The empirical results in this paper do not support the theoretical equivalence of the two models as the implied value of travel time variability under the reduced-form model is an order of magnitude larger. This finding, which is robust to various specification tests, is in line with a recent Swedish study by Börjesson, Eliasson and Franklin [Transportation Research Part B: Methodological, 46(7), 855–873 (2012)]. Since our data allows a direct comparison of the two approaches, we are able to rule out some potential explanations lined up by past research for the observed discrepancy between the two models.

Operational flexibility in the truckload trucking industry

- Transportation Research Part B: Methodological---2017---Hossein Zolfagharinia,Michael A. Haughton

Inspired by a real-life logistics provider, this study addresses a dynamic pickup and delivery problem with full truckload (DPDFL) for local operators. The primary purpose of this work is to investigate the impact of potential factors on the carriers’ operational efficiency. These factors, which are typically under managerial influence, are vehicle diversion capability, the DPDFL decision interval, and how far in advance the carrier knows of the clients’ shipment requirements (i.e., advance load information (ALI)). Through comprehensive numerical experiments and statistical analysis, we found that the ALI and decision interval significantly influence the total cost, however, the diversion capability does not. The findings also reveal that the impact of the re-optimization interval depends on the subcontracting cost and the amount of advance load information provided. A major contribution of this work is the development of an efficient benchmark solution for the static version of the DPDFL through the discretization of time windows. We observed that using three-day ALI and an appropriate decision interval can reduce deviation from the benchmark solution to less than 8%.

Air-rail cooperation: Partnership level, market structure and welfare implications

- Transportation Research Part B: Methodological---2017---Changmin Jiang,D’Alfonso, Tiziana,Yulai

Wan

We build a theoretical model to study different air-rail cooperation scenarios. We investigate two possible air-rail partnerships between a rail operator and either a domestic airline or a foreign airline. When a partnership is formed, an investment to improve the air-rail connecting service is allowed at a cost before the service is launched. We find that the cooperation level, the equilibrium partnership scenarios when air-rail cooperation is exclusive or non-exclusive, as well as the comparisons of social welfare under different partnership scenarios, all depend on the pre-investment quality of air-rail service compared with the quality of air-air service. We further apply our model to the real-life case of Strasbourg-Paris-Dubai market, showing that other factors, such as price sensitivity of demand, horizontal differentiation between air and rail, and asymmetries in partnership investment costs, also affect cooperation level.

How to mix per-flight and per-passenger based airport charges: The oligopoly case

- Transportation Research Part B: Methodological---2017---Achim I. Czerny,Simon Cowan,Anming Zhang

While airport aeronautical charges are traditionally aircraft-weight related, currently an increasing share of aeronautical airport revenues is derived from passenger related charges. This paper compares the optimal mix of per-passenger and per-flight based (cost recovering) airport charges from the carriers' and the social viewpoints when carrier markets are oligopolistic. We show that positive per-passenger charges might be able to support the implementation of monopoly fares at slot-constrained airports. They can also mitigate strategic frequency reductions at uncongested airports, leading to an increase in both carrier profit and welfare relative to a charging scheme that fully relies on per-flight charges.

Lagrangian relaxation for the reliable shortest path problem with correlated link travel times

- Transportation Research Part B: Methodological---2017---Yuli Zhang,Zuo-Jun Max Shen,Shiji Song

Finding a reliable shortest path (RSP) in a stochastic network is a fundamental problem in transportation science. Link travel time correlation significantly affects path reliability, but also greatly increases the complexity of the RSP problem due to the quadratic form of the standard deviation term. Lagrangian relaxation (LR) based on problem reformulation, which only needs to solve a series of shortest path problems, has been recognized as an efficient method to obtain near-optimal RSPs with the optimality gap guarantee. This paper proposes a novel LR approach based on a new convex problem reformulation, and new methods to update Lagrangian multipliers and handle negative cycles of the resulting shortest path problems. Different from existing LR approaches, which adopt the classical subgradient method to solve the dual problem, a constraint generation (CG) algorithm and a subgradient projection (SP) algorithm are proposed to update Lagrangian multipliers effectively, and both algorithms are further modified to handle negative cycles. We also reveal the connection between different reformulations of the RSP problem and show that the proposed approach has a smaller duality gap than existing ones. Experiments on real transportation networks validate the effectiveness of the proposed approach in terms of convergence rate, run time, duality gap and optimality by comparison with the existing LR approaches and the outer approximation algorithm.

A probabilistic Passenger-to-Train Assignment Model based on automated data

- Transportation Research Part B: Methodological---2017---Yiwen Zhu,Haris N. Koutsopoulos,Nigel H.M. Wilson

The paper presents a methodology for assigning passengers to individual trains using: (i) fare transaction records from Automatic Fare Collection (AFC) systems and (ii) Automatic Vehicle Location (AVL) data from train tracking systems. The proposed Passenger-to-Train Assignment Model (PTAM) is probabilistic and links each fare transaction to a set of feasible train itineraries. The method estimates the probability of the passenger boarding each feasible train, and the probability distribution of the number of trains a passenger is unable to board due to capacity constraints. The access/egress time distributions are important inputs to the model. The paper also suggests a maximum likelihood approach to estimate these distributions from AFC and AVL data. The methodology is applied in a case study with data from a major, congested, subway system during peak hours. Based on actual AFC and train tracking data, synthetic data was generated to validate the model. The results, both in terms of the trains passengers are assigned to and train loads, are similar to the "true" observations from the synthetic data. The probability of a passenger being left behind (due to capacity constraints) in the actual system is also estimated by time of day and compared with survey data collected by the agency at the same station. The left behind probabilities can be accurately estimated from the assignment results. Furthermore, it is shown that the PTAM output can also be used to estimate crowding metrics at transfer stations.

Modeling collusion-proof port emission regulation of cargo-handling activities under incomplete information

- Transportation Research Part B: Methodological---2017---Shiyuan Zheng,Ying-En Ge,Xiaowen Fu,Nie, Yu (Marco),Chi Xie

This study models the emission regulation of a port's cargo-handling activities when the regulatory government agency lacks complete information on the cost of reducing emissions for the port. The goal is to identify rules for determining the optimal port charge and capacity to allow port emissions to be regulated in an environment with incomplete information. We evaluate the effect of introducing a risk-averse environmental monitor as a supervisor to provide the government with additional information (a signal) on the port operator's emission reduction cost. To prevent the environmental monitor from colluding with the port operator, we develop a collusion-proof regulation scheme based on the principal–agent theory. The scheme is modeled as a bi-level problem faced by the government and the monitor. We find that, compared to the case with complete information, collusion-proof regulation do not distort optimal port charges only when the port operator is efficient and has low emission reduction costs. When distortion does occur, it depends on the monitor's degree of risk aversion and the accuracy of the signal about emission reduction cost. Besides, information asymmetry leads to less cargo throughput, a lower emission level, and reduced port capacity. Such regulation-induced downward distortion can be either alleviated or aggravated by the collusion-proof regulation, depending on the quality of the information received by the environmental monitor. Our theoretical models are tested using a case study based on container terminals in the Port of Shanghai. The numerical results suggest that a risk-averse environmental monitor can improve port user's social welfare in the presence of imperfect information.

Two-phase decomposition method for the last train departure time choice in subway networks

- Transportation Research Part B: Methodological---2017---Liujiang Kang,Qiang Meng

An urban subway network with a number of service lines forms the backbone of the public transport system for a large city of high population, such as Singapore, Hong Kong and Beijing. Passengers in these large cities heavily rely on urban subway networks for their daily life. The departure times of the last trains running on different lines of an urban subway network should be well coordinated in order to serve more passengers who can successfully transfer from one line to another, which is referred to as the last train departure time choice problem. This study aims to develop a global optimization method that can solve the last train departure time choice problem for large-scale urban subway networks. To do so, it first formulates a mixed-integer linear programming (MILP) model by introducing auxiliary binary and integer decision variables. For the real-life and large-scale instances, however, the formulated MILP model cannot be solved directly by the global optimization methods such as branch-and-bound algorithm invoked by CPLEX – one of the powerful optimization solvers because of the instance sizes. An effective two-phase decomposition method is thus proposed to globally solve the large-scale problems by decomposing the original MILP into two MILP models with small sizes. Finally, a real case study from the Beijing subway network is conducted to assess the efficiency and applicability of the two-phase decomposition method and perform the necessary sensitivity analysis of the operational parameters involved in the last train departure time choice problem.

Testing the proportionality condition with taxi trajectory data

- Transportation Research Part B: Methodological---2017---Jun Xie,(Marco) Nie, Yu,Xiaobo Liu

The proportionality condition has been widely used to produce a unique path flow solution in the user equilibrium traffic assignment problem. However, it remains an open question whether and to what extent this condition accords to real travel behavior. This paper attempts to validate the behavioural realism of the proportionality condition using more than 27 million route choice observations obtained by mining a large taxi trajectory data set. A method is first developed to uncover more than three hundred valid paired alternative segments (PAS), on which the proportionality condition is tested by performing linear regression analysis and chi-square tests. The results show that the majority of the PASs tested (up to 85%) satisfy the proportionality condition at a reasonable level of statistical significance.

When adjacent lane dependencies dominate the uncongested regime of the fundamental relationship

- Transportation Research Part B: Methodological---2017---Balaji Ponnu,Benjamin Coifman

This paper presents an empirical study of the fundamental relationship between speed, v, and flow, q, (denoted vqFR) under low flow in the uncongested regime. Using new analytical techniques to extract more information from loop detector data, the vqFR from a time of day HOV lane exhibits high v that slowly drops as q increases. This curve arises after binning several million vehicles by q and only considering those bins with $q < 1200$ vph. A surprising thing happens when further binning the data by the adjacent lane speed (v2): the vqFR expands in to a fan of curves that decrease in magnitude and slope with decreasing v2. Yet each curve in the fan continues to exhibit uncongested trends, ranging from a flat curve consistent with recent editions of the Highway Capacity Manual to downward sloping curves. It is shown that this behavior was not due to the HOV operations per se, the same behavior also arises in the non-HOV period when the lane serves all vehicles and it is also observed at another facility without any HOV restrictions. This dependency on the adjacent lane is absent from most traffic flow theories.

Macroscopic modelling and robust control of bi-modal multi-region urban road networks

- Transportation Research Part B: Methodological---2017---Konstantinos Ampountolas,Nan Zheng,Nikolas Geroliminis

The paper concerns the integration of a bi-modal Macroscopic Fundamental Diagram (MFD) modelling for mixed traffic in a robust control framework for congested single- and multi-region urban networks. The bi-modal MFD relates the accumulation of cars and buses and the outflow (or circulating flow) in homogeneous (both in the spatial distribution of congestion and the spatial mode mixture) bi-modal traffic networks. We introduce the composition of traffic in the network as a parameter that affects the shape of the bi-modal MFD. A linear parameter varying model with uncertain parameter the vehicle composition approximates the original nonlinear system of aggregated dynamics when it is near the equilibrium point for single- and multi-region cities governed by bi-modal MFDs. This model aims at designing a robust perimeter and boundary flow controller for single- and multi-region networks that guarantees robust regulation and stability, and thus smooth and efficient operations, given that vehicle composition is a slow time-varying parameter. The control gain of the robust controller is calculated off-line using convex optimisation. To evaluate the proposed scheme, an extensive simulation-based study for single- and multi-region networks is carried out. To this end, the heterogeneous network of San Francisco where buses and cars share the same infrastructure is partitioned into two homogeneous regions with different modes of composition. The proposed robust control is compared with an optimised pre-timed signal plan and a single-region perimeter control strategy. Results show that the proposed robust control can significantly: (i) reduce the overall congestion in the network; (ii) improve the traffic performance of buses in terms of travel delays and schedule reliability, and; (iii) avoid queues and gridlocks on critical paths of the network.

A train rescheduling model integrating speed management during disruptions of high-speed traffic under a quasi-moving block system

- Transportation Research Part B: Methodological---2017---Peijuan Xu,Francesco Corman,Qiyuan Peng,Xiaojie Luan

Chinese high-speed railways faced a fast development in recent years. Their performances are still confronted with disruptions unavoidably, which impact on the reliability of the traffic and passenger satisfaction. This paper presents a rescheduling model which is able to solve the critical problem of effective disruption management (namely, fast and dynamic train speed adaptation, supervision of braking and changing train sequence due to incidents, warnings or alarms), and consider in detail the signalling and safety systems based on a quasi-moving block system with variable headways. We integrate the modelling of efficient traffic management measures and the supervision of speed, braking and headway in one general job-shop model. We use a commercial solver with a custom-designed two-step method to speed up the procedure in order to solve instances from real-world high-speed networks in China quickly. Overall, the approach guarantees the resolution of the traffic control and speed management within few minutes of computation time. The output demonstrates that the proposed approach can achieve a reduction of train delays by 70% compared to the solution determined by keeping the order of the original timetable, and get the optimality for more than 90% of instances with a realistic case.

A game-theoretic model of car ownership and household time allocation

- Transportation Research Part B: Methodological---2017---Mingzhu Yao,Donggen Wang,Hai Yang

The explosive growth of private cars in China and other developing countries has attracted a great deal of renewed research interest in car ownership. This paper investigates households’ car ownership decision-making process from the perspective of household time allocation. Applying the game-theoretic approach to capturing household members’ interactive decision-making mechanism, we propose a two-stage model that links household members’ short-term time allocation decisions to long-term car ownership decisions. The first stage models the bargaining of household members (e.g., husband and wife) over the car ownership decision, taking into consideration of government policies for regulating car ownership; and the second stage is a generalized Nash equilibrium model for activity-travel pattern analysis incorporating individuals’ interactions concerning activity participation. The existence and uniqueness of the generalized Nash equilibrium solution is examined, and a heuristic procedure that combines backwards induction and method of exhaustion is adopted to solve the two-stage game. The proposed model is applied to an empirical case study in Beijing, which demonstrates the applicability of the model in predicting car ownership and examining interactions between car ownership and household time allocation. The empirical model is applied to assess the impacts of plate-number-based vehicle usage rationing policies on car ownership and time allocation to travel and daily activities. Results show that the model can be applied to evaluate the car ownership impacts of car usage rationing policies.

Networked traffic state estimation involving mixed fixed-mobile sensor data using Hamilton-Jacobi equations

- Transportation Research Part B: Methodological---2017---Edward S. Canepa,Christian G. Claudel

Nowadays, traffic management has become a challenge for urban areas, which are covering larger geographic spaces and facing the generation of different kinds of traffic data. This article presents a robust traffic estimation framework for highways modeled by a system of Lighthill Whitham Richards equations that is able to assimilate different sensor data available. We first present an equivalent formulation of the problem using a Hamilton–Jacobi equation. Then, using a semi-analytic formula, we show that the model constraints resulting from the Hamilton–Jacobi equation are linear ones. We then pose the problem of estimating the traffic density given incomplete and inaccurate traffic data as a Mixed Integer Program. We then extend the density estimation framework to highway networks with any available data constraint and modeling junctions. Finally, we present a travel estimation application for a small network using real traffic measurements obtained obtained during Mobile Century traffic experiment, and comparing the results with ground truth data.

A stochastic optimal control approach for real-time traffic routing considering demand uncertainties and travelers’ choice heterogeneity

- Transportation Research Part B: Methodological---2017---Xidong Pi,Qian, Zhen (Sean)

This paper develops a theoretical approach to identify optimal traffic routing strategy for managing transportation systems. It obtains the optimal traffic diversion ratio to each route that can be achieved in real time through cutting-edge sensing and vehicle-infrastructure communication technologies. We minimize the expected total travel time of all travelers in the network by providing and updating routing advice (or incentives) to travelers in real time. The system-optimum traffic routing problem is modeled using the stochastic control approach where demand uncertainty and travelers’ heterogeneity are explicitly considered over time. The approach is generic in the sense that the optimal routing strategies can be achieved through various technologies, such as connected vehicle technologies, navigation systems, variable message signs, dynamic pricing, etc. For a two-route representative network, we use dynamic programming to derive and approximate the analytical solution of the optimal routing policy for each time interval. The optimal diversion ratio can be updated solely upon the traffic counts measured along the preferred route in real time. The general rule is, with a high probability, to minimize the congestion and keep the maximum flow performance on the preferred route from the beginning of the peak hours. Towards the end of the peak hours, the optimal policy would allow more intensive use of the preferred route resulting over-saturation, whereas keeping the minimal use of the alternative route. The analytical solution is validated and examined in a synthesized network and a real-world network in California. It is found that it consistently outperforms the deterministic solution, and its resultant system performance is also reasonably close to the benchmark system optimum where true demand could be precisely known one day ahead.

Models for technology choice in a transit corridor with elastic demand

- Transportation Research Part B: Methodological---2017---Luigi Moccia,Giovanni Giallombardo,Gilbert Laporte

We present two optimization models for a transit line under the assumption that the demand is elastic and can be approximated by a linear function of fare and passenger travel time components. These models can be used to strategically evaluate technology choices. We study the effect of demand elasticity on the technology choice by analytic and numerical comparison with some fixed demand models. We assume a range of objective functions having as two extrema the maximization of operator’s profit and the maximization of social welfare. We show both analytically and numerically that accounting for demand elasticity does not change the conclusions that can be derived by an equivalent fixed demand model. This invariance holds for a broad range of objective functions in the elastic case. The significant difference between the two objective function extrema lies in the proportions of captured demand.

Incorporating demand dynamics in multi-period capacitated fast-charging location planning for electric vehicles

- Transportation Research Part B: Methodological---2017---Anpeng Zhang,Jee Eun Kang,Changhyun Kwon

We develop a multi-period capacitated flow refueling location problem for electric vehicles (EVs) as the EV market responds to the charging infrastructure. The optimization model will help us determine the optimal location of level 3 chargers as well as the number of charging modules at each station over multiple time periods. Our model can also be applied to fast-filling gaseous alternative fuel vehicles under similar assumptions. We define a number of demand dynamics, including flow demand growth as a function of charging opportunities on path as well as natural demand growth independent of charging infrastructure. We also present an alternative objective function of maximizing electric vehicle demand in addition to maximizing flow coverage. A case study based on a road network around Washington, D.C., New York City, and Boston is presented to provide numerical experiments related to demand dynamics, showing the potential problems in multi-period planning.

Locating multiple types of charging facilities for battery electric vehicles

- Transportation Research Part B: Methodological---2017---Haoxiang Liu,David Z.W. Wang

To reduce greenhouse gas emissions in transportation sector, battery electric vehicle (BEV) is a better choice towards the ultimate goal of zero-emission. However, the shortened range, extended recharging time and insufficient charging facilities hinder the wide adoption of BEV. Recently, a wireless power transfer technology, which can provide dynamic recharging when vehicles are moving on roadway, has the potential to solve these problems. The dynamic recharging facilities, if widely applied on road network, can allow travelers to drive in unlimited range without stopping to recharge. This paper aims to study the complex charging facilities location problem, assuming the wireless charging is technologically mature and a new type of wireless recharging BEV is available to be selected by consumers in the future other than the traditional BEV requiring fixed and static charging stations. The objective is to assist the government planners on optimally locating multiple types of BEV recharging facilities to satisfy the need of different BEV types within a given budget to minimize the public social cost. Road users’ ownership choice among multiple types BEV and BEV drivers’ routing choice behavior are both explicitly considered. A tri-level programming is then developed to model the presented problem. The formulated model is first treated as a black-box optimization, and then solved by an efficient surface response approximation model based solution algorithm.

Investing in logistics facilities today to reduce routing emissions tomorrow

- Transportation Research Part B: Methodological---2017---Fabien Tricoire,Sophie N. Parragh

We investigate the trade-off between strategic investment in facilities and the long-term environmental impact of daily logistics operations. For that purpose, we consider a bi-objective location-routing problem with the objectives of minimising the cost of strategic investments such as locating facilities and acquiring different types of vehicles, and minimising pollution by using CO2 emissions as an indicator. A set of representative days of operations are used to estimate the long-term environmental impact. After modelling that problem as a mixed-integer program, we develop a decomposition approach that constructs routes, then uses them in a separate set covering model to generate complete solutions. The suitability of our approach is investigated on benchmark test instances as well as on a case study in the city of Vienna. Experiments show that our approach is a valuable tool in aiding such long-term decisions.

Joint charging mode and location choice model for battery electric vehicle users

- Transportation Research Part B: Methodological---2017---Min Xu,Qiang Meng,Kai Liu,Toshiyuki Yamamoto

This paper aims to investigate the choice for charging mode and location with the revealed preference data of battery electric vehicle (BEV) users in Japan. Three alternatives including the normal charging at home (for private BEVs)/company premise (for commercial BEVs), normal charging at public charging stations and fast charging at public charging stations are defined. A mixed logit model is developed to investigate what and how factors influence BEV users' choice of charging mode (normal or fast) and location (home/company or public stations), by identifying an appropriate instrumental variable to correct the serious endogeneity problem caused by the midnight indicator. The parameters estimation and results interpretation are conducted for private and commercial BEVs respectively. They suggest that the battery capacity, midnight indicator, initial state of charge (SOC) and number of past fast charging events are the main predictors for users' choice of charging mode and location, that the day interval between current charging and next trip positively affects the normal charging at home/company. In addition, with the increasing of vehicle-kilometres of travel (VKT)/travel duration on former/next travel day, the probability of normal charging at home/company is increased for commercial BEVs, while is decreased for private BEVs. The findings obtained herein have provided new insights into the realization of power peak-load shifting and operation strategy for public charging stations, as well as inspired the development and application of new models and methodologies to determine the density and deployment of public charging stations.

The electric vehicle routing problem with nonlinear charging function

- Transportation Research Part B: Methodological---2017---Alejandro Montoya,Christelle Guéret,Jorge E. Mendoza,Juan G. Villegas

Electric vehicle routing problems (E-VRPs) extend classical routing problems to consider the limited driving range of electric vehicles. In general, this limitation is overcome by introducing planned detours to battery charging stations. Most existing E-VRP models assume that the battery-charge level is a linear function of the charging time, but in reality the function is nonlinear. In this paper we extend current E-VRP models to consider nonlinear charging functions. We propose a hybrid metaheuristic that combines simple components from the literature and components specifically designed for this problem. To assess the importance of nonlinear charging functions, we present a computational study comparing our assumptions with those commonly made in the literature. Our results suggest that neglecting nonlinear charging may lead to infeasible or overly expensive solutions. Furthermore, to test our hybrid metaheuristic we propose a new 120-instance testbed. The results show that our method performs well on these instances.

Energy-efficient shortest routes for electric and hybrid vehicles

- Transportation Research Part B: Methodological---2017---Martin Strehler,Sören Merting,Christian Schwan

Electric and hybrid vehicles are a big step towards a greener mobility, but they also open up completely new questions regarding the shortest path problem and the planning of trips. Since recharging an electric car will take much longer than refilling conventional fossil fuels, we have to balance between speed and range and we have to choose stops for charging wisely. For hybrid vehicles, a symbiosis between navigation system and power train control to choose a path with optimal phases for depleting and recharging the battery may yield much more energy-efficient paths. In this paper, we develop an appropriate model for finding shortest routes for these kinds of vehicles, which is mainly a constrained shortest path problem with convertible resources and charging stations. We study properties of solutions by classifying several types of cycles that may occur in the optimal route. We state sufficient conditions to exclude some of these cycle classes and we derive appropriate approximation schemes with provable quality and strict feasibility. We also study the related network flow problem for operating fleets of electric vehicles, e.g., shared vehicles or buses in urban areas.

Path-constrained traffic assignment: Modeling and computing network impacts of stochastic range anxiety

- Transportation Research Part B: Methodological---2017---Chi Xie,Tong-Gen Wang,Xiaoting Pu,Ampol Karoonsoontawong

It is notoriously known that range anxiety is one of the major barriers that hinder a wide adoption of plug-in electric vehicles, especially battery electric vehicles. Recent studies suggested that if the caused driving range limit makes any impact on travel behaviors, it more likely occurs on the tour or trip chain level than the trip level. To properly assess its impacts on travel choices and traffic congestion, this research is devoted to studying a new network equilibrium problem that implies activity location and travel path choices on the trip chain level subject to stochastic driving ranges. Convex optimization and variational inequality models are respectively constructed for characterizing the equilibrium conditions under both discretely and continuously distributed driving ranges. For deriving the equilibrium flow solutions for these problem cases, we suggested different adaptations of a well-known path-based algorithm—the projected gradient method.

Battery degradation and behaviour for electric vehicles: Review and numerical analyses of several models

- Transportation Research Part B: Methodological---2017---Samuel Pelletier,Ola Jabali,Gilbert Laporte,Marco Veneroni

The use of electric vehicles for goods distribution opens up a wide range of research problems. Battery electric vehicles (BEVs) operate on batteries that have a limited life, as well as specific charging and discharging patterns which need to be considered in the context of their use for goods distribution. While many transportation problems associated with the integration of freight electric vehicles in distribution management problems have been investigated, there is room for further research on specifically how to model battery degradation and behaviour in such problems. The aim of this paper is to provide tractable models for transportation scientists that will allow predicting the lifetime degradation and instantaneous charging and discharging behaviour of BEV batteries.

A time-space network flow approach to dynamic repositioning in bicycle sharing systems

- Transportation Research Part B: Methodological---2017---Dong Zhang,Chuhang Yu,Jitamitra Desai,H.Y.K. Lau,Sandeep Srivathsan

Faced with increasing population density, rising traffic congestion, and the resulting upsurge in carbon emissions, several urban metropolitan areas have instituted public bicycle sharing system as a viable alternative mode of transportation to complement existing long-distance bus- and metro- transit systems. A pressing issue that needs to be addressed in bike sharing systems is the accrued imbalance of bicycles between commuter demands and inventory levels at stations. To overcome this issue, a commonly employed strategy is to reposition bicycles during off-peak periods (typically at night) when no new user arrivals are expected. However, when such an imbalance occurs during day-time peak hours, such a passive strategy would result in lower resource utilization rates. To overcome this drawback, in this study, we propose a dynamic bicycle repositioning methodology that considers inventory level forecasting, user arrivals forecasting, bicycle repositioning, and vehicle routing in a unified manner. A multi-commodity time-space network flow model is presented, which results in an underlying complex nonlinear optimization problem. This problem is then reformulated into an equivalent mixed-integer problem using a model transformation approach and a novel heuristic algorithm is proposed to efficiently solve this model. Specifically, the first stage involves solving the linear relaxation of the MIP model, and a set covering problem is subsequently solved in the second stage to assign routes to the repositioning vehicles. The proposed methodology is evaluated using standard test-bed instances from the literature, and our numerical results reveal that the heuristic algorithm can achieve a significant reduction in rejected user requests when compared to existing methods, while yet expending only minimal computational effort.

Optimal assignment and incentive design in the taxi group ride problem

- Transportation Research Part B: Methodological---2017---Xinwu Qian,Wenbo Zhang,Satish V. Ukkusuri,Chao Yang

Taxi group ride (TGR) is one popular case of taxi ridesharing, where passenger trips with nearby origins and destinations and similar departure time are grouped into a single ride. The study investigates theoretical and practical aspects of TGR implementation in real world. In particular, two essential problems on operation strategy and policy making of TGR are examined. First, we investigate the optimal assignment of a set of passengers for the sake of maximizing total saved travel miles. Second, we analyze different behaviors of passengers and drivers in participating taxi group rides, and explore the best incentives for TGR in order to maximize efficiency under optimal assignment. The optimal assignment is formulated as an integer linear programming problem and is further converted into an equivalent graph problem. While the problem is NP-hard, efficient algorithms are needed for real-world on-line implementations. We develop an exact algorithm and a heuristic algorithm to solve the TGR problem, and compare the results with a bounded-error greedy algorithm. The numerical experiments suggest that the heuristic algorithm is capable of solving real-world TGR instances efficiently with good solution quality. To explore the best incentives for grouped taxi rides, comprehensive numerical experiments are conducted using taxi trip data from New York City (US), Wuhan (China), and Shenzhen (China). Our numerical results show that over 47% of the total taxi trip mileage may be saved if proper level of incentives are provided and if passengers are matched optimally.

Modeling and managing morning commute with both household and individual travels

- Transportation Research Part B: Methodological---2017---Wei Liu,Fangni Zhang,Hai Yang

This study investigates the morning commute problem with both household and individual travels, where the household travel is a shared ride of household (family) members. In particular, it considers the situation when a proportion of commuters have to drive their children to school first and then go to work (household travel). For household travel, departure time choice is a joint decision based on all household members’ preferences. Unlike the standard bottleneck model, the rush-hour dynamic traffic pattern with mixed travelers (household travelers and individual travelers) varies with the numbers of individual travelers and households, as well as the schedule difference between school and work. Given the numbers of individual travelers and households, we show that by appropriately coordinating the schedules of work and school, the traffic congestion at the highway bottleneck can be relieved, and hence the total travel cost can be reduced. This is because, departure/arrival of individual and household travels can be separated by schedule coordination. System performance under schedule coordination is quantified in terms of the relative proportions of the two classes of travelers and is compared with the extreme case when the same desired arrival time applies to both schooling and working. Furthermore, the efficiency of work and school schedule coordination in reducing travel cost is bounded. This efficiency is also compared with that at the system optimum where queuing is fully eliminated and schedule delay cost is minimized (achieved by a joint scheme of first-best pricing and schedule coordination).

Multi-objective optimal control formulations for bus service reliability with traffic signals

- Transportation Research Part B: Methodological---2017---Andy H.F. Chow,Shuai Li,Renxin Zhong

This paper presents a set of optimal control formulations for maximising bus service reliability through deriving optimal adjustments on signal timings. The traffic dynamics is captured by an underlying kinematic wave model in Hamilton–Jacobi formulation. With traffic data collected through loop detectors and bus positioning devices, the control actions are carried out through adjusting signal timing plans according to short-term estimations of traffic flows and bus arrivals. We derive the optimality conditions of multi-objective control formulations and present an open loop solution algorithm. The proposed control system is applied to a test arterial developed based upon a real-world scenario in Central London, UK. It is found that the model is capable of regulating bus service reliability through utilising traffic signals while managing delays induced to surrounding traffic. The study generates new insights on managing bus service reliability in busy urban networks.

Transit-oriented development in an urban rail transportation corridor

- Transportation Research Part B: Methodological---2017---Ya-Ting Peng,Zhi-Chun Li,Keechoo Choi

Transit-oriented development (TOD) has been recognized as an important avenue for creating a green transportation system. This paper addresses TOD investment issue in terms of the location, number and size of the TOD zones along a rail line. An urban system equilibrium problem with TOD investment is first formulated. Two social welfare maximization models, which take into account different investment regimes for TOD projects (i.e., public and private), are then proposed for optimizing TOD investment schemes along a rail line and train service frequency on that line. In the public regime model, the government is responsible for the investment cost of TOD projects, which is borne by the private property developers in the private regime model. The proposed models explicitly consider the interactions among the government, property developers and households in the urban system, together with the effects of the TOD investment on households' residential location choices and housing market. The population thresholds for investing in a TOD project under the public and private regimes are also identified. The findings show that the TOD investment can cause population agglomeration at the TOD zones and a compact city; households and the society can benefit from the TOD investment; and the private TOD investment regime outperforms the public regime in terms of total social welfare of urban system.

Alternate weibit-based model for assessing green transport systems with combined mode and route travel choices

- Transportation Research Part B: Methodological---2017---Songyot Kitthamkesorn,Anthony Chen

Reduction of vehicle emissions is a major component of sustainable transportation development. The promotion of green transport modes is a worthwhile and sustainable approach to change transport mode shares and to contribute to healthier travel choices. In this paper, we provide an alternate weibit-based model for the combined modal split and traffic assignment (CMSTA) problem that explicitly considers both similarities and heterogeneous perception variances under congestion. Instead of using the widely-adopted Gumbel distribution, both mode and route choice decisions are derived from random utility theory using the Weibull distributed random errors. At the mode choice level, a nested weibit (NW) model is developed to relax the identical perception variance of the logit model. At the route choice level, the recently developed path-size weibit (PSW) is adopted to handle both route overlapping and route-specific perception variance. Further, an equivalent mathematical programming (MP) formulation is developed for this NW-PSW model as a CMSTA problem under congested networks. Some properties of the proposed models are also rigorously proved. Using this alternate weibit-based NW-PSW model, different go-green strategies are quantitatively evaluated to examine (a) the behavioral modeling of travelers' mode shift between the private motorized mode and go-green modes and (b) travelers' route choice with consideration of both non-identical perception variance and route overlapping. The results reveal that mode shares and route choices from the NW-PSW model can better reflect the changes in model parameters and in network characteristics than the traditional logit and extended logit models.

Risky weighting in discrete choice

- Transportation Research Part B: Methodological---2017---Baibing Li,David Hensher

This paper presents a new approach to discrete choice analysis for risky prospects. Conventional discrete choice analysis focuses on riskless prospects and does not deal with the scenario where the alternatives that the decision-makers choose from are associated with risk. In this paper, we investigate decision-makers' risk perception and choice behaviour in choice experiments when they are facing several risky prospects. We propose a broad class of cumulative risky weighting functions, upon which a unified cumulative risky weighting function is developed. We show that this unified cumulative risky weighting function includes several existing cumulative risky weighting functions as special cases. We then develop a multivariate method for choice analysis with risky prospects to account for decision-makers' individual-specific risk perception and the impact of various factors on the value function respectively. We illustrate the developed method using an empirical study on road tolling in Australia.

An optimal stopping approach to managing travel-time uncertainty for time-sensitive customer pickup

- Transportation Research Part B: Methodological---2017---Neža Vodopivec,Elise Miller-Hooks

In dynamic vehicle routing, it is common to respond to real-time information with immediate updates to routes and fleet management. However, even if routes are updated continuously, in practice, some decisions once made are difficult to reverse. At times, it may thus be valuable to wait for additional information before acting on a decision. We use the theory of optimal stopping to determine the optimal timing of a recourse action when vehicles are likely to miss customer deadlines due to travel-time stochasticities and backup services are available. The factors involved in making this decision – that is, the likelihood that the primary vehicle will arrive late, the location of the backup vehicle, and value of waiting for additional travel-time information – each change dynamically over time. We develop a recourse model that accounts for this complexity. We formulate the optimal recourse policy as a stochastic dynamic program. Properties of the optimal policy are derived analytically, and its solution is approximated with a binomial lattice method used in the pricing of American options. Finally, we develop a two-stage stochastic optimization approach to show how the opportunity to take recourse dynamically might be integrated into a priori scheduling and routing. The framework is demonstrated for a stochastic dial-a-ride application in which taxis serve as backup to ridesharing vehicles.

Analysis of an idealized system of demand adaptive paired-line hybrid transit

- Transportation Research Part B: Methodological---2017---Peng Will Chen,Yu Marco Nie

This paper proposes and analyzes a new transit system that integrates the traditional fixed-route service with a demand-adaptive service. The demand-adaptive service connects passengers from their origin/destination to the fixed-route service in order to improve accessability. The proposed hybrid design is unique in that it operates the demand-adaptive service with a stable headway to cover all stops along a paired fixed-route line. Pairing demand-adaptive vehicles with a fixed-route line simplifies the complexity of on-demand routing, because the vehicles can follow a more predictable path and can be dispatched on intervals coordinated with the fixed-route line. The design of the two services are closely coupled to minimize the total system cost, which incudes both the transit agency' s operating cost and the user cost. The optimal design model is formulated as a mixed integer program and solved using a commercially available metaheuristic. Numerical experiments are conducted to compare the demand adaptive paired-line hybrid transit (DAPL-HT) system with two related transit systems that may be considered its special cases: a fixed-route system and a flexible-route system. We show that the DAPL-HT system outperforms the other two systems under a wide range of demand levels and in various scenarios of input parameters. A discrete-event simulation model is also developed and applied to confirm the correctness of the analytical results.

A two-stage stochastic optimization model for scheduling electric vehicle charging loads to relieve distribution-system constraints

- Transportation Research Part B: Methodological---2017---Fei Wu,Ramteen Sioshansi

Electric vehicles (EVs) hold promise to improve the energy efficiency and environmental impacts of transportation. However, widespread EV use can impose significant stress on electricity-distribution systems due to their added charging loads.

Detecting dominance in stated choice data and accounting for dominance-based scale differences in logit models

- Transportation Research Part B: Methodological---2017---Michiel Bliemer,John M. Rose,Caspar G. Chorus

Stated choice surveys have been used for several decades to estimate preferences of agents using choice models, and are widely applied in the transportation domain. Different types of experimental designs that underlie such surveys have been used in practice. In unlabelled experiments, where all alternatives are described by the same generic utility function, such designs may suffer from choice tasks containing a dominant alternative. Also in labelled experiments with alternative specific attributes and constants such dominance may occur, but to a lesser extent. We show that dominant alternatives are problematic because they affect scale and may bias parameter estimates. We propose a new measure based on minimum regret to calculate dominance and automatically detect such choice tasks in an experimental design or existing dataset. This measure is then used to define a new experimental design type that removes dominance and ensures the making of trade-offs between attributes. Finally, we propose a new regret-scaled multinomial logit model that takes the level of dominance within a choice task into account. Results using simulated and empirical data show that the presence of dominant alternatives can bias model estimates, but by making scale a function of a smooth approximation of normalised minimum regret we can properly account for scale differences without the need to remove choice tasks with dominant alternatives from the dataset.

Quantitative analyses of highway franchising under build-operate-transfer scheme: Critical review and future research directions

- Transportation Research Part B: Methodological---2017---Qiang Meng,Zhaoyang Lu

Private provision of the public highways through the build-operate-transfer (BOT) scheme has become popular worldwide. Studies published in dozens of academic journals have investigated various kinds of cases of BOT highway projects. However, there appears to be a lack of systematic and critical overview on what specific problems and research methodologies these studies proposed and used for quantitatively analyzing the BOT highway projects. Therefore, this study critically reviews the relevant traffic oriented quantitative studies, which mainly focus on the determination of fundamental design factors for a BOT highway project in the planning stage. The existing studies are thoroughly examined according to the characters of BOT highway projects. To conclude, this study points out the limitations of the current studies and provides some tangible future research directions with practical relevance.

Air traffic flow management under uncertainty using chance-constrained optimization

- Transportation Research Part B: Methodological---2017---J. Chen,L. Chen,D. Sun,Jinhui Chen

In order to efficiently balance traffic demand and capacity, optimization of Air Traffic Flow Management (ATFM) relies on accurate predictions of future capacity states. However, these predictions are inherently uncertain due to factors, such as weather. This paper presents a novel computationally efficient algorithm to address uncertainty in ATFM by using a chance-constrained optimization method. First, a chance-constrained model is developed based on a previous deterministic Integer Programming optimization model of ATFM to include probabilistic sector capacity constraints. Then, to efficiently solve such a large-scale chance-constrained optimization problem, a polynomial approximation-based approach is applied. The approximation is based on the numerical properties of the Bernstein polynomial, which is capable of effectively controlling the approximation error for both the function value and gradient. Thus, a first-order algorithm is adopted to obtain a satisfactory solution, which is expected to be optimal. Numerical results are reported in order to evaluate the polynomial approximation-based approach by comparing it with the brute-force method. Moreover, since there are massive independent approximation processes in the polynomial approximation-based approach, a distributed computing framework is designed to carry out the computation for this method. This chance-constrained optimization method and its computation platform are potentially helpful in their application to several other domains in air transportation, such as airport surface operations and airline management under uncertainties.

Design of energy-Efficient timetables in two-way railway rapid transit lines

- Transportation Research Part B: Methodological---2017---David Canca,Alejandro Zarzo

A methodology to design energy-efficient timetables in Rapid Railway Transit Networks is presented. Using an empirical description of the train energy consumption as a function of running times, the timetable design problem is modelled as a Mixed Integer Non-Linear optimization problem (MINLP) for a complete two-way line. In doing so, all the services in both directions along a certain planning horizon are considered while attending a known passengers' demand. The MINLP formulation, which depends on train loads, is fully linearised supposing train loads are fixed. A sequential Mixed Integer Linear solving procedure is then used to solve the timetabling optimization problem with unknown train loads. The proposed methodology emphasizes the need of considering all the services running during the planning horizon when designing energy-efficient timetables, as consequence of the relationship among train speeds, frequency and fleet size of each line. Moreover, the convenience of considering the energy consumption as part of a broad objective function that includes other relevant costs is pointed out. Otherwise, passengers and operators could face up to an increase in the whole cost and a decrease in the quality of service. A real data scenario, based on the C-2 Line of the Madrid Metropolitan Railways, is used to illustrate the proposed methodology and to discuss the differences between the energy-efficient solutions and those obtained when considering operation and acquisition costs.

Doubly dynamics for multi-modal networks with park-and-ride and adaptive pricing

- Transportation Research Part B: Methodological---2017---Wei Liu,Nikolas Geroliminis

This paper models and controls a multi-region and multi-modal transportation system, given that the travelers can adjust their mode choices from day to day, and the within-day traffic dynamics in the network also evolve over days. In particular, it considers that the city network can be partitioned into two regions (center and periphery). There are park-and-ride facilities located at the boundary between the city center region and the periphery. Travelers can either drive to the city center, or take public transit, or drive to the park-and-ride facilities and then transfer to the public transit. Travelers can "learn" from their travel experience, as well as real-time information about traffic conditions, thus will adjust their choices accordingly. It follows that the dynamic traffic pattern (within-day) in the city network will evolve over (calendar) time (day-to-day). To improve traffic efficiency in the network, an adaptive mechanism, which does not need detailed travelers' behavioral characteristics, is developed to update parking pricing (or congestion pricing) from period to period (e.g., one period can be one month). The developed doubly dynamics methodological framework coupled with a feedback pricing mechanism unfolds and influences equilibrium system characteristics that traditional static day-to-day models cannot observe. The proposed adaptive pricing approach is practical for implementation in large-scale networks as the variables involved can be observed in real life with monitoring techniques. Also, it can contribute to reduce total social cost effectively, as shown in the numerical experiments.

Stochastic network link transmission model

- Transportation Research Part B: Methodological---2017---G. Flötteröd,C. Osorio

This article considers the stochastic modeling of vehicular network flows, including the analytical approximation of joint queue-length distributions. The article presents two main methodological contributions. First, it proposes a tractable network model for finite space capacity Markovian queueing networks. This methodology decomposes a general topology queueing network into a set of overlapping subnetworks and approximates the transient joint queue-length distribution of each subnetwork. The subnetwork overlap allows to approximate stochastic dependencies across multiple subnetworks with a complexity that is linear in the number of subnetworks. Additionally, the network model maintains mutually consistent overlapping subnetwork distributions. Second, a stochastic network link transmission model (SLTM) is formulated that builds on the proposed queueing network decomposition and on the stochastic single-link model of Osorio and Flötteröd (2015). The SLTM represents each direction of a road and each road intersection as one queueing subnetwork. Three experiments are presented. First, the analytical approximations of the queueing-theoretical model are validated against simulation-based estimates. An experiment with intricate traffic dynamics and multimodal joint distributions is studied. The analytical model captures most dependency structure and approximates well the simulated network dynamics and joint distributions. Even for the considered simple network, which consists of only eight links, the proposed subnetwork decomposition yields significant gains in computational efficiency: It uses less than 0.0025% of the memory that is required by the use of a full network model. Second and third, the proposed SLTM is illustrated with a linear test network adopted from the literature and a more general topology network containing a diverge node and a merge node. Time-dependent probabilistic performance measures (occupancy uncertainty bands, spillback probabilities) are presented and discussed.

A stochastic program approach for path reconstruction oriented sensor location model

- Transportation Research Part B: Methodological---2017---Chenyi Fu,Ning Zhu,Shoufeng Ma

Path flow identification is of particular interest for a number of traffic applications, such as OD demand estimation, link flow inference, and toll freeway revenue management. Optimal positioning of active sensors can help to identify path flows. Due to the stochastic nature of transportation systems, we propose a scenario based two stage stochastic programming framework which considers the uncertainty of the link-path matrix. The first stage model aims to minimize the total traffic sensor installation cost and the expected penalty for uncovered and undifferentiated paths. The second stage model attempts to minimize uncovered and undifferentiated paths for a given sensor location pattern and a specific scenario. In addition, a mean risk measure is also incorporated into the two stage stochastic programming framework, and consequently a mean risk two stage stochastic programming model is proposed. Both models have the same structure, where the first stage and second stage decision variables are binary. The second stage decision variable can be relaxed to a continuous variable without changing the nature of the model. To solve the two stochastic programming models, a branch and bound based integer L-shaped algorithm is presented. Finite steps convergence is guaranteed for the algorithm. To handle the problem with a large number of scenarios, a sampling technique is introduced, and the confidence bound is analyzed with respect to the scenario size. Extensive numerical experiments are conducted to verify the effectiveness of the proposed models and algorithm. The most important numerical results are as follows: (i) the stochastic programming framework is capable of capturing the reality more efficiently and accurately, (ii) the path differentiation factor is more critical than the path coverage factor in determining the sensor placement pattern, and (iii) in the partial parameter setting case, the mean risk based stochastic programming model results in a significantly different sensor placement pattern compared to the normal stochastic programming model. The study contributes to practical sensor placement design.

Scalable space-time trajectory cube for path-finding: A study using big taxi trajectory data

- Transportation Research Part B: Methodological---2017---Lin Yang,Mei-Po Kwan,Xiaofang Pan,Bo Wan,Shunping Zhou

Route planning is an important daily activity and has been intensively studied owing to their broad applications. Extracting the driving experience of taxi drivers to learn about the best routes and to support dynamic route planning can greatly help both end users and governments to ease traffic problems. Travel frequency representing the popularity of different road segments plays an important role in experience-based path-finding models and route computation. However, global frequency used in previous studies does not take into account the dynamic space-time characteristics of origins and destinations and the detailed travel frequency in different directions on the same road segment. This paper presents the space-time trajectory cube as a framework for dividing and organizing the trajectory space in terms of three dimensions (origin, destination, and time). After that, space-time trajectory cube computation and origin-destination constrained experience extraction methods are proposed to extract the fine-grained experience of taxi drivers based on a dataset of real taxi trajectories. Finally, space-time constrained graph was generated by merging drivers' experience with the road network to compute optimal routes. The framework and methods were implemented using a taxi trajectory dataset from Shenzhen, China. The results show that the proposed methods effectively extracted the driving experience of the taxi drivers and the entailed trade-off between route length and travel time for routes with high trajectory coverage. They also indicate that road segment global frequency is not appropriate for representing driving experience in route planning models. These results are important for future research on route planning or path finding methods and their applications in navigation systems.

Bounded rationality can make parking search more efficient: The power of lexicographic heuristics

- Transportation Research Part B: Methodological---2017---Merkouris Karaliopoulos,Konstantinos Katsikopoulos,Lambros Lambrinos

The search for parking space in busy urban districts is one of those routine human activities that are expected to benefit from the widespread adoption of pervasive sensing and radio communication technologies. Proposed parking assistance solutions combine sensors, either as part of fixed infrastructure or onboard vehicles, wireless networking technologies and mobile social applications running on smartphones to collect, share and present to drivers real-time information about parking demand and availability.

Traffic state estimation based on Eulerian and Lagrangian observations in a mesoscopic modeling framework

- Transportation Research Part B: Methodological--2017---Aurélien Duret,Yufei Yuan

The paper proposes a model-based framework for estimating traffic states from Eulerian (loop) and/or Lagrangian (probe) data. Lagrangian-Space formulation of the LWR model adopted as the underlying traffic model provides suitable properties for receiving both Eulerian and Lagrangian external information. Three independent methods are proposed to address Eulerian data, Lagrangian data and the combination of both, respectively. These methods are defined in a consistent framework so as to be implemented simultaneously. The proposed framework has been verified on the synthetic data derived from the same underlying traffic flow model. Strength and weakness of both data sources are discussed. Next, the proposed framework has been applied to a freeway corridor. The validity has been tested using the data from a microscopic simulator, and the performance is satisfactory even for low rate of probe vehicles around 5%.

Goal-based models for discrete choice analysis

- Transportation Research Part B: Methodological--2017---A.A.J. Marley,Joffre Swait

Goals direct decision making, from the most abstract levels of motivation to the multitudinous details of evaluation of options available for choice. However, the pervasive influence of goals in decision processes is generally not explicitly recognized at the level of demand model formulation and specification. In applied economics generally, and transportation specifically, demand models relate product/service attributes directly to behavior, using utility (or value) as a shorthand representation for the impact of goals. In this paper we argue that this is a limiting view that restricts our thinking about decision making and, hence, our representation and inference-making about that behavior. We support this argument by reinterpreting and/or extending various applications of hybrid models in transportation to a goal-based framework and formulating goal-based choice models which recognize that goals (1) are drivers of choice, (2) explain the choice of strategy, (3) are part of the constraint set and (4) contribute to explaining impacts of the decision context on the allocation of cognitive resources by the decision maker.

Hub-airport congestion pricing and capacity investment

- Transportation Research Part B: Methodological--2017---Ming Hsin Lin,Yimin Zhang

This study examines hub-airport congestion pricing and capacity investment using a simple hub-spoke network model, in which hub-carrier scheduling causes both schedule delays and congestion delays. The "fixed-proportion assumption" is removed. We find the following. (i) A public hub airport requires both per-flight charges, which must be movement-related but cannot be weight-related, and discriminatory per-local and per-connecting passenger charges to reach the first-best outcome. (ii) Either weight-related per-flight charges or the marginal-operating-cost (MOC) pricing on local and/or connecting passengers cannot reach the first-best. (iii) First-best charges can lead capacity investment to be socially efficient. However, weight-related per-flights charges result in under-investment, whereas the MOC pricing results in over-investment in runway capacity. (iv) Private hubs that charge positive movement-related per-flight charges subsidize passengers through per-passenger charges. Finally, (v) movement-related per-flight charges lead private hubs to overinvest, whereas weight-related per-flight charges lead to either over- or under-investment.

Downtown parking supply, work-trip mode choice and urban spatial structure

- Transportation Research Part B: Methodological---2017---Sofia F. Franco

This paper examines the effects of changes in downtown parking supply on urban welfare, modal choice decisions and urban spatial structure using a spatial general equilibrium model of a closed monocentric city with two transport modes, endogenous residential parking and a form of bottleneck congestion at the CBD. Our analysis shows that parking reforms at the CBD that increase delay congestion costs in the short-run such as parking supply limits can be welfare improving if other commuting externalities such as air pollution can be reduced. In addition, because parking limits can also change location decisions such as where to live and invest they may complement anti-sprawl policies efforts by leading to a more compact urban spatial structure in the long run. We also show that changes in downtown parking supply can have different spatial impacts on the market supply of residential parking by affecting urban residents' location decisions. Finally, we investigate whether the self-financing theorem of transportation economics holds within the context of our spatial urban model.

Stochastic user equilibrium traffic assignment with equilibrated parking search routes

- Transportation Research Part B: Methodological---2017---Adam J. Pel,Emmanouil Chaniotakis

In this paper we define and formulate the concept of parking search routes (PSR) where a driver visits a sequence of parking locations until the first vacant parking spot is found and in doing so may account for (expected) parking probabilities. From there we define and formulate the stochastic user equilibrium (SUE) traffic assignment in which no driver, by unilaterally changing its PSR, can lower its perceived expected generalized costs. Recognizing the interdependency between PSR flows, travel times and parking probabilities, we propose a queuing model in order to compute endogenous parking probabilities accounting for these factors as well as maximum admissible search times. To solve the SUE assignment with equilibrated PSR we propose a solution algorithm, including a method for PSR choice set generation. The model is implemented and applied both to a number of experimental cases to verify its properties and to a real-life setting to illustrate its usefulness in parking-related studies.

Rolling stock rescheduling in passenger railway transportation using dead-heading trips and adjusted passenger demand

- Transportation Research Part B: Methodological---2017---Joris Wagenaar,Leo Kroon,Ioannis Fragkos

In this paper we introduce dead-heading trips and adjusted passenger demand in the Rolling Stock Rescheduling Problem (RSRP). Unfortunately, disruptions disturb passenger railway transportation on a daily basis. Such a disruption causes infeasibilities in the timetable, rolling stock circulation, and crew schedule. We propose a Mixed-Integer Linear Programming model to tackle the RSRP. This formulation includes the possibility of using dead-heading trips (moving empty trains) during, and after, a disruption. Furthermore, passenger flows are included to handle the adjusted passenger demand after the occurrence of a disruption. Many rolling stock rescheduling models are unable to cope with changing passenger demand. In this paper we include passenger demand on a more accurate level in the RSRP. We have tested the model on different cases from Netherlands Railways. The results show that dead-heading trips are useful to reduce the number of cancelled trips and that adjusted passenger demand has a large influence on the rescheduled circulation.

The cumulative capacitated vehicle routing problem with min-sum and min-max objectives: An effective hybridisation of adaptive variable neighbourhood search and large neighbourhood search

- Transportation Research Part B: Methodological---2017---Jeeu Fong Sze,Said Salhi,Niaz Wassan

The cumulative capacitated vehicle routing problem (CCVRP) is a relatively new variant of the classical capacitated vehicle routing problem in which the objective is to minimise the sum of arrival times at customers (min-sum) instead of the total route distance. While the literature for the CCVRP is scarce, this problem has useful applications especially in the area of supplying humanitarian aid after a natural disaster. In this paper, a two-stage adaptive variable neighbourhood search (AVNS) algorithm that incorporates large neighbourhood search (LNS) as a diversification strategy is proposed. When tested on the benchmark data sets, the results show that the proposed AVNS is highly competitive in producing new best known solutions to more than half of the instances. An alternative but related objective that minimises the maximum arrival time (min-max) is also explored in this study demonstrating the flexibility and the effectiveness of the proposed metaheuristic. To the best of our knowledge, this is the first study that exploits the min-max objective of the CCVRP in addition to providing extensive computational results for a large number of instances for the min-sum. As a by-product of this study, managerial insights for decision making are also presented.

A Nash equilibrium formulation of a tradable credits scheme for incentivizing transport choices: From next-generation public transport mode choice to HOT lanes

- Transportation Research Part B: Methodological--2017---Salem Lahlou,Laura Wynter

We consider a tradable credits scheme for binary transport games where one option is faster (or more comfortable) than the other, but its quality of service suffers when usage is high. Applications can be found in mode choice (public transit versus road transport), premium (i.e., express bus) versus ordinary public transit, and fast (e.g., high-occupancy toll, or HOT) versus regular lanes on expressways. We are motivated in particular by the choice between public transport and use of the road network as a privilege to be discouraged. In a future where GPS-based time-distance-place road charging exists, such next-generation transport management strategies become realizable as the choice to drive or not can be linked to a fixed fee toll, or indeed to a tradable credits scheme. When public transport payment uses the same smart card as the road usage fee (via tolls or tradable credits) usage of the two may be linked. In this setting, a public transport vs. road-use tradable credit scheme becomes feasible. In this case, individuals wishing to choose the faster option must obtain credits from other commuters via credit trading, rather than pay a direct toll or fee. Such a scheme creates a kind of equity, in the sense that lower-income commuters have an economic incentive to resort to the slower or less comfortable choice. We study the underlying market and its effects on individuals' utilities; we use an atomic game framework so as to model explicitly the exchange process across users. The market we define determines the quantities of users choosing each option, as opposed to the prices themselves. Using the properties of potential games, we show that under mild assumptions, efficient Nash equilibria exist and can be reached using simple learning algorithms. We show that these equilibria can satisfy the transport authority's requirements, and thus drive the transport system to a state where a desired proportion of individuals resort to each of the two options, when the scheme's parameters are well tuned.

On the distribution of individual daily driving distances

- Transportation Research Part B: Methodological--2017---Patrick Plötz,Niklas Jakobsson,Frances Sprei

Plug-in electric vehicles (PEV) can reduce greenhouse gas emissions. However, the utility of PEVs, as well as reduction of emissions is highly dependent on daily vehicle kilometres travelled (VKT). Further, the daily VKT by individual passenger cars vary strongly between days. A common method to analyse individual daily VKT is to fit distribution functions and to further analyse these fits. However, several distributions for individual daily VKT have been discussed in the literature without conclusive decision on the best distribution. Here we analyse three two-parameter distribution functions for the variation in daily VKT with four sets of travel data covering a total of 190,000 driving days and 9.5 million VKT. Specifically, we look at overall performance of the distributions on the data using four goodness of fit measures, as well as the consequence of choosing one distribution over the others for two common PEV applications: the days requiring adaptation for battery electric vehicles and the utility factor for plug-in hybrid electric vehicles. We find the Weibull distribution to fit most vehicles well but not all and at the same time yielding good predictions for PEV related attributes. Furthermore, the choice of distribution impacts PEV usage factors. Here, the Weibull distribution yields reliable estimates for electric vehicle applications whereas the log-normal distribution yields more conservative estimates for PEV usage factors. Our results help to guide the choice of distribution for a specific research question utilising driving data and provide a methodological advancement in the application of distribution functions to longitudinal driving data.

Robust routing and timetabling in complex railway stations

- Transportation Research Part B: Methodological---2017---Sofie Burggraeve,Pieter Vansteenwegen

In nearly saturated station areas the limited capacity is one of the main reasons of delay propagation. Spreading the trains well in time and space in these areas has a big impact on the passenger robustness, i.e. the total travel time in practice of all passengers in the railway network in case of frequently occurring small delays. We focus on improving the performance in the bottleneck of the network in order to improve the performance of the whole railway network. This paper proposes a method that builds from scratch a routing plan and a cyclic timetable that optimizes the infrastructure occupation and the passenger robustness. An integer linear routing model assigns, without considering a timetable, every train to a route such that the maximal node usage is minimized and that the number of times that each node is used, is quadratically penalized. Thereafter, a mixed integer linear timetabling model assigns to each train the blocking times at which the nodes on its route, assigned by the routing model, are reserved and released. Different from other approaches is that we focus on the occupation of the railway infrastructure before constructing the timetable. The approach is validated on the complex railway station area of Brussels (Belgium). Our routing plan and timetable from scratch improve the passenger robustness up to 11% compared to a reference timetable and routing plan composed by the Belgian railway infrastructure manager Infrabel and by up to 2% compared to a reference timetable and routing plan from literature.

Macroscopic urban dynamics: Analytical and numerical comparisons of existing models

- Transportation Research Part B: Methodological---2017---Guilhem Mariotte,Ludovic Leclercq,Jorge A. Laval

Large-scale network modeling using the Macroscopic Fundamental Diagram (MFD) is widely based on the single-reservoir model, where the variation of the accumulation of circulating vehicles in the reservoir equals inflow minus outflow. However, inconsistent lags for information propagation between boundaries may be observed with this single accumulation-based model. For example, outflow is reacting too fast when inflow varies rapidly, whereas this information should be carried by vehicles that are never driving faster than the free-flow speed. To overcome this limitation, a trip-based model has been recently proposed, but whose solution cannot be obtained analytically.

Dynamic macroscopic simulation of on-street parking search: A trip-based approach

- Transportation Research Part B: Methodological---2017---Ludovic Leclercq,Alméria Sénécat,Guilhem Mariotte

This paper extends a trip-based aggregate dynamic traffic model to account for on-street parking search. The trip-based approach for a road network defined as a reservoir characterizes the internal traffic states by a macroscopic fundamental diagram (MFD) in speed while individualizing all vehicle travel distances. This paper first investigates distances to park for on-street parking based on real data in Lyon (France) and stochastic numerical experiments. An updated formulation compared to the existing literature is proposed for the relation between such distances and the parking occupancy. This new formulation is then incorporated into an event-based numerical scheme that solves the trip-based MFD model. The complete framework is able to account for different vehicle categories with respect to their parking strategies and to finely tune the related travel distances. Finally, the capabilities of the full framework are illustrated based on three different scenarios. The first two correspond to strategies with static and dynamic (reactive) switch of the demand from on- to off-street parking. While being very classical, they permit to demonstrate that the proposed model reacts as expected in such cases. The third scenario assesses the effect of a smart-parking technology that informs the users when a free parking spot is available on one of the downstream links at each intersection. In such a case, the model permits to estimate the benefit for the equipped users but also the impacts on all other vehicle categories. The three scenarios highlight that the proposed framework is versatile and can quickly provide a first assessment with a low calibration burden of different parking strategies or policies.

Urban land use, sorting, and population density: A continuous logit model

- Transportation Research Part B: Methodological---2017---Matthias Wrede

This paper analyzes land use, sorting, and population density in a polycentric city. To this end, the paper develops a continuous spatial choice logit model of a closed polycentric city with multiple income classes and endogenous land use where households select their workplace and residence locations probabilistically. In contrast to the classic urban model with deterministic location choices, the continuous logit model predicts incomplete segregation of citizens who work in different business centers, and, therefore, cross commuting. The relative size of income elasticity of both land demand and commuting costs determines income sorting of individuals working in a particular business district. Due to heterogeneous preferences for residence locations and workplaces, this may not hold for the aggregate spatial pattern of multiple income classes. Finally, individual land use may decrease as distance between workplace and residence increases.

Construction cost estimation: A parametric approach for better estimates of expected cost and variation

- Transportation Research Part B: Methodological---2017---Omar Swei,Jeremy Gregory,Randolph Kirchain

As project planners continue to move towards frameworks such as probabilistic life-cycle cost analysis to evaluate competing transportation investments, there is a need to enhance the current cost-estimation approaches that underlie these models to enable improved project selection. This paper presents an approach for cost estimation that combines a maximum likelihood estimator for data transformations with least angle regression for dimensionality reduction. The authors apply the proposed method for 15 different pavement bid items across five states in the United States. The results from the study demonstrate that the proposed approach frequently leads to consistent parametric estimates that address the structural bias and heteroscedasticity that plague the current cost-estimation procedures. Both of these aspects are particularly important for large-scale construction projects, where traditional methods tend to systematically underestimate expected construction costs and overestimate the associated variance.

Step tolling in an activity-based bottleneck model

- Transportation Research Part B: Methodological---2017---Zhi-Chun Li,William H.K. Lam,S.C. Wong

This paper investigates the step tolling problem in an activity-based bottleneck model in which activity scheduling utilities of commuters at home and at work vary by the time of day. The commuters choose their departure times from home to work in the morning to maximize their own scheduling utility. Step tolling models with homogeneous and heterogeneous preferences are presented. The properties of the models and the optimal step toll schemes with constant and linear time-varying marginal activity utilities are analytically explored and compared. It was found that for a given number of toll steps the efficacy of a step toll in terms of queuing removal rate is higher in the activity-based bottleneck model with linear marginal utilities than in the conventional bottleneck model with constant marginal utilities, and ignoring the preference heterogeneity of commuters would underestimate the efficacy of a step toll.

Deficit function related to public transport: 50 year retrospective, new developments, and prospects

- Transportation Research Part B: Methodological---2017---Tao Liu,(Avi) Ceder, Avishai

The Deficit Function (DF), with its graphical concept and modelling, was introduced 50 years ago by Linis and Maksim (1967) under the title of “On the problem of constructing routes.” Since then, there have been many developments in the understanding of the theoretical, methodological and application aspects of the DF concept. This work, for the first time, makes a comprehensive and thorough retrospective examination of the major developments of DF modelling and applications in public transport (PT) planning and operations over the past 50 years, introduces some new developments, and offers future research directions. It is shown and proven that the graphical DF concept helps in creating efficient PT vehicle schedules, timetables, crew duties, networks of routes, bus rapid transit systems, and operational parking spaces. For instance, in one large bus company the total number of vehicles and crew duties were reduced by 6% to 12% and 8% to 15%, respectively. This work intends to stimulate further use of the DF concept as a bridge between the world of researchers and the world of practitioners.

Network signal setting design with stage sequence optimisation

- Transportation Research Part B: Methodological---2017---Silvio Memoli,Giulio E. Cantarella,Stefano de Luca,Roberta Di Pace

One of the most straightforward short term policies to mitigate urban traffic congestion is control through traffic lights at a single junction or network level. Existing approaches for single junction Signal Setting Design (SSD) can be grouped into two classes: Stage-based or Phase-based methods. Both these approaches take the lane marking layouts as exogenous inputs, but lane-based optimisation method may be found in literature, even though for isolated signal-controlled junctions only. The Network Signal Setting Design (NSSD) requires that offsets are introduced; a traffic flow model is also needed to compute total delay. All existing methods for NSSD follow a stage-based approach; these methods do not allow for stage matrix optimisation: it is shown that explicit enumeration of stage sequences is only practicable for very small networks.

Taxi market equilibrium with third-party hailing service

- Transportation Research Part B: Methodological---2017---Xinwu Qian,Satish V. Ukkusuri

With the development and deployment of new technologies, the oligopolistic taxi industry is transforming into a shared market with coexistence of both traditional taxi service (TTS) and app-based third-party taxi service (ATTS). The ATTS is different from TTS in both entry policy and fare setting, and brings competition into the market. To account for the revolution of the taxi industry, in this study, we analyze the characteristics of the TTS and ATTS, model the taxi market as a multiple-leader-follower game at the network level, and investigate the equilibrium of taxi market with competition (TMC Equilibrium). In particular, passengers are modeled as the leaders who seek to minimize their travel cost associated with taxi rides. Followers involve TTS and ATTS drivers, who compete for passengers to maximize their revenue. The network model captures selfish behavior of passengers and drivers in the taxi market, and we prove the existence of TMC Equilibrium for the proposed model using variational inequality formulations. An iterative algorithm is further developed to find the TMC Equilibrium, which corresponds to the strongly stationary point of the multi-leader-follower game. Based on numerical results, it is observed that fleet size and pricing policy are closely associated with the level of competition in the market and may have significant impact on total passengers cost, average waiting time, and fleet utilization.

Urban intermodal terminals: The entropy maximising facility location problem

- Transportation Research Part B: Methodological---2017---Collins Teye,Michael G H Bell,Michiel Bliemer

An important problem confronting port cities is where and how to accommodate port growth. Larger ships combined with increased container throughput require more yard space and generate more traffic, straining the urban fabric in the vicinity of the port. A promising solution to this problem is the development of urban intermodal container terminals (IMTs) that interface with both road and rail (or possibly inland waterway) networks. This raises two linked choices; where to locate the intermodal terminals and what will be their likely usage by multiple shippers, each having a choice of whether or not to use the IMT as part of an intermodal transport chain. The use of an IMT by a shipper indicates the shipper's choice of intermodal transport, which comprises a combined use of a high capacity mode (rail or barge between the port and the IMT) and trucks (between the IMT and the cargo origin or destination). The overall problem therefore comprises a mode choice problem embedded within a facility location problem. This paper employs the method of entropy maximisation to combine a logit mode choice model with a facility location model, leading to a non-linear mixed integer programming model. The principal features of the entropy maximising facility location model are illustrated by small and large numerical examples.

Offset optimization in signalized traffic networks via semidefinite relaxation

- Transportation Research Part B: Methodological---2017---Samuel Coogan,Eric Kim,Gabriel Gomes,Murat Arcak,Pravin Varaiya

We study the problem of selecting offsets of the traffic signals in a network of signalized intersections to reduce queues of vehicles at all intersections. The signals in the network have a common cycle time and a fixed timing plan. It is assumed that the exogenous demands are constant or periodic with the same period as the cycle time and the intersections are under-saturated. The resulting queuing processes are periodic. These periodic processes are approximated by sinusoids. The sinusoidal approximation leads to an analytical expression of the queue lengths at every intersection as a function of the demands and the vector of offsets. The optimum offset vector is the solution of a quadratically constrained quadratic program (QCQP), which is solved via its convex semidefinite relaxation. Unlike existing techniques, our approach accommodates networks with arbitrary topology and scales well with network size. We illustrate the result in two case studies. The first is an academic example previously proposed in the literature, and the second case study consists of an arterial corridor network in Arcadia, California.

Modeling airport capacity choice with real options

- Transportation Research Part B: Methodological---2017---Yi-bin Xiao,Xiaowen Fu,Tae H. Oum,Jia Yan

This study models airport capacity choice when a real option for expansion can be purchased. Facing demand uncertainty, an airport first determines the capacity for immediate investment (the prior capacity) and the size of the land or other resources to be reserved for possible future expansion (the reserve). Once demand is observed, the airport can use a portion of the reserve to build extra capacity and set airport charge. Our analytical results show that if demand uncertainty is low and capacity and reserve costs are relatively high, an airport will not acquire a real option for expansion. Otherwise, it can use an expansion option to improve its expected profit or social welfare. Both the magnitude of profit or welfare gain and the optimal size of the reserve increase with demand uncertainty. A higher reserve cost leads to a larger prior capacity and a smaller reserve, whereas a higher capital cost leads to lower prior capacity. A profit-maximizing airport would choose a smaller prior capacity and reserve than would a welfare-maximizing airport. Competition within the airline market promotes airport capacity investment and the adoption of real options by profit-maximizing airports, whereas airport commercial services increase prior capacity but not the reserve.

A branch-and-price algorithm for the vehicle routing problem with roaming delivery locations

- Transportation Research Part B: Methodological---2017---Gizem Ozbaygin,Oya Ekin Karasan,Martin Savelsbergh,Hande Yaman

We study the vehicle routing problem with roaming delivery locations in which the goal is to find a least-cost set of delivery routes for a fleet of capacitated vehicles and in which a customer order has to be delivered to the trunk of the customer’s car during the time that the car is parked at one of the locations in the (known) customer’s travel itinerary. We formulate the problem as a set-covering problem and develop a branch-and-price algorithm for its solution. The algorithm can also be used for solving a more general variant in which a hybrid delivery strategy is considered that allows a delivery to either a customer’s home or to the trunk of the customer’s car. We evaluate the effectiveness of the many algorithmic features incorporated in the algorithm in an extensive computational study and analyze the benefits of these innovative delivery strategies. The computational results show that employing the hybrid delivery strategy results in average cost savings of nearly 20% for the instances in our test set.

A model of pedestrian delay at unsignalized intersections in urban networks

- Transportation Research Part B: Methodological---2017---Yinan Zheng,Lily Elefteriadou

Delay is an important performance measure for pedestrian crossings considering their interactions with other road users. This study provides an improved analytical model to mathematically estimate pedestrian delay using renewal theory, which considers driver yielding and vehicle platooning. A generalized model is first provided to accommodate different traffic flow and driver behavior assumptions. Then the proposed model is developed on the basis of a mixture of free traffic and platooned traffic with consideration of driver yielding behaviors to better replicate field conditions in an urban setting. A second application using the HCM 2010 assumptions is also derived to compare it to the HCM 2010 model. Lastly, field data were collected and used for validation from two locations: Gainesville, FL and Washington, D.C. A simulation via MATLAB is performed to evaluate the model results for a variety of cases. The comparisons to the field data as well as the simulation confirm the applicability and accuracy of the proposed model. It is also found that the current HCM 2010 model overestimates the pedestrian delay compared with field data.

Optimal transportation and shoreline infrastructure investment planning under a stochastic climate future

- Transportation Research Part B: Methodological---2017---Ali Asadabadi,Elise Miller-Hooks

This paper studies the problem of optimal long-term transportation investment planning to protect from and mitigate impacts of climate change on roadway performance. The problem of choosing the extent, specific system components, and timing of these investments over a long time horizon (e.g., 40–60 years) is modeled as a multi-stage, stochastic, bi-level, mixed-integer program wherein cost-effective investment decisions are taken in the upper level. The effects of possible episodic precipitation events on experienced travel delays are estimated from solution of a lower-level, traffic equilibrium problem. The episodic events and longer-term sea level changes exist on different time scales, making their integration a crucial element in model development. The optimal investment strategy is obtained at a Stackelberg equilibrium that is reached upon solution to the bilevel program. A recursive noisy genetic algorithm (rNGA), designed to address large-scale applications, is proposed for this purpose. The rNGA seeks the optimal combination of investment decisions to take now given only probabilistic information on the predicted sea level rise trend for a long planning horizon and associated likely extreme climatic events (in terms of their frequencies and intensities) that might arise over that planning period. The proposed solution method enables the evaluation of decisions concerning where, when and to what level to make infrastructure investments. The proposed rNGA has broad applicability to more general multi-stage, stochastic, bilevel, nonconvex, mixed integer programs that arise in many applications. The proposed solution methodology is demonstrated on an example representing a portion of the Washington, D.C. Greater Metropolitan area adjacent to the Potomac River.

A time allocation model considering external providers

- Transportation Research Part B: Methodological---2017---Jorge Rosales-Salas,Sergio R. Jara-Díaz

Time use models have advanced significantly during the last decade: their theoretical approach has been refined, functional forms have improved and new constraints have been incorporated, among other aspects. However, there is an incipient development of an issue of great importance: the role and influence of external agents on individual time allocation and the recognition of unpaid/domestic work as a distinctive area of research. In this paper we introduce domestic production and the potential domestic work substitution by external providers in a time use model, improving its formulation and the interpretation of the values of time. We take into account the marginal utility of domestic activities, their cost - either if self-produced or hired - and the relation between the domestic output and domestic work hours considering the difference in skills between providers and household members. A stochastic system of equations is proposed and estimated using three Dutch time use and expenses data sets, from which the values of leisure and work are computed and analyzed. Comparative results show that a model with no consideration of hired domestic providers overestimates the values of leisure.

Towards vehicle automation: Roadway capacity formulation for traffic mixed with regular and automated vehicles

- Transportation Research Part B: Methodological---2017---Danjue Chen,Soyoung Ahn,Madhav Chitturi,David A. Noyce

This paper provides formulations of traffic operational capacity in mixed traffic, consisting of automated vehicles (AVs) and regular vehicles, when traffic is in equilibrium. The capacity formulations take into account (1) AV penetration rate, (2) micro/mesoscopic characteristics of regular and automated vehicles (e.g., platoon size, spacing characteristics), and (3) different lane policies to accommodate AVs such as exclusive AV and/or RV lanes and mixed-use lanes. A general formulation is developed to determine the valid domains of different lane policies and more generally, AV distributions across lanes with respect to demand, as well as optimal solutions to accommodate AVs.

A dynamic taxi traffic assignment model: A two-level continuum transportation system approach

- Transportation Research Part B: Methodological---2017---Jiancheng Long,W.Y. Szeto,Jie Du,R.C.P. Wong

This paper proposes a two-level continuum transportation system approach to modeling a dynamic taxi traffic assignment (DTTA) problem in a dense network with real-time traffic information provision and three types of vehicles, including private cars, occupied taxis, and vacant taxis. The proposed approach treats the dense network as a continuum in the first level, in which private car and occupied taxi drivers are free to choose their paths in a two-dimensional continuous space. The proposed approach also divides the modeling region into many identical squares to form a cell-based network in the second level, in which the cells are classified into two categories: target cell with an acceptable expected rate of return (EROR) to vacant taxi drivers and non-target cell with an unacceptable EROR. The EROR associated with a cell is the ratio of the cumulative expected profit of a taxi driver who successfully picks up a customer during the customer search that starts from that cell to the sum of expected search time for this customer and expected occupied travel time to serve this customer. Based on the cell-based network, we develop a cell-based intervening opportunity model to capture the fact that vacant taxi drivers can meet a customer on the way to their destination zones and estimate the EROR. Each vacant taxi driver has a mixed strategy to determine his/her customer-search direction according to the EROR: Each vacant taxi driver in a target cell selects its neighbor cells with maximum EROR, and each vacant taxi driver in a non-target cell selects the travel time-based shortest path to his/her target cell. Meanwhile, each private car driver chooses the path that minimizes his/her own generalized travel cost, and each occupied taxi driver chooses the path that minimizes his/her customer's generalized in-vehicle travel cost. In our model, traffic density in the system is governed by the conservation law (CL), and the flow directions of different vehicles are determined by the path-choice strategies of their drivers, which are captured by Hamilton–Jacobi (HJ) equations. Both the proposed CL and HJ equations can be solved by the Lax–Friedrichs scheme, which forms the backbone of the developed solution algorithm. Finally, numerical examples and a case study are used to demonstrate the properties of the model, the performance of the solution algorithm, and the value of using our methodology for estimating network performance.

Emission modeling and pricing on single-destination dynamic traffic networks

- Transportation Research Part B: Methodological---2017---Rui Ma,Ban, Xuegang (Jeff),W.Y. Szeto

This paper proposes an emission pricing model for single-destination dynamic traffic networks. The model contains two sub-models derived from the corresponding two sub-problems: a system optimum dynamic traffic assignment problem and a first-best dynamic emission pricing scheme. For the first problem, it proves that under certain conditions, an optimal solution, if exists, must be a free-flow solution to minimize the generalized system cost including the costs of total travel times and total emissions (or fuel consumption). The optimal first-best emission pricing can then be determined by solving an optimal control problem, using the free-flow dynamic system optimal solution as the input. Numerical results are provided to illustrate the proposed models and the solution methods.

Representation requirements for perfect first-in-first-out verification in continuous flow dynamic models

- Transportation Research Part B: Methodological---2017---Hillel Bar-Gera,Malachy Carey

Dynamic models of traffic require answers for many issues. One of them is the way priorities of different traffic streams (commodities) are managed. This is particularly challenging when flows are treated as continuous. It is common to consider the First-In-First-Out (FIFO) rule as a baseline for setting priorities; but most practical continuous flow dynamic models do not satisfy FIFO perfectly. This paper examines the difficulties associated with full adherence to network-wide FIFO.

A decomposition algorithm to solve the multi-hop Peer-to-Peer ride-matching problem

- Transportation Research Part B: Methodological---2017---Neda Masoud,R. Jayakrishnan

In this paper, we mathematically model the multi-hop Peer-to-Peer (P2P) ride-matching problem as a binary program. We formulate this problem as a many-to-many problem in which a rider can travel my transferring between multiple drivers, and a driver can carry multiple riders. We propose a pre-processing procedure to reduce the size of the problem, and devise a decomposition algorithm to solve the original ride-matching problem to optimality by means of solving multiple smaller problems. We conduct extensive numerical experiments to demonstrate the computational efficiency of the proposed algorithm and show its practical applicability to reasonably-sized dynamic ride-matching contexts. Finally, in the interest of even lower solution times, we propose heuristic solution methods, and investigate the trade-offs between solution time and accuracy.

Pedestrian flows through a narrow doorway: Effect of individual behaviours on the global flow and microscopic dynamics

- Transportation Research Part B: Methodological---2017---Alexandre Nicolas,Sebastián Bouzat,Marcelo N. Kuperman

We study the dynamics of pedestrian flows through a narrow doorway by means of controlled experiments. The influence of the pedestrians' behaviours is investigated by prescribing a selfish attitude to a fraction cs of the participants, while the others behave politely. Thanks to an original setup enabling the re-injection of egressed participants into the room, the analysis is conducted in a (macroscopically) quasi-stationary regime. We find that, as cs is increased, the flow rate J rises, interpolating between published values for egresses in normal conditions and measurements for competitive evacuations. The dependence of several flow properties on the pedestrian density ρ at the door, independently of cs, suggests that macroscopically the behavioural aspects could be subsumed under the density, at least in our specific settings with limited crowd pressure. In particular, under these conditions, J grows monotonically with ρ up to "close-packing" (ρ ≈9m 2). The flow is then characterised microscopically. Among other quantities, the time lapses between successive escapes, the pedestrians' waiting times in front of the door, and their angles of incidence are analysed statistically. In a nutshell, our main results show that the flow is orderly for polite crowds, with narrowly distributed time lapses between egresses, while for larger cs the flow gets disorderly and vanishing time lapses emerge. For all cs, we find an alternation between short and long time lapses, which we ascribe to a generalised zipper effect. The average waiting time in the exit zone increases with its occupancy. The disorder in the flow and the pressure felt by participants are also assessed.

Optimal design of autonomous vehicle zones in transportation networks

- Transportation Research Part B: Methodological---2017---Zhibin Chen,Fang He,Yafeng Yin,Yuchuan Du

This paper advocates the need for infrastructure planning to adapt to and further promote the deployment of autonomous vehicle (AV) technology. It is envisioned that in the future government agencies will dedicate certain areas of road networks to AVs only to facilitate the formulation of vehicle platoons to improve throughput and hopefully improve the performance of the whole network. This paper aims to present a mathematical framework for the optimal design of AV zones in a general network. With the presence of AV zones, AVs may apply different routing principles outside of and within the AV zones. A novel network equilibrium model (we refer to it as the "mixed routing equilibrium model") is thus firstly proposed to capture such mixed-routing behaviors. We then proceed to formulate a mixed-integer bi-level programming model to optimize the deployment plan of AV zones. Numerical examples are presented to demonstrate the performance of the proposed models.

Design and modeling of a crowdsource-enabled system for urban parcel relay and delivery

- Transportation Research Part B: Methodological---2017---Nabin Kafle,Bo Zou,Jane Lin

This paper proposes a crowdsource-enabled system for urban parcel relay and delivery. We consider cyclists and pedestrians as crowdsources who are close to customers and interested in relaying parcels with a truck carrier and undertaking jobs for the last-leg parcel delivery and the first-leg parcel pickup. The crowdsources express their interests in doing so by submitting bids to the truck carrier. The truck carrier then selects bids and coordinates crowdsources' last-leg delivery (first-leg pickup) with its truck operations. The truck carrier's problem is formulated as a mixed integer non-linear program which simultaneously i) selects crowdsources to complete the last-leg delivery (first-leg pickup) between customers and selected points for crowdsource-truck relay; and ii) determines the relay points and truck routes and schedule. To solve the truck carrier problem, we first decompose the problem into a winner determination problem and a simultaneous pickup and delivery problem with soft time windows, and propose a Tabu Search based algorithm to iteratively solve the two subproblems. Numerical results show that this solution approach is able to yield close-to-optimum solutions with much less time than using off-the-shelf solvers. By adopting this new system, truck vehicle miles traveled (VMT) and total cost can be reduced compared to pure-truck delivery. The advantage of the system over pure-truck delivery is sensitive to factors such as penalty for servicing outside customers' desired time windows, truck unit operating cost, time value of crowdsources, and the crowdsource mode.

Dynamic resource allocation for intermodal freight transportation with network effects: Approximations and algorithms

- Transportation Research Part B: Methodological---2017---Hua Wang,Xinchang Wang,Xiaoning Zhang

This paper investigates a dynamic resource allocation problem, in which an intermodal operator attempts to determine the policy that characterizes the optimal quantities of each service product allowed to be sold during each time interval within a finite selling horizon. The problem is formulated as a Markov decision process (MDP) model and a variety of mathematical programming models are developed to approximate the MDP model. A series of policies are obtained from the optimal solutions to the approximation models and theoretical results are provided to characterize the comparisons between the MDP model and the approximation models. Various policies are further evaluated through theoretical analysis and simulation tests. We finally gain insights into the importance of the dynamic decisions, stochastic demands, model re-solving, and integer variables in formulating approximation models.

Joint optimal train regulation and passenger flow control strategy for high-frequency metro lines

- Transportation Research Part B: Methodological---2017---Shukai Li,Maged M. Dessouky,Lixing Yang,Ziyou Gao

To improve the headway regularity and commercial speed of high-frequency metro lines with overloaded passenger flow, this paper systematically investigates a joint optimal dynamic train regulation and passenger flow control design for metro lines. A coupled state-space model for the evolution of the departure time and the passenger load of each train at each station is explicitly developed. The dwell time of the train is affected by the number of entering and exiting passengers. Combining dynamic train regulation and passenger flow control, a dynamic optimisation problem that minimises the timetable and the headway deviations for metro lines is developed. By applying a model predictive control (MPC) method, we formulate the problem of finding the optimal joint train regulation and passenger flow control strategy as the problem of solving a set of quadratic programming (QP) problems, under which an optimal control law can be numerically calculated efficiently using a quadratic programming algorithm. Moreover, based on the Lyapunov stability theory, the stability (convergence) of the metro line system under the proposed optimal control algorithm is verified. Numerical examples are given to illustrate the effectiveness of the proposed method.

Network user equilibrium problems for the mixed battery electric vehicles and gasoline vehicles subject to battery swapping stations and road grade constraints

- Transportation Research Part B: Methodological---2017---Min Xu,Qiang Meng,Kai Liu

There has been growing attention on battery electric vehicles (BEVs) due to their energy efficiency and environmental friendliness. This paper deals with the user equilibrium (UE) problems for the mixed BEVs and traditional gasoline vehicles (GVs) in transportation networks with battery swapping stations and road grade constraints. Under the assumption that electricity consumption rate is not affected by traveling speed or traffic flow, a nonlinear minimization model in terms of path flows is first formulated by incorporating effects of road grade on the electricity consumption rate. The battery swapping action based paths are defined for BEVs in the represented network to facilitate the model building with flow-dependent dwell time at the battery swapping stations. The Frank-Wolfe (F-W) algorithm, where descent direction is found by the multi-label method in a pseudo-polynomial time, is adopted to solve the model. Moreover, the aforementioned assumption about the flow-independent electricity consumption rate is then relaxed and a system of inequalities has been proposed to formulate the UE conditions. For the nonlinear minimization model, two numerical examples are presented to assess the propose model and algorithm, as well as to analyze the impact of usable battery capacity, BEVs' market share and some attributes of battery swapping stations on the equilibrium link flows and/or swapping flows. The system of inequalities is exactly solved for a small network by path enumeration to demonstrate the non-uniqueness of UE link flow solutions.

A dynamic programming approach for optimizing train speed profiles with speed restrictions and passage points

- Transportation Research Part B: Methodological---2017---Jørgen Thorlund Haahr,David Pisinger,Mohammad Sabbaghian

This paper considers a novel solution method for generating improved train speed profiles with reduced energy consumption. The solution method makes use of a time-space graph formulation which can be solved through Dynamic Programming. Instead of using uniform discretization of time and space as seen previously in the literature, we rely on an event-based decomposition that drastically reduces the search space. This approach is very flexible, making it easy to handle, e.g., speed limits, changes in altitude, and passage points that need to be crossed within a given time window. Based on solving an extensive number of real-life problem instances, our benchmarks show that the proposed solution method is able to satisfy all secondary constraints and still be able to decrease energy consumption by 3.3% on average compared to a commercial solver provided by our industrial collaborator, Cubris. The computational times are generally very low, making it possible to recompute the train speed profile in case of unexpected changes in speed restrictions or timings. This is a great advantage over static offline lookup tables. Also, the framework is very flexible, making it possible to handle a number of additional constraints on robustness, passenger comfort etc. Selected details of the method and benchmark are only described at a high level for confidentiality reasons.

Modeling heterogeneous traffic flow: A pragmatic approach

- Transportation Research Part B: Methodological---2017---(Sean) Qian, Zhen,Jia Li,Xiaopeng Li,Michael Zhang,Haizhong Wang

Modeling dynamics of heterogeneous traffic flow is central to the control and operations of today's increasingly complex transportation systems. We develop a macroscopic heterogeneous traffic flow model. This model considers interplay of multiple vehicle classes, each of which is assumed to possess homogeneous car-following behavior and vehicle attributes. We propose the concepts of road capacity split and perceived equivalent density for each class to model both lateral and longitudinal cross-class interactions across neighboring cells. Rather than leveraging hydrodynamic analogies, it establishes pragmatic cross-class interaction rules aspired by capacity allocation and approximate inter-cell fluxes. This model generalizes the classical Cell Transmission Model (CTM) to three types of traffic regimes in general, i.e. free flow, semi-congestion, and full congestion regimes. This model replicates prominent empirical characteristics exhibited by mixed vehicular flow, including formation and spatio-temporal propagation of shockwaves, vehicle overtaking, as well as oscillatory waves. Those features are validated against numerical experiments and the NGSIM I-80 data. Realistic class-specific travel times can be computed from this model efficiently, which demonstrates the feasibility of applying this multi-class model to large-scale real-world networks.

On the use of reservation-based autonomous vehicles for demand management

- Transportation Research Part B: Methodological---2017---Raphaël Lamotte,André de Palma,Nikolas Geroliminis

Automated mobility on demand is foreseen as the future of urban passenger mobility. While mixed-traffic for autonomous and conventional vehicles could be considered, separation amplifies the benefits of automation. Combined with mobility as a service, separation also opens new possibilities in terms of demand management. We consider in this paper a single bottleneck dynamic framework, in which the capacity of a freeway is dedicated either to conventional or to autonomous vehicles. Users of conventional vehicles freely choose their departure time from home and compete for the best departure times from the bottleneck. Users of autonomous vehicles need to book their trip in advance. As the number of time slots available for booking does not exceed the capacity, booking users are guaranteed no delay at the bottleneck. An individual-specific cooperation cost is introduced in the modeling framework. We then investigate how a central planner should allocate the capacity to these two vehicle types depending on the regime (laissez-faire, welfare- or profit-maximizing). Two major findings are that the equilibrium demand split Pareto-dominates the case with only conventional cars and that the social cost difference between equilibrium and socially optimal demand splits is small compared to their benefits. Although the Pareto-improvement result may not hold for every single user in the case of richer heterogeneity, it remains a key advantage of our booking scheme. Profit-maximizing strategies however turn out to be hardly compatible with welfare maximization.

A Branch-and-Price algorithm for railway rolling stock rescheduling

- Transportation Research Part B: Methodological---2017---Richard M. Lusby,Jørgen Thorlund Haahr,Jesper Larsen,David Pisinger

How to best reschedule their fleet of rolling stock units during a disruption is an optimization problem regularly faced by railway operators. Despite the problem’s high complexity, it is still usually solved manually. In this paper we propose a path based mathematical formulation and solve it using a Branch-and-Price algorithm. We demonstrate that, unlike flow based approaches, our formulation is more easily extended to handle certain families of constraints, such as train unit maintenance restrictions. The proposed algorithm is benchmarked on several real-life instances provided by the suburban railway operator in Copenhagen, DSB S-tog. When used in combination with a lower bound method taken from the literature we show that near-optimal solutions to this rescheduling problem can be found within a few seconds. Furthermore, we show that the proposed methodology can be used, with minor modification, on a tactical planning level, where it produces near-optimal rolling stock schedules in minutes of CPU time.

Investigating transport network vulnerability by capacity weighted spectral analysis

- Transportation Research Part B: Methodological---2017---Michael G.H. Bell,Fumitaka Kurauchi,Supun Perera,Walter Wong

Transport networks operating at or near capacity are vulnerable to disruptions, so flow bottlenecks are potent sources of vulnerability. This paper presents an efficient method for finding transport network cuts, which may constitute such bottlenecks. Methods for assessing network vulnerability found in the literature require origin-destination demands and path assignment. However, in transport network planning and design, demand information is often missing, out of date, partial or inaccurate. Capacity weighted spectral partitioning is proposed to identify potential flow bottlenecks in the network, without reference to demand information or path assignments. This method identifies the network cut with least capacity, taking into account the relative sizes of the sub-networks either side of the cut. Spectral analysis has the added advantage of tractability, even for large networks, as shown by numerical examples for a five-node illustrative example, the Sioux Falls road network and the Gifu Prefecture road network.

Group-based approach to predictive delay model based on incremental queue accumulations for adaptive traffic control systems

- Transportation Research Part B: Methodological---2017---Seunghyeon Lee,S.C. Wong

In this study, we develop a mathematical framework to estimate lane-based incremental queue accumulations with group-based variables and a predictive model of lane-based control delay. Our objective is to establish the rolling horizon approach to lane-based control delay for group-based optimization of signal timings in adaptive traffic control systems. The challenges involved in this task include identification of the most appropriate incremental queue accumulations based on group-based variables for individual lanes to the queueing formation patterns and establishment of the rolling horizon procedure for predicting the future components of lane-based incremental queue accumulations in the time windows. For lane-based estimation of incremental queue accumulations, temporal and spatial information were collected on the basis of estimated lane-based queue lengths from our previous research to estimate lane-based incremental queue accumulations. We interpret the given signal plan as group-based variables, including the start and duration of the effective green time and the cycle time. Adjustment factors are defined to identify the characteristics of the control delay in a specific cycle and to clarify the relationship between group-based variables and the temporal information of queue lengths in the proposed estimation method. We construct the rolling horizon procedure based on Kalman filters with appropriate time windows. Lane-based queue lengths at an inflection point and adjustment factors in the previous cycle are used to estimate the adjustment factors, arrival rates, and discharge rates in the next cycle, in which the predictive computation is performed in the current cycle. In the simulations sets and the case study, the proposed model is robust and accurate for estimation of lane-based control delay under a wide range of traffic conditions. Adjustment factors play a significant role in increasing the accuracy of the proposed model and in classifying queueing patterns in a specific cycle. The Kalman filters enhance the accuracy of the predictions by minimizing the error terms caused by the fluctuation in traffic flow.

A Riemann solver for a system of hyperbolic conservation laws at a general road junction

- Transportation Research Part B: Methodological---2017---Wen-Long Jin

The kinematic wave model of traffic flow on a road network is a system of hyperbolic conservation laws, for which the Riemann solver is of physical, analytical, and numerical importance. In this paper, we present a new Riemann solver at a general network junction in the demand-supply space. In the Riemann solutions, traffic states on a link include the initial, stationary, and interior states, and a discrete Cell Transmission Model flux function in interior states is used as an entropy condition, which is consistent with fair merging and first-in-first-out diverging rules. After deriving the feasibility conditions for both stationary and interior states, we obtain a set of algebraic equations, and prove that the Riemann solver is well-defined, in the sense that the stationary states, the out-fluxes of upstream links, the in-fluxes of downstream links, and kinematic waves on all links can be uniquely solved. In addition, we show that the resulting global flux function in initial states is the same as the local one in interior states. Hence we presents a new definition of invariant junction models, in which the global and local flux functions are the same. We also present a simplified framework for solving the Riemann problem with invariant junction flux functions.

On the stability of stationary states in general road networks

- Transportation Research Part B: Methodological---2017---Wen-Long Jin

In [Jin, W.-L., 2015. On the existence of stationary states in general road networks. Transportation Research Part B 81, 917–929.], with a discrete map in critical demand levels, it was proved that there exist stationary states for the kinematic wave model of general road networks with constant origin demands, route choice proportions, and destination supplies. In this study we further examine the stability property of stationary states with the same map, and the results will help us to understand the long-term trend of a network traffic system. We first review a network kinematic wave model and properties of stationary states on a link, define the criticality of junctions in stationary states, and discuss information propagation in stationary states on links and junctions. We then present the map and examine information propagation in the map. We apply the map to analytically study the stability of stationary states on ring roads and diverge-merge networks with circular information propagation and compare them with results obtained from the Poincaré map [Jin, W.-L., 2013. Stability and bifurcation in network traffic flow: A Poincaré map approach. Transportation Research Part B 57, 191–208]. We further study the stability property of general stationary states in a grid network. We find that the stability of fixed points of the map is the same as that of stationary states in a network, and the new approach is more general than the Poincaré map approach. We conclude the study with future directions and implications.

A branch-and-price method for integrated yard crane deployment and container allocation in transshipment yards

- Transportation Research Part B: Methodological---2017---Xin Jia Jiang,Jian Gang Jin

With the trend towards mega-vessels and shipping alliance, the importance of transshipment activities keeps increasing. In transshipment yards, a “yard template” is often used to stack containers in dedicated areas (sub-blocks) pre-reserved for their own destination vessels. At short-term planning level, the yard template is given, but the containers going to a specific vessel still have high flexibility to be allocated among many pre-reserved sub-blocks. The amount of containers allocated to each sub-block, i.e. “container allocation”, not only affects the traffic congestion, but more importantly determines the number of yard cranes (YCs) required in each block. The limited YCs have to switch blocks to fit the needs of container allocation in different periods, i.e. “YC deployment”. This study integrated these two closely related problems and formulated a MIP model. Since the model has a nice block-diagonal structure, column generation under Dentzig Wolfe decomposition was proposed to get lower bounds. A novel branch-and-price (B&P) method was proposed to find near-optimal solutions. To reduce the searching tree size, our B&P method branched on YC paths during the planning horizon, instead of branching on decision variables directly. Numerical experiments under both small and large scale problems showed that our B&P method could efficiently solve the integrated planning problem. The results also showed that YC movements could be reduced effectively without sacrificing operational efficiency or using more yard cranes.

The political economy of pricing car access to downtown commercial districts

- Transportation Research Part B: Methodological---2017---Bruno De Borger,Antonio Russo

We study the political economy of pricing access to downtown commercial districts, using curbside parking fees as the main example. A spatial equilibrium model is embedded in a political economy framework in which special interest groups (urban and suburban retailers, local residents) lobby the city government. We have the following results. If downtown and suburban stores sell a homogeneous good, the local government underprices downtown parking if suburban stores operate with low enough markups. If goods are heterogeneous and some consumers engage in multiple-stop shopping (i.e., shop both downtown and in the suburbs), suburban stores will not lobby at all; lobbying by downtown retailers leads to parking fees below the social optimum. Furthermore, local residents do not necessarily lobby for high parking fees on downtown shoppers. If a decline in urban stores leads to negative externalities (urban blight) they may join forces with downtown retailers and lobby against high parking fees on shoppers.

Multi-objective integration of timetables, vehicle schedules and user routings in a transit network

- Transportation Research Part B: Methodological---2017---Gilbert Laporte,Francisco A. Ortega,Miguel A. Pozo,Justo Puerto

The Transit Network Timetabling and Scheduling Problem (TNTSP) aims at determining an optimal timetable for each line of a transit network by establishing departure and arrival times at each station and allocating a vehicle to each timetable. The current models for the planning of timetables and vehicle schedules use the a priori knowledge of users' routings. However, the actual route choice of a user depends on the timetable. This paper solves the TNTSP in a public transit network by integrating users' routings in the model. The proposed formulation guarantees that each user is allocated to the best possible timetable, while satisfying capacity constraints. In addition, we perform a trade-off analysis by means of a multi-objective formulation which jointly optimizes the operator's and the users' criteria.

Variable speed limit control at fixed freeway bottlenecks using connected vehicles

- Transportation Research Part B: Methodological---2017---Youngjun Han,Danjue Chen,Soyoung Ahn

The connected vehicle (CV) technology is applied to develop VSL strategies to improve bottleneck discharge rates and reduce system delays. Three VSL control strategies are developed with different levels of complexity and capabilities to enhance traffic stability using: (i) only one CV (per lane) (Strategy 1), (ii) one CV (per lane) coupled with variable message signs (Strategy 2), and (iii) multiple CVs (Strategy 3). We further develop adaptive schemes for the three strategies to remedy potential control failures in real time. These strategies are designed to accommodate different queue detection schemes (by CVs or different sensors) and CV penetration rates. Finally, probability of control failure is formulated for each strategy based on the stochastic features of traffic instability to develop a general framework to (i) estimate expected delay savings, (ii) assess the stability of different VSL control strategies, and (iii) determine optimal control speeds under uncertainty. Compared to VMS-only strategies, the CV-based strategies can effectively impose dynamic control over continuous time and space, enabling (i) faster queue clearance around a bottleneck, (ii) less restrictive control with higher control speed (thus smoother transition), and (iii) simpler control via only one or a small number of CVs.

Optimization of vehicle and pedestrian signals at isolated intersections

- Transportation Research Part B: Methodological---2017---Chunhui Yu,Wanjing Ma,Ke Han,Xiaoguang Yang

In most traffic signal optimization problems, pedestrian traffic at an intersection receives minor consideration compared to vehicular traffic, and usually in the form of simplistic and exogenous constraints (e.g., minimum green time). This could render the resulting signal timings sub-optimal especially in dense urban areas with significant pedestrian traffic, or when two-stage pedestrian crosswalks are present. This paper proposes a convex (quadratic) programming approach to optimize traffic signal timings for an isolated intersection with one- and two-stage crosswalks, assuming undersaturated vehicular traffic condition. Both vehicle and pedestrian traffic are integrated into a unified framework, where the total weighted delay of pedestrians and vehicles at different types of crosswalks (i.e. one- or two-stage) is adopted as the objective function, and temporal and spatial constraints (e.g. signal phasing plan and spatial capacity of the refuge island) are explicitly formulated. A case study demonstrates the impacts of incorporating pedestrian delay as well as geometric and spatial constraints (e.g., available space on the refuge island) in the signal optimization. A further analysis shows that a two-stage crosswalk may outperform a one-stage crosswalk in terms of both vehicle and pedestrian delays in some circumstances.

Extending the Link Transmission Model with non-triangular fundamental diagrams and capacity drops

- Transportation Research Part B: Methodological---2017---Jeroen P.T. van der Gun,Adam J. Pel,Bart van Arem

The original Link Transmission Model as formulated by Yperman et al. (2006) simulates traffic according to Lighthill–Whitham–Richards theory with a very small numerical error, yet only supports triangular fundamental diagrams. This paper relaxes that restriction in two steps. Firstly, we extend the model to handle any continuous concave fundamental diagram, and prove that this extension is still consistent with Lighthill–Whitham–Richards theory. Secondly, we extend the theory and model to handle a capacity drop, explicitly looking into the handling of both the onset and release of congestion. The final model is still first-order and suitable for general networks. Numerical examples show that it qualitatively improves on the original model due to uniquely featuring complex traffic patterns including stop-and-go waves, with crisp shockwaves between traffic states, as well as acceleration fans.

A dynamic programming approach for quickly estimating large network-based MEV models

- Transportation Research Part B: Methodological---2017---Tien Mai,Emma Frejinger,Mogens Fosgerau,Fabian Bastin

We propose a way to estimate a family of static Multivariate Extreme Value (MEV) models with large choice sets in short computational time. The resulting model is also straightforward and fast to use for prediction. Following Daly and Bierlaire (2006), the correlation structure is defined by a rooted, directed graph where each node without successor is an alternative. We formulate a family of MEV models as dynamic discrete choice models on graphs of correlation structures and show that the dynamic models are consistent with MEV theory and generalize the network MEV model (Daly and Bierlaire, 2006). Moreover, we show that these models can be estimated quickly using the concept of network flows and the nested fixed point algorithm (Rust, 1987). The main reason for the short computational time is that the new formulation allows to benefit from existing efficient solution algorithms for sparse linear systems of equations.

A cycle time optimization model for generating stable periodic railway timetables

- Transportation Research Part B: Methodological---2017---Daniel Sparing,Rob M.P. Goverde

As train passengers expect a high degree of reliability from a railway network with minimal delays, during the timetabling process planners need to balance the goals of maximizing the offered capacity and delay resistance. This is often done in a two-step process where first a feasible timetable is found for a given line structure, and consecutively the stability of this timetable is evaluated and local modifications are performed to the timetable. This paper describes an optimization method to find a feasible periodic timetable that also ensures maximum stability for heterogeneous railway networks. The model is capable to handle flexible train orders, running and dwell times, and overtaking locations. We use the minimum cycle time of the periodic timetable as an indicator for stability, and define an optimization problem with this minimum cycle time as the objective function to be minimized. We also present dimension reduction methods and an iterative optimization approach to improve the mathematical optimization process. We show the applicability of the approach with case studies on the central part of the Dutch railway network.

Designing alternative railway timetables under infrastructure maintenance possessions

- Transportation Research Part B: Methodological---2017---Sander Van Aken,Nikola Bešinović,Rob M.P. Goverde

Increasing supply in railway networks comes at the cost of an increased need for infrastructure maintenance. This also means adjusting the timetable due to long maintenance or constructions' possessions. In this article, we introduce the Train Timetable Adjustment Problem (TTAP), which for given station and open-track possessions, finds an alternative timetable that minimizes the deviation from the original timetable. We propose a mixed integer linear programming (MILP) model for solving TTAP, and apply retiming, reordering, short-turning and cancellation to generate alternative timetables. The model represents an extended periodic event scheduling problem (PESP) formulation and introduces new constraints for cancelling and retiming train lines, while short-turning is being applied in a preprocessing step. In order to solve larger and more complex instances, we use a row generation approach to add station capacity constraints. The model solves real-life instances with multiple possessions for a large area of the Dutch railway network in reasonable time, and could be upscaled to the complete Dutch network. Additionally, it may be applicable for disruption management after some modifications. Operators and infrastructure managers could use it to automatically generate optimal alternative timetables on the macroscopic level in case of maintenance or construction works and thus, coordinate traffic for the complete network.

A search acceleration method for optimization problems with transport simulation constraints

- Transportation Research Part B: Methodological---2017---Gunnar Flötteröd

This work contributes to the rapid approximation of solutions to optimization problems that are constrained by iteratively solved transport simulations. Given an objective function, a set of candidate decision variables and a black-box transport simulation that is solved by iteratively attaining a (deterministic or stochastic) equilibrium, the proposed method approximates the best decision variable out of the candidate set without having to run the transport simulation to convergence for every single candidate decision variable. This method can be inserted into a broad class of optimization algorithms or search heuristics that implement the following logic: (i) Create variations of a given, currently best decision variable, (ii) identify one out of these variations as the new currently best decision variable, and (iii) iterate steps (i) and (ii) until no further improvement can be attained. A probabilistic and an asymptotic performance bound are established and exploited in the formulation of an efficient heuristic that is tailored towards tight computational budgets. The efficiency of the method is substantiated through a comprehensive simulation study with a non-trivial road pricing problem. The method is compatible with a broad range of simulators and requires minimal parametrization.

Traffic predictive control from low-rank structure

- Transportation Research Part B: Methodological---2017---Samuel Coogan,Christopher Flores,Pravin Varaiya

The operation of most signalized intersections is governed by predefined timing plans that are applied during specified times of the day. These plans are designed to accommodate average conditions and are unable to respond to large deviations in traffic flow. We propose a control approach that adjusts time-of-day signaling plans based on a prediction of future traffic flow. The prediction algorithm identifies correlated, low rank structure in historical measurement data and predicts future traffic flow from real-time measurements by determining which structural trends are prominent in the measurements. From this prediction, the controller then determines the optimal time of day to apply new timing plans. We demonstrate the potential benefits of this approach using eight months of high resolution data collected at an intersection in Beaufort, South Carolina.

Morning commute in a single-entry traffic corridor with early and late arrivals

- Transportation Research Part B: Methodological---2017---Chuan-Yao Li,Hai-Jun Huang

The purpose of this paper is to extend the work of DePalma and Arnott (2012) by investigating the solutions for social optimum (SO) and user equilibrium (UE) assignment in a single-entry traffic corridor with consideration of both early and late arrivals. The LWR model and the Greenshields' relation are used to describe the dynamic properties of traffic flow. The closed-form SO solution and quasi-analytic UE solution are developed and well illustrated by numerical examples. It is shown that the SO assignment is associated with a smooth cumulative outflow curve, while the UE assignment will result in recursively generated cumulative inflow and outflow curves. In UE, however, the system finally becomes a free flow state.

Fosgerau's travel time reliability ratio and the Burr distribution

- Transportation Research Part B: Methodological---2017---Michael A.P. Taylor

Recent international research has seen the development of methods for the inclusion of travel time reliability as a separate factor in economic analysis of transportation projects, including the valuation of travel time variability. Fosgerau's valuation method includes the consideration of travel time reliability in cost-benefit analysis by adding travel time variability to the set of generalised travel costs. This requires: (1) a defined unit of measurement for travel time variability, (2) estimates of the quantity of travel time variability, and (3) identification of the cost to travellers per unit of travel time variability. The chosen unit of measurement is the standard deviation of the travel time distribution, and the value of this unit of measurement can be defined relative to the average value of travel time by a reliability ratio that depends on user preference parameters (related to risk aversion) and the shape of the upper tail of the cumulative distribution function (cdf) of the travel time distribution. This shape is represented by a definite integral of the inverse of the cdf. Determining the shape of the cdf and its inverse function is facilitated if the distribution can be defined by an explicit algebraic function. The Burr (type XII) distribution is one distribution with this feature, and has been used to successfully represent observed travel time data. This paper describes the Burr distribution, demonstrates that it can provide a good representation of observed travel time data, and explains how it can be used to develop an exact expression for the reliability ratio and thus can aid the use of the method for the valuation of travel time reliability.

A cooperative game approach to cost allocation in a rapid-transit network

- Transportation Research Part B: Methodological---2017---Edward C. Rosenthal

We consider the problem of allocating costs of a regional transit system to its users, who employ shortest path routes between all pairs of nodes in the system network. We provide an axiomatic set of conditions that a solution should satisfy and use cooperative game theory to model the cost allocation problem. We provide an allocation, called the equal cost share solution, which is efficient to compute and is the unique solution that satisfies the conditions. In addition, we show not only that the cost allocation game has a nonempty core, but further, that the game is concave, meaning that the Shapley value allocation, which coincides with the equal cost share solution, always lies in the core of the game. We provide an application of the equal cost share solution to the Washington, D.C. Metro transit network and compare it to the existing fare pricing structure. As compared to equal cost share pricing, the Metro overcharges for short downtown trips and undercharges for very long commutes. The equal cost share solution is easy to update in real time as the cost data and user distribution change, or when the transit network expands.

Who canvasses for cargos? Incentive analysis and channel structure in a shipping supply chain

- Transportation Research Part B: Methodological---2017---Fan Wang,Xiaopo Zhuo,Baozhuang Niu,Jiayi He

Ocean shipping (OS) and inland shipping (IS) are vertically complementary services in the shipping supply chain. In practice, we have observed that both OS and IS companies canvass for cargos. In addition, we have observed that more and more IS companies are forming alliances to obtain a better price from the OS companies by hiring a negotiation agent. We solve the strategy matrix based on the following questions: "Who canvasses for cargos?" "Should a negotiation agent be hired?" We find that when an OS company canvasses for cargos, a negotiation agent can raise the IS service price; however, when IS companies canvass for cargos, a negotiation agent can weaken an OS company's monopolistic advantage. We show that there exists a win–win situation when an OS company canvasses for cargos without a negotiation agent and that this win–win situation is Pareto-optimal for all shipping supply chain parties. Interestingly, by comparing the equilibriums under optimal strategies and equilibrium strategies, we identify a lose–lose situation. That is, a classic Prisoner's Dilemma occurs when IS companies canvass for cargos and a negotiation agent is hired. We find that the shipping supply chain's overall profit and social welfare are maximized when an OS company canvasses for cargos and IS companies do not hire a negotiation agent.

Solving the battery swap station location-routing problem with capacitated electric vehicles using an AVNS algorithm for vehicle-routing problems with intermediate stops

- Transportation Research Part B: Methodological---2017---Julian Hof,Michael Schneider,Dominik Goeke

In this paper, we show how to extend solution methods for vehicle-routing problems with intermediate stops (using the example of an Adaptive Variable Neighborhood Search (AVNS) algorithm) to solve the recently introduced battery swap station location-routing problem with capacitated electric vehicles. The problem calls for the simultaneous determination of (i) the battery swap stations (BSSs) to be constructed out of a set of candidate locations, and (ii) the electric vehicle routes to serve a set of customers with the goal of minimizing the sum of construction and routing cost. On the benchmark instances from the literature, the extended AVNS is able to significantly improve the previously known best solutions for the large majority of instances while using only a small fraction of the runtimes reported for the comparison methods of Yang and Sun (2015). Moreover, the AVNS proves robust with regard to its average solution quality and is able to strongly reduce the number of constructed BSSs in the solutions compared to the results from the literature. Therefore, we generate additional benchmark instances which prove to be more meaningful with respect to the necessity of using BSSs and that are suitable to analyze the impact of varying construction cost on the location decision.

The valuation of travel time reliability: does congestion matter?

- Transportation Research Part B: Methodological---2017---Yu Xiao,Nicolas Coulombel,André de Palma

This paper addresses the valuation of travel time reliability in the presence of endogenous congestion and the role of scheduling preferences. The bottleneck model of road congestion is amended by considering stochastic travel times. We thereby take into account the influence of travel time variability on the congestion profile. The cost of travel time variability is the same with exogenous or endogenous congestion for two classes of preferences: linear marginal utility of time (MUT) at work and constant-exponential MUT. Therefore, cost-benefit analyses of travel time reliability improvements yield consistent results even if departure time adjustments are not accounted for. For α β γ preferences, departure time adjustments decrease congestion, which strongly mitigates the cost of travel time variability. Cost-benefit analyses need in this case to explicitly consider the departure time choice, to avoid being biased for the rush hour period (when congestion is strong). A method is proposed to correct this bias when necessary.

Balance of efficiency and robustness in passenger railway timetables

- Transportation Research Part B: Methodological---2017---Yusin Lee,Li-Sin Lu,Mei-Ling Wu,Dung-Ying Lin

For a passenger railway system with a published timetable, train timetable adherence and punctuality are critical performance indicators. Compared with other resource allocation methods, timetable adjustment is a relatively cost-effective approach for improving timetable adherence. The insertion of appropriate time supplement and buffer time into a timetable to reduce delays as well as their propagation can improve punctuality. However, to appropriately distribute available supplement/buffer time is a challenging task, especially for real-world cases. Moreover, a very robust timetable may not necessarily be a good choice, since ideal punctuality might come at the cost of large time slacks. In this study, we propose a simulation-based approach that embeds a linear programming model to effectively adjust the time supplement and buffer time in a given passenger railway timetable to reduce the average delay. The proposed solution approach is empirically applied to instances of various sizes. It is shown that the heuristic can quantify the relationship between timetable efficiency and robustness, which helps railway operators select their ideal balance between these two important yet conflicting issues. Further, numerical studies with a real timetable demonstrate that the timetable can achieve better punctuality with an even lower time supplement after adjustment, and the insights observed in this work have not only academic value but also value for practitioners in their preparation of timetables.

Joint optimization of high-speed train timetables and speed profiles: A unified modeling approach using space-time-speed grid networks

- Transportation Research Part B: Methodological---2017---Leishan Zhou,Tong, Lu (Carol),Junhua Chen,Jinjin Tang,Xuesong Zhou

This paper considers a high-speed rail corridor that requires high fidelity scheduling of train speed for a large number of trains with both tight power supply and temporal capacity constraints. This research aims to systematically integrate problems of macroscopic train timetabling and microscopic train trajectory calculations. We develop a unified modeling framework using three-dimensional space-time-speed grid networks to characterize both second-by-second train trajectory and segment-based timetables at different space and time resolutions. The discretized time lattices can approximately track the train position, speed, and acceleration solution through properly defined spacing and modeling time intervals. Within a Lagrangian relaxation-based solution framework, we propose a dynamic programming solution algorithm to find the speed/acceleration profile solutions with dualized train headway and power supply constraints. The proposed numerically tractable approach can better handle the non-linearity in solving the differential equations of motion, and systematically describe the complex connections between two problems that have been traditionally handled in a sequential way. We further use a real-world case study in the Beijing-Shanghai high-speed rail corridor to demonstrate the effectiveness and computational efficiency of our proposed methods and algorithms.

Dynamic passenger demand oriented metro train scheduling with energy-efficiency and waiting time minimization: Mixed-integer linear programming approaches

- Transportation Research Part B: Methodological---2017---Jiateng Yin,Lixing Yang,Tao Tang,Ziyou Gao,Bin Ran

In the daily operation of metro systems, the train scheduling problem aims to find a set of space-time paths for multiple trains that determine their departure and arrival times at metro stations, while train operations are in charge of selecting the best operational speed to satisfy the punctuality and operation costs. Different from the most existing researches that treat these two problems separately, this paper proposes an integrated approach for the train scheduling problem on a bi-direction urban metro line in order to minimize the operational costs (i.e., energy consumption) and passenger waiting time. More specifically, we simultaneously consider (1) the train operational velocity choices that correspond to the energy consumption of trains on each travelling arc, and (2) the dynamic passenger demands at each station for the calculation of total passenger waiting time in the planning horizon. By employing a space-time network representation in the formulations, this complex train scheduling and control problem with dynamic passenger demands is rigorously formulated into two optimization models with linear forms. The first model is an integer programming model that jointly minimizes train traction energy consumption and passenger waiting time. The second model, which is formulated as a mixed-integer programming model, further considers the utilization of regenerative braking energy on the basis of the first model. Due to the computational complexity of these two models, especially for large-scale real-world instances, we develop a Lagrangian relaxation (LR)-based heuristic algorithm that decomposes the primal problem into two sets of subproblems and thus enables to find a good solution in short computational time. Finally, two sets of numerical experiments, involving a relatively small-scale case and a real-world instance based on the operation data of Beijing metro are implemented to verify the effectiveness of the proposed approaches.

Efficient calibration techniques for large-scale traffic simulators

- Transportation Research Part B: Methodological---2017---Chao Zhang,Carolina Osorio,Gunnar Flötteröd

Road transportation simulators are increasingly used by transportation stakeholders around the world for the analysis of intricate transportation systems. Model calibration is a crucial prerequisite for transportation simulators to reliably reproduce and predict traffic conditions. This paper considers the calibration of transportation simulators. The methodology is suitable for a broad family of simulators. Its use is illustrated with stochastic and computationally costly simulators. The calibration problem is formulated as a simulation-based optimization (SO) problem. We propose a metamodel approach. The analytical metamodel combines information from the simulator with information from an analytical differentiable and tractable network model that relates the calibration parameters to the simulation-based objective function. The proposed algorithm is validated by considering synthetic experiments on a toy network. It is then used to address a calibration problem with real data for a large-scale network: the Berlin metropolitan network with over 24300 links and 11300 nodes. The performance of the proposed approach is compared to a traditional benchmark method. The proposed approach significantly improves the computational efficiency of the calibration algorithm with an average reduction in simulation runtime until convergence of more than 80%. The results illustrate the scalability of the approach and its suitability for the calibration of large-scale computationally inefficient network simulators.

Optimal perimeter control synthesis for two urban regions with aggregate boundary queue dynamics

- Transportation Research Part B: Methodological---2017---Jack Haddad

Perimeter control policies for urban regions with Macroscopic Fundamental Diagram (MFD) modeling have been presented in previous works. The control policies might meter the number of transferring vehicles from one region to another, resulting in queueing vehicles at regional boundaries. Concentrated vehicles at boundaries might affect the existence of well-defined MFDs. Most previous works neglect the effect of the boundary concentrated vehicles on the traffic flow dynamics, and do not explicitly consider their effect on the perimeter control policy.

Enhancing model-based feedback perimeter control with data-driven online adaptive optimization

- Transportation Research Part B: Methodological---2017---Anastasios Kouvelas,Mohammadreza Saeedmanesh,Nikolas Geroliminis

Most feedback perimeter control approaches that are based on the Macroscopic Fundamental Diagram (MFD) and are tested in detailed network structures restrict inflow from the external boundary of the network. Although such a measure is beneficial for the network performance, it creates virtual queues that do not interact with the rest of the traffic and assumes small unrestricted flow (i.e. almost zero disturbance). In reality, these queues can have a negative impact to traffic conditions upstream of the protected network that is not modelled. In this work an adaptive optimization scheme for perimeter control of heterogeneous transportation networks is developed and the aforementioned boundary control limitation is dropped. A nonlinear model is introduced that describes the evolution of the multi-region system over time, assuming the existence of well-defined MFDs. Multiple linear approximations of the model (for different set-points) are used for designing optimal multivariable integral feedback regulators. Since the resulting regulators are derived from approximations of the nonlinear dynamics, they are further enhanced in real-time with online learning/adaptive optimization, according to performance measurements. An iterative data-driven technique is integrated with the model-based design and its objective is to optimize the gain matrices and set-points of the multivariable perimeter controller based on real-time observations. The efficiency of the derived multi-boundary control scheme is tested in microsimulation for a large urban network with more than 1500 roads that is partitioned in multiple regions. The proposed control scheme is demonstrated to achieve a better distribution of congestion (by creating “artificial” inter-regional queues), thus preventing the network degradation and improving total delay and outflow.

Multiperiod-based timetable optimization for metro transit networks

- Transportation Research Part B: Methodological---2017---Xin Guo,Huijun Sun,Jianjun Wu,Jiangang Jin,Jin Zhou,Ziyou Gao

This paper tackles the train timetable optimization problem for metro transit networks (MTN) in order to enhance the performance of transfer synchronization between different rail lines. Train timetables of connecting lines are adjusted in such a way that train arrivals at transfer stations can be well synchronized. This study particularly focuses on the timetable optimization problem in the transitional period (from peak to off-peak hours or vice versa) during which train headway changes and passenger travel demand varies significantly. A mixed integer nonlinear programming model is proposed to generate an optimal train timetable and maximize the transfer synchronization events. Secondly, an efficient hybrid optimization algorithm based on the Particle Swarm Optimization and Simulated Annealing (PSO-SA) is designed to obtain near-optimal solutions in an efficient way. Meanwhile, in order to demonstrate the effectiveness of the proposed method, the results of numerical example solved by PSO-SA are compared with a branch-and-bound method and other heuristicalgorithms. Finally, a real-world case study based on the Beijing metro network and travel demand is conducted to validate the proposed timetabling model. Computational results demonstrate the effectiveness of adjusting train timetables and the applicability of the developed approach to real-world metro networks.

Optimizing on-time arrival probability and percentile travel time for elementary path finding in time-dependent transportation networks: Linear mixed integer programming reformulations

- Transportation Research Part B: Methodological---2017---Lixing Yang,Xuesong Zhou

Aiming to provide a generic modeling framework for finding reliable paths in dynamic and stochastic transportation networks, this paper addresses a class of two-stage routing models through reformulation of two commonly used travel time reliability measures, namely on-time arrival probability and percentile travel time, which are much more complex to model in comparison to expected utility criteria. A sample-based representation is adopted to allow time-dependent link travel time data to be spatially and temporally correlated. A number of novel reformulation methods are introduced to establish equivalent linear integer programming models that can be easily solved. A Lagrangian decomposition approach is further developed to dualize the non-anticipatory coupling constraints across different samples and then decompose the relaxed model into a series of computationally efficient time-dependent least cost path sub-problems. Numerical experiments are implemented to demonstrate the solution quality and computational performance of the proposed approaches.

Analyzing the performance of distributed conflict resolution among autonomous vehicles

- Transportation Research Part B: Methodological---2017---Ítalo Romani de Oliveira

This paper presents a study on how cooperation versus non-cooperation, and centralization versus distribution impact the performance of a traffic game of autonomous vehicles. A model using a particle-based, Lagrange representation, is developed, instead of an Eulerian, flow-based one, usual in routing problems of the game-theoretical approach. This choice allows representation of phenomena such as fuel exhaustion, vehicle collision, and wave propagation. The elements necessary to represent interactions in a multi-agent transportation system are defined, including a distributed, priority-based resource allocation protocol, where resources are nodes and links in a spatial network and individual routing strategies are performed. A fuel consumption dynamics is developed in order to account for energy cost and vehicles having limited range. The analysis shows that only the scenarios with cooperative resource allocation can achieve optimal values of either collective cost or equity coefficient, corresponding respectively to the centralized and to the distributed cases.

Modeling technical and service efficiency

- Transportation Research Part B: Methodological---2017---Mike Tsionas,A. George Assaf,David Gillen,Anna S. Mattila

Previous research on service failures, often measured by customer complaints, has not examined how organizations can measure or monitor their service efficiency. In this article, we introduce a new model that is suitable for measuring both service efficiency and technical efficiency when both bad outputs (i.e. service complaints) and good outputs (i.e. passenger trips and flights) are present. We develop our model with an output distance function, using Bayesian methods of inference organized around Markov chain Monte Carlo (MCMC). We illustrate our model with an application in the U.S. airline industry, an industry sector beset with service failures affecting both revenues and costs. We present the service inefficiency results of various US airlines and discuss the determinants of bad outputs in this industry. We also test whether our results are in line with market expectations by comparing the service efficiency estimates against the “American Customer Satisfaction Index” data.

A framework for capturing heterogeneity, heteroskedasticity, non-linearity, reference dependence and design artefacts in value of time research

- Transportation Research Part B: Methodological---2017---Stephane Hess,Andrew Daly,Thijs Dekker,Manuel Ojeda Cabral,Richard Batley

In early 2014, the UK Department for Transport (DfT) commissioned the first national value of travel time (VTT) study since the mid-1990s. This paper presents the methodological work undertaken for this study, with important innovations along a number of dimensions, both in terms of survey design and modelling methodology. Our findings show a rich pattern of heterogeneity across the travelling public, in terms of an impact on the VTT by both person and trip characteristics, as well as a major role for a number of characteristics that relate to the specific choices faced in a hypothetical stated choice setting, including reference dependence and non-linearities in sensitivities. We also discuss how these behavioural values were translated into values for use in appraisal, and the challenges faced when doing this on the basis of results obtained with advanced models.

Cruise service planning considering berth availability and decreasing marginal profit

- Transportation Research Part B: Methodological---2017---Kai Wang,Shuaian Wang,Lu Zhen,Xiaobo Qu

This paper addresses a decision problem on planning cruise services for a cruise ship so as to maximize the total profit during a planning horizon. The service is a sequence of ports (harbor cities) that the cruise ship visits. In this decision problem, the constraint about the availability of berths at each port is taken into account. In reality, if a cruise service is executed by the ship repeatedly for several times, the profit earned by the cruise service in each time decreases gradually. This effect of decreasing marginal profit is also considered in this study. We propose a nonlinear integer programming model to cater to the concavity of the function for the profit of operating a cruise service repeatedly. To solve the nonlinear model, two linearization methods are developed, one of which takes advantage of the concavity for a tailored linearization. Some properties of the problem are also investigated and proved by using the dynamic programming (DP) and two commonly used heuristics. In particular, we prove that if there is only one candidate cruise service, a greedy algorithm can derive the optimal solution. Numerical experiments are conducted to validate the effectiveness of the proposed models and the efficiency of the proposed linearization methods. In case some parameters needed by the model are estimated inexactly, the proposed decision model demonstrates its robustness and can still obtain a near-optimal plan, which is verified by experiments based on extensive real cases.

Strategic fleet planning for city logistics

- Transportation Research Part B: Methodological---2017---Anna Franceschetti,Dorothée Honhon,Gilbert Laporte,Tom Van Woensel,Jan C. Fransoo

We study the strategic problem of a logistics service provider managing a (possibly heterogeneous) fleet of vehicles to serve a city in the presence of access restrictions. We model the problem as an area partitioning problem in which a rectangular service area has to be divided into sectors, each served by a single vehicle. The length of the routes, which depends on the dimension of the sectors and on customer density in the area, is calculated using a continuous approximation. The aim is to partition the area and to determine the type of vehicles to use in order to minimize the sum of ownership or leasing, transportation and labor costs. We formulate the problem as a mixed integer linear problem and as a dynamic program. We develop efficient algorithms to obtain an optimal solution and present some structural properties regarding the optimal partition of the service area and the set of vehicle types to use. We also derive some interesting insights, namely we show that in some cases traffic restrictions may actually increase the number of vehicles on the streets, and we study the benefits of operating a heterogeneous fleet of vehicles.

A method to directly derive taste heterogeneity of travellers’ route choice in public transport from observed routes

- Transportation Research Part B: Methodological---2017---Sung-Pil Hong,Kyung min

- Kim,Geunyeong Byeon,Yun-Hong Min

The heterogeneity of passengers' route choice has been explained by randomizing the parameters, also known as taste parameters, that determine the way the attributes are relatively weighed in the disutility he/she perceives from a route. Growing availability of massive route choice data from, e.g. GPS or Smart Card system has made expected a model that derives the distribution of taste parameters from RP-data rather than relies on a prescribed distribution. This study availed itself of the intensive set of route choice data from Smart Card system as well as inverse optimization to calibrate the joint pdf of taste parameters to best signify the user-optimality of observed routes. Tested on 5 daily sets of real route choice, which amounts to 50,000 trips from the metro of Seoul metropolitan area, the proposed model notably enhanced the predictability compared to the previous models adopting a mixed-logit-based SUE or a non-parametric estimation method.

A link-based mean-excess traffic equilibrium model under uncertainty

- Transportation Research Part B: Methodological---2017---Xiangdong Xu,Anthony Chen,Lin Cheng,Chao Yang

Traffic equilibrium models under uncertainty characterize travelers' route choice behaviors under travel time variability. In this paper, we develop a link-based mean-excess traffic equilibrium (L-METE) model by integrating the sub-additivity property and complete travel time variability characterization of mean-excess travel time (METT), and the computationally tractable additive route cost structure of the conventional user equilibrium (UE) problem. Compared to the majority of relevant models formulated in the route domain, the link-based modeling has two desirable features on modeling flexibility and algorithmic development. First, it avoids the normal route travel time distribution assumption (uniformly imposed for all routes) that inherits from the Central Limit Theorem in most route-based models, permitting the use of any suitable link travel time distributions from empirical studies. Second, the additive route cost structure makes the L-METE model solvable by readily adapting existing UE algorithms without the need of storing/enumerating routes while avoiding the computationally demanding nonadditive shortest path problem and route flow allocations in route-based models, which is a significant benefit for large-scale network applications under uncertainty.

Discrete intermodal freight transportation network design with route choice behavior of intermodal operators

- Transportation Research Part B: Methodological---2017---Xinchang Wang,Qiang Meng

We consider a discrete intermodal network design problem for freight transportation, in which the network planner needs to determine whether or not to build up or expand a link to minimize the total operating cost of carriers and hub operators under a general route choice model of intermodal operators. We formulate the problem as a mixed-integer nonlinear and non-convex program that involves congestion effects, piecewise linear cost functions, and a fixed-point constraint. We develop a series of relaxed and equivalent models to reduce the hardness of the problem and provide theoretical results to show the equivalences. We present two solution methods to solve the problem with one returning heuristic solutions and the other generating a globally optimal solution. We offer two numerical experiments to test the two solution algorithms and also shed light on their performance comparisons.

Crowding cost estimation with large scale smart card and vehicle location data

- Transportation Research Part B: Methodological---2017---Daniel Hörcher,Daniel J. Graham,Richard J. Anderson

Crowding discomfort is an external cost of public transport trips imposed on fellow passengers that has to be measured in order to derive optimal supply-side decisions. This paper presents a comprehensive method to estimate the user cost of crowding in terms of the equivalent travel time loss, in a revealed preference route choice framework. Using automated demand and train location data we control for fluctuations in crowding conditions on the entire length of a metro journey, including variations in the density of standing passengers and the probability of finding a seat. The estimated standing penalty is 26.5% of the uncrowded value of in-vehicle travel time. An additional passenger per square metre on average adds 11.9% to the travel time multiplier. These results are in line with earlier revealed preference values, and suggest that stated choice methods may overestimate the user cost of crowding. As a side-product, and an important input of the route choice analysis, we derive a novel passenger-to-train assignment method to recover the daily crowding and standing probability pattern in the metro network.

A spatial generalized ordered-response model with skew normal kernel error terms with an application to bicycling frequency

- Transportation Research Part B: Methodological---2017---Chandra R. Bhat,Sebastian Astroza,Amin S. Hamdi

This paper proposes a new spatial generalized ordered response model with skew-normal kernel error terms and an associated estimation method. It contributes to the spatial analysis field by allowing a flexible and parametric skew-normal distribution for the kernel error term in traditional specifications of the spatial model. The resulting model is estimated using Bhat's (2011) maximum approximate composite marginal likelihood (MACML) inference approach. The model is applied to an analysis of bicycling frequency, using data from the 2014 Puget Sound household travel survey undertaken in the Puget Sound region in the State of Washington in the United States. Our results underscore the important effects of demographic variables, as well as the miles of bicycle lanes in an individual's immediate residential neighborhood, on bicycling propensity. An interesting finding is that women and young individuals (18–34 years of age) in particular “warm up” to bicycling as more investment is made in bicycling infrastructure, thus leading not only to a larger pool of bicyclists due to bicycling infrastructure enhancements, but also a more diverse and inclusive one. The results highlight the importance of introducing social dependence effects and non-normal kernel error terms from a policy standpoint. Specifically, our results suggest that ignoring these effects, as has been done by all earlier bicycling studies, can underestimate the impacts of bicycling infrastructure improvements and public campaigns on bicycle use frequency, potentially leading to under-investments in bicycling infrastructure projects.

A dynamic network loading model for anisotropic and congested pedestrian flows

- Transportation Research Part B: Methodological---2017---Flurin S. Hänseler,William H.K. Lam,Michel Bierlaire,Gael Lederrey,Marija Nikolić

A macroscopic loading model for multi-directional, time-varying and congested pedestrian flows is proposed. Walkable space is represented by a network of streams that are each associated with an area in which they interact. To describe this interaction, a stream-based pedestrian fundamental diagram is used that relates density and walking speed in multi-directional flow. The proposed model is applied to two different case studies. The explicit modeling of anisotropy in walking speed is shown to significantly improve the ability of the model to reproduce empirically observed walking time distributions. Moreover, the obtained model parametrization is in excellent agreement with the literature.

Time-dependent vehicle routing problem with path flexibility

- Transportation Research Part B: Methodological---2017---Yixiao Huang,Lei Zhao,Tom van Woensel,Jean-Philippe Gross

Conventionally, vehicle routing problems are defined on a network in which the customer locations and arcs are given. Typically, these arcs somehow represent the distances or expected travel time derived from the underlying road network. When executed, the quality of the solutions obtained from the vehicle routing problem depends largely on the quality of the road network representation. This paper explicitly considers path selection in the road network as an integrated decision in the time-dependent vehicle routing problem, denoted as path flexibility (PF). This means that any arc between two customer nodes has multiple corresponding paths in the road network (geographical graph). Hence, the decisions to make are involving not only the routing decision but also the path selection decision depending upon the departure time at the customers and the congestion levels in the relevant road network. The corresponding routing problem is a time-dependent vehicle routing problem with path flexibility (TDVRP–PF). We formulate the TDVRP–PF models under deterministic and stochastic traffic conditions. We derive important insights, relationships, and solution structures. Based on a representative testbed of instances (inspired on the road network of Beijing), significant savings are obtained in terms of cost and fuel consumption, by explicitly considering path flexibility. Having both path flexibility and time-dependent travel time seems to be a good representation of a wide range of stochasticity and dynamics in the travel time, and path flexibility serves as a natural recourse under stochastic conditions. Exploiting this observation, we employ a Route-Path approximation method generating near-optimal solutions for the TDVRP–PF under stochastic traffic conditions.

A statistical method for estimating predictable differences between daily traffic flow profiles

- Transportation Research Part B: Methodological---2017---F. Crawford,D.P. Watling,R.D. Connors

It is well known that traffic flows in road networks may vary not only within the day but also between days. Existing models including day-to-day variability usually represent all variability as unpredictable fluctuations. In reality, however, some of the differences in flows on a road may be predictable for transport planners with access to historical data. For example, flow profiles may be systematically different on Mondays compared to Fridays due to predictable differences in underlying activity patterns. By identifying days of the week or times of year where flows are predictably different, models can be developed or model inputs can be amended (in the case of day-to-day dynamical models) to test the robustness of proposed policies or to inform the development of policies which vary according to these predictably different day types. Such policies could include time-of-day varying congestion charges that themselves vary by day of the week or season, or targeting public transport provision so that timetables are more responsive to the day of the week and seasonal needs of travellers. A statistical approach is presented for identifying systematic variations in daily traffic flow profiles based on known explanatory factors such as the day of the week and the season. In order to examine day-to-day variability whilst also considering within-day dynamics, the distribution of flows throughout a day are analysed using Functional Linear Models. F-type tests for functional data are then used to compare alternative model specifications for the predictable variability. The output of the method is an average flow profile for each predictably different day type, which could include day of the week or time of year. An application to real-life traffic flow data for a two-year period is provided. The shape of the daily profile was found to be significantly different for each day of the week, including differences in the timing and width of peak flows and also the relationship between peak and inter-peak flows. Seasonal differences in flow profiles were also identified for each day of the week.

An integrated optimization-simulation framework for vehicle and personnel relocations of electric carsharing systems with reservations

- Transportation Research Part B: Methodological---2017---Burak Boyacı,Konstantinos G. Zografos,Nikolas Geroliminis

One-way electric vehicle carsharing systems are receiving increasing attention due to their mobility, environmental, and societal benefits. One of the major issues faced by the operators of these systems is the optimization of the relocation operations of personnel and vehicles. These relocation operations are essential in order to ensure that vehicles are available for use at the right place at the right time. Vehicle availability is a key indicator expressing the level of service offered to customers. However, the relocation operations, that ensure this availability, constitute a major cost component for the provision of these services. Therefore, clearly there is a trade-off between the cost of vehicle and personnel relocation and the level of service offered. In this paper we are developing, solving, and applying, in a real world context, an integrated multi-objective mixed integer linear programming (MMILP) optimization and discrete event simulation framework to optimize operational decisions for vehicle and personnel relocation in a carsharing system with reservations. We are using a clustering procedure to cope with the dimensionality of the operational problem without compromising on the quality of the obtained results. The optimization framework involves three mathematical models: (i) station clustering, (ii) operations optimization and (iii) personnel flow. The output of the optimization is used by the simulation in order to test the feasibility of the optimization outcome in terms of vehicle recharging requirements. The optimization model is solved iteratively considering the new constraints restricting the vehicles that require further charging to stay in the station until the results of the simulation are feasible in terms of electric vehicles' battery charging levels. The application of the proposed framework using data from a real world system operating in Nice, France sheds light to trade-offs existing between the level of service offered, resource utilization, and certainty of fulfilling a trip reservation.

Stated and revealed exit choices of pedestrian crowd evacuees

- Transportation Research Part B: Methodological---2017---Milad Haghani,Majid Sarvi

Understanding fundamental behavioural features regulating the escape wayfinding decisions of pedestrian humans in built environments has major implications for the safety planning and the risk-analysis of crowded public facilities. In contrast to the vast interest invested in modelling the momentary responses of evacuees to their immediate surroundings (i.e. the collision-avoidance models), their global navigation behaviour is poorly understood albeit believed to be a major determinant of the accuracy of the crowd simulation models. The primary challenge arises from the scarcity of reliable data suitable for modelling purposes causing the experimental knowledge in the field lagging substantially behind the corresponding model developments. Observations derived from fully natural emergency contexts (in the form of modelling material) are rare and collecting data in realistic experimental settings poses its own major challenges. Only few experimental modelling attempts have been reported thus far in relation with this problem primarily using the stated-choice (SC) methods. Modelling based on revealed choices (RC), however, has remained absent in this context leaving the findings of the SC experiments mostly unverified. It is still unclear whether we can reliably learn from the wayfinding choices made in virtually visualised environments without the decision-makers interacting with real individuals and the physical elements of the environment as they do in the real-world settings. Furthermore, the extent to which the findings of these experiments are specific to the particular characteristics of the environment visualised in the experiments is also unclear.

Optimization for gate re-assignment

- Transportation Research Part B: Methodological---2017---Dong Zhang,Diego Klabjan

Disruptions such as adverse weather, flight delays and flight cancellations are a frequent occurrence in airport operations. A sophisticated gate assignment plan can be easily disrupted and serious consequences might be caused. Therefore, an efficient gate re-assignment methodology is of great importance for the airline industry. In this paper, we propose an efficient gate re-assignment methodology to deal with the disruptions, in which the objective function is to minimize the weighted sum of the total flight delays, the number of gate re-assignment operations and the number of missed passenger connections. Two multi-commodity network flow models are built for the pure gate re-assignment problem and the gate re-assignment problem with connecting passengers. Recognizing the inherent NP hard nature of the gate re-assignment problem, two heuristic algorithms are proposed to solve the models efficiently. The proposed models and algorithms are tested based on real-world data of a large U.S. carrier and computational results reveal that the proposed methodologies can provide high quality solutions within a short computational time.

Optimization of the issuance of evacuation orders under evolving hurricane conditions

- Transportation Research Part B: Methodological---2017---Wenqi Yi,Linda Nozick,Rachel Davidson,Brian Blanton,Brian Colle

This paper develops a bi-level programming model to optimize the issuance of evacuation orders with explicit consideration of (i) the highly uncertain evolution of the storm, and (ii) the complexity of the behavioral reaction to evolving storm conditions. A solution procedure based on progressive hedging is developed. A realistic case study for the eastern portion of the state of North Carolina is presented. Through the case study we demonstrate (1) the value of developing an evacuation order policy based on the evolution of the storm in contrast to a static policy; (2) the richness in the insights that can be provided by linking the behavioral models for evacuation decision-making with dynamic traffic assignment-based network flow models in a hurricane context; and (3) the computational promise of a progressive hedging-based solution procedure to solve large instances of the model.

On the analytical approximation of joint aggregate queue-length distributions for traffic networks: A stationary finite capacity Markovian network approach

- Transportation Research Part B: Methodological---2017---Carolina Osorio,Carter Wang

This paper is motivated by recent results in the design of signal plans for Manhattan that highlight the importance of providing signal control algorithms with an analytical description of between-link dependencies. This is particularly important for congested networks prone to the occurrence of spillbacks. This paper formulates a probabilistic network model that proposes an aggregate description of the queue-length, and then approximates the joint aggregate queue-length distribution of subnetworks. The goal is to model between-queue dependencies beyond first-order moments, yet to do so in a tractable manner such that these techniques can be used for optimization purposes.

A hybrid large neighborhood search for the static multi-vehicle bike-repositioning problem

- Transportation Research Part B: Methodological---2017---Sin C. Ho,W.Y. Szeto

This paper addresses the multi-vehicle bike-repositioning problem, a pick-up and delivery vehicle routing problem that arises in connection with bike-sharing systems. Bike-sharing is a green transportation mode that makes it possible for people to use shared bikes for travel. Bikes are retrieved and parked at any of the stations within the bike-sharing network. One major challenge is that the demand for and supply of bikes are not always matched. Hence, vehicles are used to pick up bikes from surplus stations and transport them to deficit stations to satisfy a particular service level. This operation is called a bike-repositioning problem. In this paper, we propose a hybrid large neighborhood search for solving the problem. Several removal and insertion operators are proposed to diversify and intensify the search. A simple tabu search is further applied to the most promising solutions. The heuristic is evaluated on three sets of instances with up to 518 stations and five vehicles. The results of computational experiments indicate that the heuristic outperforms both CPLEX and the math heuristic proposed by Forma et al. (2015) [Transportation Research Part B 71: 230–247]. The average improvement of our heuristic over the math heuristic is 1.06%, and it requires only a small fraction of the computation time.

Stochastic modeling for vehicle platoons (I): Dynamic grouping behavior and online platoon recognition

- Transportation Research Part B: Methodological---2017---Baibing Li

A vehicle platoon is a group of vehicles traveling together at approximately the same speed. Traffic platooning is an important phenomenon that can substantially increase the capacity of roads. This two-part paper presents a new approach to stochastic dynamic modeling for vehicle platoons. In part I, we develop a vehicle platoon model with two interconnected components: a Markov regime-switching stochastic process that is used to model the dynamic behavior of platoon-to-platoon transitions, and a state space model that is employed to describe individual vehicles' dynamic movements within each vehicle platoon. On the basis of the developed stochastic dynamic model, we then develop an algorithm for online platoon recognition. The proposed stochastic dynamic model for vehicle platoons also provides a new approach to vehicle speed filtering for traffic with a platoon structure.

Stochastic modeling for vehicle platoons (II): Statistical characteristics

- Transportation Research Part B: Methodological---2017---Baibing Li

This two-part paper presents a new approach to stochastic dynamic modeling for vehicle platoons. Part I develops a vehicle platoon model to capture the dynamics of vehicles' grouping behavior and proposes an online platoon recognition algorithm. On the basis of the developed platoon model, Part II investigates various important characteristics of vehicle platoons and derives their statistical distribution models, including platoon size, within-platoon headway, between-platoon headway and platoon speed. It is shown that the derived statistical distributions include some important existing models in the literature as their special cases. These statistical distribution models are crucial for us to understand the traffic platooning phenomenon. In practice, they can be used as the inputs for the design of traffic management and control algorithms for traffic with a platoon structure. Real traffic data is used to illustrate the obtained theoretical results.

Parsimonious shooting heuristic for trajectory design of connected automated traffic part I: Theoretical analysis with generalized time geography

- Transportation Research Part B: Methodological---2017---Fang Zhou,Xiaopeng Li,Jiaqi Ma

This paper studies a problem of designing trajectories of a platoon of vehicles on a highway segment with advanced connected and automated vehicle technologies. This problem is very complex because each vehicle trajectory is essentially an infinite-dimensional object and neighboring trajectories have complex interactions (e.g., car-following behavior). A parsimonious shooting heuristic algorithm is proposed to construct vehicle trajectories on a signalized highway segment that comply with boundary conditions for vehicle arrivals, vehicle mechanical limits, traffic lights and vehicle following safety. This algorithm breaks each vehicle trajectory into a few sections that are analytically solvable. This decomposes the originally hard trajectory design problem to a simple constructive heuristic. Then we slightly adapt this shooting heuristic algorithm to efficiently solve a leading vehicle problem on an uninterrupted freeway. To study theoretical properties of the proposed algorithms, the time geography theory is generalized by considering finite accelerations. With this generalized theory, it is found that under mild conditions, these algorithms can always obtain a feasible solution to the original complex trajectory design problem. Further, we discover that the shooting heuristic solution is a generalization of the solution to the classic kinematic wave theory by incorporating finite accelerations. We identify the theoretical bounds to the difference between the shooting heuristic solution and the kinematic wave solution. Numerical experiments are conducted to verify the theoretical results and to draw additional managerial insights into the potential of trajectory design in improving traffic performance. In summary, this paper provides a methodological and theoretical foundation for advanced traffic control by optimizing the trajectories of connected and automated vehicles. Building upon this foundation, an optimization framework will be presented in a following paper as Part II of this study.

Parsimonious shooting heuristic for trajectory design of connected automated traffic part II: Computational issues and optimization

- Transportation Research Part B: Methodological----2017---Jiaqi Ma,Xiaopeng Li,Fang Zhou,Jia Hu,B. Brian Park

Advanced connected and automated vehicle technologies enable us to modify driving behavior and control vehicle trajectories, which have been greatly constrained by human limits in existing manually-driven highway traffic. In order to maximize benefits from these technologies on highway traffic management, vehicle trajectories need to be not only controlled at the individual level but also coordinated collectively for a stream of traffic. As one of the pioneering attempts to highway traffic trajectory control, Part I of this study (Zhou et al., 2016) proposed a parsimonious shooting heuristic (SH) algorithm for constructing feasible trajectories for a stream of vehicles considering realistic constraints including vehicle kinematic limits, traffic arrival patterns, car-following safety, and signal operations. Based on the algorithmic and theoretical developments in the preceding paper, this paper proposes a holistic optimization framework for identifying a stream of vehicle trajectories that yield the optimum traffic performance measures on mobility, environment and safety. The computational complexity and mobility optimality of SH is theoretically analyzed, and verifies superior computational performance and high solution quality of SH. A numerical sub-gradient-based algorithm with SH as a subroutine (NG-SH) is proposed to simultaneously optimize travel time, a surrogate safety measure, and fuel consumption for a stream of vehicles on a signalized highway section. Numerical examples are conducted to illustrate computational and theoretical findings. They show that vehicle trajectories generated from NG-SH significantly outperform the benchmark case with all human drivers at all measures for all experimental scenarios. This study reveals a great potential of transformative trajectory optimization approaches in transportation engineering applications. It lays a solid foundation for developing holistic cooperative control strategies on a general transportation network with emerging technologies.

Ocean container transport in global supply chains: Overview and research opportunities

- Transportation Research Part B: Methodological---2017---Chung-Yee Lee,Dong-Ping Song

This paper surveys the extant research in the field of ocean container transport. A wide range of issues is discussed including strategic planning, tactical planning and operations management issues, which are categorized into six research areas. The relationships between these research areas are discussed and the relevant literature is reviewed. Representative models are selected or modified to provide a flavour of their functions and application context, and used to explain current shipping practices. Future research opportunities bearing in mind the emerging phenomena in the field are discussed. The main purpose is to raise awareness and encourage more research into and application of operations management techniques and tools in container transport chains.

Proactive route guidance to avoid congestion

- Transportation Research Part B: Methodological----2016---E. Angelelli,I. Arsik,V. Morandi,M. Savelsbergh,M.G. Speranza

We propose a proactive route guidance approach that integrates a system perspective: minimizing congestion, and a user perspective: minimizing travel inconvenience. The approach assigns paths to users so as to minimize congestion while not increasing their travel inconvenience too much. A maximum level of travel inconvenience is ensured and a certain level of fairness is maintained by limiting the set of considered paths for each Origin-Destination pair to those whose relative difference with respect to the shortest (least-duration) path, called travel inconvenience, is below a given threshold. The approach hierarchically minimizes the maximum arc utilization and the weighted average experienced travel inconvenience. Minimizing the maximum arc utilization in the network, i.e., the ratio of the number of vehicles entering an arc per time unit and the maximum number of vehicles per time unit at which vehicles can enter the arc and experience no slow-down due to congestion effects, is a system-oriented objective, while minimizing the weighted average experienced travel inconvenience, i.e., the average travel inconvenience over all eligible paths weighted by the number of vehicles per time unit that traverse the path, is a user-oriented objective. By design, to ensure computational efficiency, the approach only solves linear programming models. In a computational study using benchmark instances reflecting a road infrastructure encountered in many cities, we analyze, for different levels of maximum travel inconvenience and, the minimum maximum arc utilization and the weighted average experienced travel inconvenience. We find that accepting relatively small levels of maximum travel inconvenience can result in a significant reduction, or avoiding, of congestion.

Envy-minimizing pareto efficient intersection control with brokered utility exchanges under user heterogeneity

- Transportation Research Part B: Methodological---2016---Roger Lloret-Batlle,R. Jayakrishnan

We propose PEXIC (Priced EXchanges in Intersection Control), a new concept and algorithm for traffic signal control that incorporates user heterogeneity on value of delay savings. The algorithm assigns phases with associated delays, taking into account the vehicle travelers' values for experienced delay. Applying principles of envy-freeness, we develop a pricing scheme that addresses fairness by minimizing user envy via compensatory monetary transfers among users. PEXIC is Pareto efficient and budget balanced, and thus financially self-sustainable without external subsidy. The optimization is solved sequentially on a rolling horizon basis: first the phasing, and next the pricing. PEXIC achieves significant cost reductions for a large range of volumes and users' value heterogeneity levels. Inclusion of user heterogeneity also proved to be fairer than standard delay minimization that disregards individual vehicles' values for delay savings. Furthermore, we show that arbitrage is not possible, thus there are no incentives to drive just to collect those payments. The method used has polynomial complexity and it is suitable for real-world implementation.

Autonomous cars and dynamic bottleneck congestion: The effects on capacity, value of time and preference heterogeneity

- Transportation Research Part B: Methodological---2016---Vincent A.C. van den Berg,Erik Verhoef

'Autonomous cars' are cars that can drive themselves without human control. Autonomous cars can safely drive closer together than cars driven by humans, thereby possibly increasing road capacity. By allowing drivers to perform other activities in the vehicle, they may reduce the value of travel time losses (VOT). We investigate the effects of autonomous cars using a dynamic equilibrium model of congestion that captures three main elements: the resulting increase in capacity, the decrease in the VOT for those who acquire one and the implications of the resulting changes in the heterogeneity of VOTs. We do so for three market organizations: private monopoly, perfect competition and public supply. Even though an increased share of autonomous cars raises average capacity, it may hurt existing autonomous car users as those who switch to an autonomous car will impose increased congestion externalities due to their altered departure time behaviour. Depending on which effect dominates, switching to an autonomous vehicle may impose a net negative or positive externality. Often public supply leads to 100% autonomous cars, but it may be optimal to have a mix of car types, especially when there is a net negative externality. With a positive (negative) externality, perfect competition leads to an undersupply (oversupply) of autonomous cars, and a public supplier needs to subsidise (tax) autonomous cars to maximise welfare. A monopolist supplier ignores the capacity effect and adds a mark-up to its price.

A disjunctive convex programming approach to the pollution-routing problem

- Transportation Research Part B: Methodological---2016---Ricardo Fukasawa,Qie He,Yongjia Song

The pollution-routing problem (PRP) aims to determine a set of routes and speed over each leg of the routes simultaneously to minimize the total operational and environmental costs. A common approach to solve the PRP exactly is through speed discretization, i.e., assuming that speed over each arc is chosen from a prescribed set of values. In this paper, we keep speed as a continuous decision variable within an interval and propose new formulations for the PRP. In particular, we build two mixed-integer convex optimization models for the PRP, by employing tools from disjunctive convex programming. These are the first arc-based formulations for the PRP with continuous speed. We also derive several families of valid inequalities to further strengthen both models. We test the proposed formulations on benchmark instances. Some instances are solved to optimality for the first time.

A new random utility model with flexible correlation pattern and closed-form covariance expression: The CoRUM

- Transportation Research Part B: Methodological---2016---Andrea Papola

This paper proposes a new random utility model characterised by a cumulative distribution function (cdf) obtained as a finite mixture of different cdfs. This entails that choice probabilities, covariances and elasticities of this model are also a finite mixture of choice probabilities, covariances and elasticities of the mixing models. As a consequence, by mixing nested logit cdfs, a model is generated with closed-form expressions for choice probabilities, covariances and elasticities and with, potentially, a very flexible correlation pattern. Importantly, the closed-form covariance expression opens up interesting application possibilities in some special choice contexts, like route choice, where prior expectations in terms of the covariance matrix can be formulated.

A branch-and-price approach for solving the train unit scheduling problem

- Transportation Research Part B: Methodological---2016---Zhiyuan Lin,Raymond S.K. Kwan

We propose a branch-and-price approach for solving the integer multicommodity flow model for the network-level train unit scheduling problem (TUSP). Given a train operator’s fixed timetable and a fleet of train units of different types, the TUSP aims at determining an assignment plan such that each train trip in the timetable is appropriately covered by a single or coupled train units. The TUSP is challenging due to its complex nature. Our branch-and-price approach includes a branching system with multiple branching rules for satisfying real-world requirements that are difficult to realize by linear constraints, such as unit type coupling compatibility relations and locations banned for coupling/decoupling. The approach also benefits from an adaptive node selection method, a column inheritance strategy and a feature of estimated upper bounds with node reservation functions. The branch-and-price solver designed for TUSP is capable of handling instances of up to about 500 train trips. Computational experiments were conducted based on real-world problem instances from First ScotRail. The results are satisfied by rail practitioners and are generally competitive or better than the manual ones.

Designing a supply chain resilient to major disruptions and supply/demand interruptions

- Transportation Research Part B: Methodological---2016---Armin Jabbarzadeh,Behnam Fahimnia,Jiuh-Biing Sheu,Hani Shahmoradi Moghadam

Global supply chains are more than ever under threat of major disruptions caused by devastating natural and man-made disasters as well as recurrent interruptions caused by variations in supply and demand. This paper presents a hybrid robust-stochastic optimization model and a Lagrangian relaxation solution method for designing a supply chain resilient to (1) supply/demand interruptions and (2) facility disruptions whose risk of occurrence and magnitude of impact can be mitigated through fortification investments. We study a realistic problem where a disruption can cause either a complete facility shutdown or a reduced supply capacity. The probability of disruption occurrence is expressed as a function of facility fortification investment for hedging against potential disruptions in the presence of certain budgetary constraints. Computational experiments and thorough sensitivity analyses are completed using some of the existing widely-used datasets. The performance of the proposed model is also examined using a Monte Carlo simulation method. To explore the practical application of the proposed model and methodology, a real world case example is discussed which addresses mitigating the risk of facility fires in an actual oil production company. Our analysis and investigation focuses on exploring the extent to which supply chain design decisions are influenced by factors such as facility fortification strategies, a decision maker's conservatism degree, demand fluctuations, supply capacity variations, and budgetary constraints.

Parametric search for the bi-attribute concave shortest path problem

- Transportation Research Part B: Methodological---2016---Yuli Zhang,Zuo-Jun Max Shen,Shiji Song

A bi-attribute concave shortest path (BC-SP) problem seeks to find an optimal path in a bi-attribute network that minimizes a linear combination of two path costs, one of which is evaluated by a nondecreasing concave function. Due to the nonadditivity of its objective function, Bellman's principle of optimality does not hold. This paper proposes a parametric search method to solve the BC-SP problem, which only needs to solve a series of shortest path problems, i.e., the parameterized subproblems (PSPs). Several techniques are developed to reduce both the number of PSPs and the computation time for these PSPs. Specifically, we first identify two properties of the BC-SP problem to guide the parametric search using the gradient and concavity of its objective function. Based on the properties, a monotonic descent search (MDS) and an intersection point search (IPS) are proposed. Second, we design a speedup label correcting (LC) algorithm, which uses optimal solutions of previously solved PSPs to reduce the number of labeling operations for subsequent PSPs. The MDS, IPS and speedup LC techniques are embedded into a branch-and-bound based interval search to guarantee optimality. The performance of the proposed method is tested on the mean-standard deviation shortest path problem and the route choice problem with a quadratic disutility function. Experiments on both real transportation networks and grid networks show that the proposed method reduces the computation time of existing algorithms by one to two orders of magnitude.

The two-echelon time-constrained vehicle routing problem in linehaul-delivery systems

- Transportation Research Part B: Methodological---2016---Hongqi Li,Lu Zhang,Tan Lv,Xinyu Chang

Most of the studies address issues relating to the delivery from satellites to customers, which is throughout the end part of the linehaul-delivery system. Differing from the long-term strategic problems including the two-echelon vehicle routing problem (2E-VRP), the two-echelon location routing problem (2E-LRP) and the truck and trailer routing problem (TTRP) which make location decisions in depots or satellites, the paper introduces a short-term tactical problem named the two-echelon time-constrained vehicle routing problem in linehaul-delivery systems (2E-TVRP) that does not involve location decisions. The linehaul level and the delivery level are linked through city distribution centers (CDCs) located on the outskirts of cities. The 2E-TVRP has inter-CDC linehaul on the first level and urban delivery from CDCs to satellites on the second level. Vehicle routes on different levels are interacted by time constraints. A mixed integer nonlinear programming model for the 2E-TVRP is put forward, and a mixed integer linear programming model is used as the benchmark model. The Clarke and Wright savings heuristic algorithm (CW) improved by a local search phase is adopted. The 2E-TVRP formulations and the heuristic algorithm are tested by using 140 randomly-generated instances with up to 10 CDCs and 500 satellites. The computational results indicate that the heuristic can effectively solve various instances of the 2E-TVRP.

Finding the k reliable shortest paths under travel time uncertainty

- Transportation Research Part B: Methodological---2016---Bi Yu Chen,Qingquan Li,William H.K. Lam

This paper investigates the problem of finding the K reliable shortest paths (KRSP) in stochastic networks under travel time uncertainty. The KRSP problem extends the classical K loopless shortest paths problem to the stochastic networks by explicitly considering travel time reliability. In this study, a deviation path approach is established for finding K α-reliable paths in stochastic networks. A deviation path algorithm is proposed to exactly solve the KRSP problem in large-scale networks. The A* technique is introduced to further improve the KRSP finding performance. A case study using real traffic information is performed to validate the proposed algorithm. The results indicate that the proposed algorithm can determine KRSP under various travel time reliability values within reasonable computational times. The introduced A* technique can significantly improve KRSP finding performance.

The impact of source terms in the variational representation of traffic flow

- Transportation Research Part B: Methodological---2016---Jorge A. Laval,Guillaume Costeseque,Bargavarama Chilukuri

This paper revisits the variational theory of traffic flow, now under the presence of continuum lateral inflows and outflows to the freeway. It is found that a VT solution apply only in Eulerian coordinates when source terms are exogenous, but not when they are a function of traffic conditions, e.g. as per a merge model. In discrete time, however, these dependencies become exogenous, which allowed us to propose improved numerical solution methods. In space-Lagrangian and time-Lagrangian coordinates, VT solutions may not apply even if source terms are exogenous.

Eco-system optimal time-dependent flow assignment in a congested network

- Transportation Research Part B: Methodological---2016---Chung-Cheng Lu,Jiangtao Liu,Yunchao Qu,Srinivas Peeta,Nagui M. Rouphail,Xuesong Zhou

This research addresses the eco-system optimal dynamic traffic assignment (ESODTA) problem which aims to find system optimal eco-routing or green routing flows that minimize total vehicular emission in a congested network. We propose a generic agent-based ESODTA model and a simplified queueing model (SQM) that is able to clearly distinguish vehicles' speed in free-flow and congested conditions for multi-scale emission analysis, and facilitates analyzing the relationship between link emission and delay. Based on the SQM, an expanded space-time network is constructed to formulate the ESODTA with constant bottleneck discharge capacities. The resulting integer linear model of the ESODTA is solved by a Lagrangian relaxation-based algorithm. For the simulation-based ESODTA, we present the column-generation-based heuristic, which requires link and path marginal emissions in the embedded time-dependent least-cost path algorithm and the gradient-projection-based descent direction method. We derive a formula of marginal emission which encompasses the marginal travel time as a special case, and develop an algorithm for evaluating path marginal emissions in a congested network. Numerical experiments are conducted to demonstrate that the proposed algorithm is able to effectively obtain coordinated route flows that minimize the system-wide vehicular emission for large-scale networks.

On accommodating spatial interactions in a Generalized Heterogeneous Data Model (GHDM) of mixed types of dependent variables

- Transportation Research Part B: Methodological---2016---Chandra R. Bhat,Abdul R. Pinjari,Subodh K. Dubey,Amin S. Hamdi

We develop an econometric framework for incorporating spatial dependence in integrated model systems of latent variables and multidimensional mixed data outcomes. The framework combines Bhat's Generalized Heterogeneous Data Model (GHDM) with a spatial (social) formulation to parsimoniously introduce spatial (social) dependencies through latent constructs. The applicability of the spatial GHDM framework is demonstrated through an empirical analysis of spatial dependencies in a multidimensional mixed data bundle comprising a variety of household choices – household commute distance, residential location (density) choice, vehicle ownership, parents' commute mode choice, and children's school mode choice – along with other measurement variables for two latent constructs – parent's safety concerns about children walking/biking to school and active lifestyle propensity. The GHDM framework identifies an intricate web of causal relationships and endogeneity among the endogenous variables. Furthermore, the spatial (social) version of the GHDM model reveals a high level of spatial (social) dependency in the latent active lifestyle propensity of different households and moderate level of spatial dependency in parents' safety concerns. Ignoring spatial (social) dependencies in the empirical model results in inferior data fit, potential bias and statistical insignificance of the parameters corresponding to nominal variables, and underestimation of policy impacts.

Preferences for travel time under risk and ambiguity: Implications in path selection and network equilibrium

- Transportation Research Part B: Methodological---2016---Jin Qi,Melvyn Sim,Defeng Sun,Xiaoming Yuan

In this paper, we study the preferences for uncertain travel times in which probability distributions may not be fully characterized. In evaluating an uncertain travel time, we explicitly distinguish between risk, where the probability distribution is precisely known, and ambiguity, where it is not. In particular, we propose a new criterion called ambiguity-aware CARA travel time (ACT) for evaluating uncertain travel times under various attitudes of risk and ambiguity, which is a preference based on blending the Hurwicz criterion and Constant Absolute Risk Aversion (CARA). More importantly, we show that when the uncertain link travel times are independently distributed, finding the path that minimizes travel time under the ACT criterion is essentially a shortest path problem. We also study the implications on Network Equilibrium (NE) model where travelers on the traffic network are characterized by their knowledge of the network uncertainty as well as their risk and ambiguity attitudes under the ACT. We derive and analyze the existence and uniqueness of solutions under NE. Finally, we obtain the Price of Anarchy that characterizes the inefficiency of this new equilibrium. The computational study suggests that as uncertainty increases, the influence of selfishness on inefficiency diminishes.

Carrier collaboration with endogenous fleets and load factors when networks are complementary

- Transportation Research Part B: Methodological---2016---Achim I. Czerny,Vincent A.C. van den Berg,Erik Verhoef

This paper analyzes the effect of carrier collaboration on fleet capacity, fleet structures in terms of the number and the size of vehicles, and load factors. The model features complementary networks, scheduling, price elastic demands, and demand uncertainty. For the case of a given number of vehicles, the analysis shows that carrier collaboration increases vehicle sizes (thus, fleet capacity) if marginal seat costs are low while fleet capacity remains unchanged if marginal seat costs are high. If both vehicle sizes and vehicle numbers can be varied, then collaboration will always increase vehicle numbers and fleet capacity, while the effects on vehicle sizes and, thus, also load factors, are ambiguous and therewith hard to predict. Numerical simulations indicate that collaboration increases expected load factors also when the number of vehicles is endogenous.

Optimal public transport networks for a general urban structure

- Transportation Research Part B: Methodological---2016---Andrés Fielbaum,Sergio Jara-Diaz,Antonio Gschwender

Using a quite general parametric description of an urban setting in terms of its network, centers structure and demand pattern, we find the optimal spatial arrangement of transit lines out of four basic strategic competing options: direct, exclusive, hub-and-spoke and feeder-trunk. We identify clearly the relation between the characteristics of both the urban setting (mostly monocentric, polycentric or dispersed) and the users (transfer penalty, patronage) with the line structure that shows the best response.

Constrained optimization and distributed computation based car following control of a connected and autonomous vehicle platoon

- Transportation Research Part B: Methodological---2016---Siyuan Gong,Jinglai Shen,Lili Du

Motivated by the advancement in connected and autonomous vehicle technologies, this paper develops a novel car-following control scheme for a platoon of connected and autonomous vehicles on a straight highway. The platoon is modeled as an interconnected multi-agent dynamical system subject to physical and safety constraints, and it uses the global information structure such that each vehicle shares information with all the other vehicles. A constrained optimization based control scheme is proposed to ensure an entire platoon’s transient traffic smoothness and asymptotic dynamic performance. By exploiting the solution properties of the underlying optimization problem and using primal-dual formulation, this paper develops dual based distributed algorithms to compute optimal solutions with proven convergence. Furthermore, the asymptotic stability of the unconstrained linear closed-loop system is established. These stability analysis results provide a principle to select penalty weights in the underlying optimization problem to achieve the desired closed-loop performance for both the transient and the asymptotic dynamics. Extensive numerical simulations are conducted to validate the efficiency of the proposed algorithms.

Day-to-day traffic dynamics considering social interaction: From individual route choice behavior to a network flow model

- Transportation Research Part B: Methodological---2016---Fangfang Wei,Ning Jia,Shoufeng Ma

Social interaction is increasingly recognized as an important factor that influences travelers’ behaviors. It remains challenging to incorporate its effect into travel choice behaviors, although there has been some research into this area. Considering random interaction among travelers, we model travelers’ day-to-day route choice under the uncertain traffic condition. We further explore the evolution of network flow based on the individual-level route choice model, though that travelers are heterogeneous in decision-making under the random-interaction scheme. We analyze and prove the existence of equilibrium and the stability of equilibrium. We also analyzed and described the specific properties of the network flow evolution and travelers’ behaviors. Two interesting phenomena are found in this study. First, the number of travelers that an individual interacts with can affect his route choice strategy. However, the interaction count exerts no influence on the evolution of network flow at the aggregate-level. Second, when the network flow reaches equilibrium, the route choice strategy at the individual-level is not necessarily invariable. Finally, two networks are used as numerical examples to show model properties and to demonstrate the two study phenomena. This study improves the understanding of travelers’ route choice dynamics and informs how the network flow evolves under the influence of social interaction.

A multi-period dial-a-ride problem with driver consistency

- Transportation Research Part B: Methodological---2016---Kris Braekers,Attila A. Kovacs

Dial-a-ride services provide disabled and elderly people with a personalized mode of transportation to preserve their mobility. Typically, several users with different pickup and dropoff locations are transported on a vehicle simultaneously. The focus in dial-a-ride problems (DARPs) is mainly on minimizing routing cost. Service quality has been taken into account in the models by imposing time windows and limiting the maximum ride time of each user. We extend the classical DARP by an additional feature of service quality referred to as driver consistency. Customers of dial-a-ride services are often sensitive to changes in their daily routine. This aspect includes the person who is providing the transportation service, i.e., the driver of the vehicle. Our problem, called the driver consistent dial-a-ride problem (DC-DARP), considers driver consistency by bounding the maximum number of different drivers that transport a user over a multi-period planning horizon.

Robust models for transportation service network design

- Transportation Research Part B: Methodological---2016---ManWo Ng,Hong K. Lo

In this paper robust models are presented for the transportation service network design problem, using the ferry service network design problem as an example application. The base assumption is that only the mean and an upper bound on the passenger demand are known. In one robust model, this information is supplemented by a lower bound on the demand, whereas in a second robust model, the assumption is made that the variance of the demand is known, in addition to the mean and upper bound. The relationship between the two models is investigated and characterized analytically. A case study using the ferry service in Hong Kong is provided to illustrate the models.

A new look at the rate of change of energy consumption with respect to journey time on an optimal train journey

- Transportation Research Part B: Methodological---2016---Phil Howlett

We present a new derivation of a key formula for the rate of change of energy consumption with respect to journey time on an optimal train journey. We use a standard mathematical model (Albrecht et al., 2015b; Howlett, 2000; Howlett et al., 2009; Khmelnitsky, 2000; Liu and Golovitcher, 2003) to define the problem and show by explicit calculation of switching points that the formula also applies for all basic control subsequences within the optimal strategy on appropriately chosen fixed track segments. The rate of change was initially derived as a known strictly decreasing function of the optimal driving speed in a text edited by Isayev (1987, Section 14.2, pp 259–260) using an empirical resistance function. An elegant derivation by Liu and Golovitcher (2003, Section 3) with a general resistance function required an underlying assumption that the optimal strategy is unique and that the associated optimal driving speed is a strictly decreasing and continuous function of journey time. An earlier proof of uniqueness (Khmelnitsky, 2000) showed that the optimal driving speed decreases when journey time increases. A subsequent constructive proof (Albrecht et al., 2013a, 2015c) used a local energy minimization principle to find optimal switching points and show explicitly that the optimal driving speed is a strictly decreasing and continuous function of journey time. Our new derivation of the key formula also uses the local energy minimization principle and depends on the following observations. If no speed limits are imposed the optimal strategy consists of a finite sequence of phases with only five permissible control modes. By considering all basic control subsequences and subdividing the track into suitably chosen fixed segments we show that the key formula is valid on each individual segment. The formula is extended to the entire journey by summation. The veracity of the formula is demonstrated with an elementary but realistic example.

Simultaneous passenger train routing and timetabling using an efficient train-based Lagrangian relaxation decomposition

- Transportation Research Part B: Methodological---2016---Wenliang Zhou,Hualiang Teng

This paper focuses on the simultaneous passenger train routing and timetabling problem on the rail network consisting of both unidirectional and bidirectional tracks using an efficient train-based Lagrangian relaxation decomposition. We first build an integer linear programming model with many 0–1 binary and non-negative integer decision variables, after then reformulate it as a train path-choice model for providing an easier train-based Lagrangian relaxation decomposition mechanism based on the construction of space-time discretized network extending from node-cell-based rail network. Moreover, through reformulating safety usage interval restrictions with a smaller number of constraints in this reformulated model, the train-based decomposition needs fewer Lagrangian multipliers to relax these constraints. On the basis of this decomposition, a solving framework including a heuristic algorithm is proposed to simultaneously optimize both the dual and feasible solutions. A set of numerical experiments demonstrate the proposed Lagrangian relaxation decomposition approach has better performances in terms of minimizing both train travel time and computational times.

Discrete choice with spatial correlation: A spatial autoregressive binary probit model with endogenous weight matrix (SARBP-EWM)

- Transportation Research Part B: Methodological---2016---Yiwei Zhou,Xiaokun Wang,José Holguín-Veras

Discrete choice modeling is widely applied in transportation studies. However, the need to consider correlation between observations creates a challenge. In spatial econometrics, a spatial lag term with a predefined weight matrix is often used to capture such a correlation. In most previous studies, the weight matrix is assumed to be exogenous. However, this assumption is invalid in many cases, leading to biased and inconsistent parameter estimates. Although some attempts have been made to address the endogenous weight matrix issue, none has focused on discrete choice modeling. This paper fills an existing gap by developing a Spatial Autoregressive Binary Probit Model with Endogenous Weight Matrix (SARBP-EWM). The SARBP-EWM model explicitly considers the endogeneity by using two equations whose error terms are correlated. Markov Chain Monte Carlo (MCMC) method is used to estimate the model. Model validation with simulated data shows that the model parameters can converge to their true values and the endogenous weight matrix can be reliably recovered. The model is then applied to a simplified firm relocation choice problem, assuming that similar size firms influence one another. The model quantifies the peer effect, and takes into consideration other independent variables including industry type and population density. The estimation results suggest that peer influence among firms indeed affect their relocation choices. The application results offer important insights into business location choice and can inform future policy making. The sample size for applying the model is currently limited to hundreds of observations. This paper contributes to the existing literature on discrete choice modeling and spatial econometrics. It provides a new tool to discover spatial correlations that are hidden in a wide range of transportation issues, such as land development, location choice, and various travel behavior. Those hidden spatial correlations are otherwise difficult to identify and estimation results may be biased. Establishing a new model that explicitly considers endogenous weight matrix and applying the model to a real life transportation issue represent a significant contribution to the body of literature.

High-speed rail and air transport competition and cooperation: A vertical differentiation approach

- Transportation Research Part B: Methodological---2016---Wenyi Xia,Anming Zhang

This paper considers vertical differentiation between air transport and high-speed rail (HSR) with different ranges of travel distance to analyze the air-HSR competition effects on fares, traffic volumes and welfare, as well as the conditions under which air-HSR cooperation is welfare-enhancing. The analysis is conducted in a hub-and-spoke network with a network carrier, an HSR operator, and a spoke airline, taking into account potential hub airport capacity constraint. We find that air-HSR competition in the connecting market may result in the network airline charging an excessively high price in the HSR-inaccessible market. This effect is present even when the HSR-inaccessible route is a duopoly-airline market. On the other hand, air-HSR cooperation increases fares in the connecting market, and an improvement in rail speed or air-HSR connecting time reduces airfare on the routes where HSR and the airline compete. When the airline cannot serve all the markets due to limited hub airport capacity, it would withdraw from the market in which it has less competitive advantage over HSR. Finally, air-HSR cooperation is more likely to be welfare-improving when the hub airport is capacity constrained, and when either air transport or HSR exhibits strong economies of traffic density.

The key principles of optimal train control—Part 1: Formulation of the model, strategies of optimal type, evolutionary lines, location of optimal switching points

- Transportation Research Part B: Methodological---2016---Amie Albrecht,Phil Howlett,Peter Pudney,Xuan Vu,Peng Zhou

We discuss the problem of finding an energy-efficient driving strategy for a train journey on an undulating track with steep grades subject to a maximum prescribed journey time. We review the state-of-the-art and establish the key principles of optimal train control for a general model with continuous control. The model with discrete control is not considered. We assume only that the tractive and braking control forces are bounded by non-increasing speed-dependent magnitude constraints and that the rate of energy dissipation from frictional resistance is given by a non-negative strictly convex function of speed. Partial cost recovery from regenerative braking is allowed. The cost of the strategy is the mechanical energy required to drive the train. Minimising the mechanical energy is an effective way of reducing the fuel or electrical energy used by the traction system. The paper is presented in two parts. In Part 1 we discuss formulation of the model, determine the characteristic optimal control modes, study allowable control transitions, establish the existence of optimal switching points and consider optimal strategies with speed limits. We find algebraic formulae for the adjoint variables in terms of speed on track with piecewise-constant gradient and draw phase plots of the associated optimal evolutionary lines for the state and adjoint variables. In Part 2 we will establish important integral forms of the necessary conditions for optimal switching, find general bounds on the positions of the optimal switching points, justify the local energy minimization principle and show how these ideas are used to calculate optimal switching points. We will prove that an optimal strategy always exists and use a perturbation analysis to show the strategy is unique. Finally we will discuss computational techniques in realistic examples with steep gradients and describe typical optimal strategies for a complete journey.

The key principles of optimal train control—Part 2: Existence of an optimal strategy, the local energy minimization principle, uniqueness, computational techniques

- Transportation Research Part B: Methodological---2016---Amie Albrecht,Phil Howlett,Peter Pudney,Xuan Vu,Peng Zhou

We discuss the problem of finding an energy-efficient driving strategy for a train journey on an undulating track with steep grades subject to a maximum prescribed journey time. In Part 1 of this paper we reviewed the state-of-the-art and established the key principles of optimal train control for a general model with continuous control. We assumed only that the tractive and braking control forces were bounded by non-increasing speed-dependent magnitude constraints and that the rate of energy dissipation from frictional resistance was given by a non-negative strictly convex function of speed. Partial cost recovery from regenerative braking was allowed. Our aim was to minimize the mechanical energy required to drive the train. We examined the characteristic optimal control modes, studied allowable control transitions and established the existence of optimal switching points. We found algebraic formulae for the adjoint variables in terms of speed on track with piecewise-constant gradient and drew phase plots of the associated optimal evolutionary lines for the state and adjoint variables. In Part 2 we will establish integral forms of the necessary conditions for optimal switching, find general bounds on the positions of the optimal switching points, justify an extended local energy minimization principle and show how these ideas can be used to calculate the optimal strategy. We prove that an optimal strategy always exists and use a perturbation analysis to show that the optimal strategy is unique. Finally we discuss computation of optimal switching points in two realistic examples with steep grades and describe the optimal control strategies and corresponding speed profiles for a complete journey with several different allowed journey times. In practice the strategies described here have been shown to reduce the costs of energy used by as much as 20%.

Special issue in Transportation Research Part B – Shipping, port and maritime logistics

- Transportation Research Part B: Methodological---2016---Michael G.H. Bell,Qiang Meng

2016

Multi-period yard template planning in container terminals

- Transportation Research Part B: Methodological---2016---Lu Zhen,Zhou Xu,Kai Wang,Yi Ding

This paper is about yard management in container ports. As a tactical level decision-making tool in a port, a yard template determines the assignment of spaces (subblocks) in a yard for arriving vessels, which visit the port periodically. The objective of yard template planning is to minimize the transportation cost of moving containers around the yard. To handle yard template planning, a mixed integer programming model is proposed that also takes into account traffic congestion in the yard. A further complication is that the cycle time of the vessels' periodicities is not uniform and varies among them, perhaps being one week, ten days, or two weeks, etc. However, this multiple cycle time of the periodicities of vessel arrival patterns, which complicates the yard template decision, is also considered in the model. Moreover, a local branching based solution method and a Particle Swarm Optimization based solution method are developed for solving the model. Numerical experiments are also conducted to validate the effectiveness of the proposed model, which can save around 24% of the transportation costs of yard trucks when compared with the commonly used First-Come-First-Served decision rule. Moreover, the proposed solution methods can not only solve the proposed model within a reasonable time, but also obtain near-optimal results with about 0.1–2% relative gap.

Bi-objective optimization for the container terminal integrated planning

- Transportation Research Part B: Methodological---2016---Ming Liu,Chung-Yee Lee,Zizhen Zhang,Chengbin Chu

In this paper, we study the joint optimization of the tactical berth allocation and the tactical yard allocation in container terminals, which typically consist of berth side and yard side operations. The studied two objectives are: (i) the minimization of the violation of the vessels' expected turnaround time windows with the purpose of meeting the timetables published by shipping liners, and (ii) the minimization of the total yard transportation distance with the aim to lower terminal operational cost. We propose a bi-objective integer program which can comprehensively address the import, export and transshipment tasks in port daily practice. Traditionally, a container transshipment task is performed as a couple of import and export tasks, called indirect-transshipment mode, in which the transit container are needed to be temporally stored in the yard. As the way of transferring containers directly from the incoming vessel to the outgoing vessel, called direct-transshipment mode, has potential to save yard storage resources, the proposed model also incorporates both indirect- and direct-transshipment modes. To produce Pareto solutions efficiently, we devise heuristic approaches. Numerical experiments have been conducted to demonstrate the efficiency of the approaches.

Finding potential hub locations for liner shipping

- Transportation Research Part B: Methodological---2016---Zhuo Sun,Jianfeng Zheng

The current models for hub location problems are unable to find potential hub locations in uncharted areas that currently have no port. To explore hub locations that are not selected from the present ports, this study proposes a two-stage method to address this gap in knowledge. A concave cost multicommodity network flow model is solved in the first stage to obtain container traffic in waterways. Then, in the second stage, a hubbing probability is evaluated for each node to indicate potential hub locations. A case study including emerging Arctic routes is provided to demonstrate this method.

Real-time schedule recovery in liner shipping service with regular uncertainties and disruption events

- Transportation Research Part B: Methodological---2016---Chen Li,Xiangtong Qi,Dongping Song

This paper studies real-time schedule recovery policies for liner shipping under various regular uncertainties and the emerging disruption event that may delay a vessel from its planned schedule. The aim is to recover the affected schedule in the most efficient way. One important contribution of this work is to explicitly distinguish two types of uncertainties in liner shipping, and propose different strategies to handle them. The problem can be formulated as a multi-stage stochastic control problem that minimizes the total expected fuel cost and delay penalty. For regular uncertainties that can be characterized by appropriate probabilistic models, we develop the properties of the optimal control policy; then we show how an emerging disruption may change the control policies. Numerical studies demonstrate the advantages of real-time schedule recovery policies against some typical alternatives.

A green intermodal service network design problem with travel time uncertainty

- Transportation Research Part B: Methodological---2016---Emrah Demir,Wolfgang Burgholzer,Martin Hrušovský,Emel Arıkan,Werner Jammernegg,Tom Van Woensel

In a more and more competitive and global world, freight transports have to overcome increasingly long distances while at the same time becoming more reliable. In addition, a raising awareness of the need for environmentally friendly solutions increases the importance of transportation modes other than road. Intermodal transportation, in that regard, allows for the combination of different modes in order to exploit their individual advantages. Intermodal transportation networks offer flexible, robust and environmentally friendly alternatives to transport high volumes of goods over long distances. In order to reflect these advantages, it is the challenge to develop models which both represent multiple modes and their characteristics (e.g., fixed-time schedules and routes) as well as the transhipment between these transportation modes. In this paper, we introduce a Green Intermodal Service Network Design Problem with Travel Time Uncertainty (GISND-TTU) for combined offline intermodal routing decisions of multiple commodities. The proposed stochastic approach allows for the generation of robust transportation plans according to different objectives (i.e., cost, time and greenhouse gas (GHG) emissions) by considering uncertainties in travel times as well as demands with the help of the sample average approximation method. The proposed methodology is applied to a real-world network, which shows the advantages of stochasticity in achieving robust transportation plans.

Measuring reliability of transportation networks using snapshots of movements in the network – An analytical and empirical study

- Transportation Research Part B: Methodological---2016---David Gillen,Hamed Hasheminia

In this paper we introduce an analytical framework based on discrete Likelihood Maximization techniques that provides estimates of operational level data of Queuing models and Transportation networks based on snapshots of data on movements of commodities in a network. We apply our methodology to detailed data on movements of containers imported from S.E. Asian ports to marine ports on the west coast of Canada, unloaded at these ports, moved to rail cars, and transported by rail to destinations in U.S. and Canada. We show how one can estimate operational level parameters such as the number of servers at the ports, schedules of departure and capacity of trains, and even speed of trains based on only snapshots of container movements in the network. Subsequently, we were able to calibrate the entire inter-continental transportation network, were able to identify the sources of variability in the network and were able to measure the reliability of the network to shocks.

Gap-based transit assignment algorithm with vehicle capacity constraints: Simulation-based implementation and large-scale applicationAuthor-Name: Verbas, Ömer

- Transportation Research Part B: Methodological---2016---Hani S. Mahmassani,Michael F. Hyland

This paper presents a gap-based solution method for the time-dependent transit assignment problem with vehicle capacity constraints. A two-level, simulation-based methodology is proposed, which finds the least cost hyperpaths at the upper level and performs the assignment of transit travelers on the hyperpaths at the lower level. The detailed simulation of travelers and vehicles at the lower level allows modelers to capture transit network complexities such as transfers/missed connections, receiving a seat/standing and boarding/being rejected to board. This ‘hard’ implementation of vehicle capacity constraints at the lower level is aggregated into ‘soft constraints’ at the upper level for the least cost hyperpath calculation. Using a gap-based assignment procedure, user equilibrium is reached on large-scale networks in a computationally efficient manner. The algorithm is tested on the large-scale Chicago Transit Authority network. The gap-based approach outperforms the commonly used method of successive averages approach in terms of rate of convergence and quality of results. Furthermore, sensitivity analyses with respect to network parameters illustrate the robustness of the proposed two-level solution procedure.

Modeling the first train timetabling problem with minimal missed trains and synchronization time differences in subway networks

- Transportation Research Part B: Methodological---2016---Liujiang Kang,Xiaoning Zhu,Huijun Sun,Jakob Puchinger,Mario Ruthmair,Bin Hu

Urban railway transportation organization is a systematic activity that is usually composed of several stages, including network design, line planning, timetabling, rolling stock and staffing. In this paper, we study the optimization of first train timetables for an urban railway network that focuses on designing convenient and smooth timetables for morning passengers. We propose a mixed integer programming (MIP) model for minimizing train arrival time differences and the number of missed trains, i.e., the number of trains without transfers within a reasonable time at interchange stations as an alternative to minimize passenger transfer waiting times. This is interesting from the operator's point of view, and we show that both criteria are equivalent. Starting from an intuitive model for the first train transfer problem, we then linearize the non-linear constraints by utilizing problem specific knowledge. In addition, a local search algorithm is developed to solve the timetabling problem. Through computational experiments involving the Beijing subway system, we demonstrate the computational efficiency of the exact model and the heuristic approach. Finally, three practical suggestions are proposed for the operation and management of the urban railway transit system.

Bus network structure and mobility pattern: A monocentric analytical approach on a grid street layout

- Transportation Research Part B: Methodological--2016---Hugo Badia,Miquel Estrada,Francesc Robusté

This study discusses which transit network structure is the best option to serve urban mobility. As a consequence of the evolution of urban form, cities have undergone a process of dispersion of their activities that has caused a change in mobility needs in the last few decades. Mobility networks and services should progressively adapt to the new demand patterns, especially the bus transit network, which has more flexibility to absorb the changes. We compare four base transit network structures: a radial scheme, a direct trip-based network, and a transfer-based system by means of either a complete grid or a hybrid structure. An analytical model is used to estimate the behavior of these structures for idealized monocentric mobility patterns with several degrees of concentration. The purpose is to determine the right range of situations for the applicability of each bus transit structure, and to determine guidelines about the transit network planning process. It turns out that the best structure is not always the same, and depends on the mobility spatial pattern. A radial network is the best alternative in very concentrated cities; however, a direct trip-based system is more suitable for intermediate degrees of dispersion. A transfer-based structure is the best option when the activities are more decentralized. Nevertheless, the decentralization degree that justifies a specific transit structure is not constant. This degree depends on the characteristics of the city, transport technology and users.

A two-step linear programming model for energy-efficient timetables in metro railway networks

- Transportation Research Part B: Methodological--2016---Shuvomoy Das Gupta,J. Kevin Tobin,Lacra Pavel

In this paper we propose a novel two-step linear optimization model to calculate energy-efficient timetables in metro railway networks. The resultant timetable minimizes the total energy consumed by all trains and maximizes the utilization of regenerative energy produced by braking trains, subject to the constraints in the railway network. In contrast to other existing models, which are NP-hard, our model is computationally the most tractable one being a linear program. We apply our optimization model to different instances of service PES2-SFM2 of line 8 of Shanghai Metro network spanning a full service period of one day (18 h) with thousands of active trains. For every instance, our model finds an optimal timetable very quickly (largest runtime being less than 13 s) with significant reduction in effective energy consumption (the worst case being 19.27%). Code based on the model has been integrated with Thales Timetable Compiler - the industrial timetable compiler of Thales Inc that has the largest installed base of communication-based train control systems worldwide.

An indirect latent informational conformity social influence choice model: Formulation and case study

- Transportation Research Part B: Methodological--2016---Michael Maness,Cinzia Cirillo

The current state-of-the-art in social influence models of travel behavior is conformity models with direct benefit social influence effects; indirect effects have seen limited development. This paper presents a latent class discrete choice model of an indirect informational conformity hypothesis. Class membership depends on the proportion of group members who adopt a behavior. Membership into the “more informed” class causes taste variation in those individuals thus making adoption more attractive. Equilibrium properties are derived for the informational conformity model showing the possibility of multiple equilibria but under different conditions than the direct-benefit formulations. Social influence elasticity is computed for both models types and non-linear elasticity behavior is represented. Additionally, a two-stage control function is developed to obtain consistent parameter estimates in the presence of an endogenous class membership model covariate that is correlated with choice utility unobservables. The modeling framework is applied in a case study on social influence for bicycle ownership in the United States. Results showed that "more informed" households had a greater chance of owning a bike due to taste variation. These households were less sensitive to smaller home footprints and limited incomes. The behavioral hypothesis of positive preference change due to information transfer was confirmed. Observed ownership share closely matched predicted local-level equilibrium in some metropolitan areas, but the model was unable to fully achieve the expected prediction rates within confidence intervals. The elasticity of social influence was found to range locally from about 0.5% to 1.0%.

Strategic investments in accessibility under port competition and inter-regional coordination

- Transportation Research Part B: Methodological---2016---Yulai Wan,Leonardo J. Basso,Anming Zhang

This paper analyzes the incentives for and welfare implications of collaboration among local governments in landside port accessibility investment. In particular, we consider two seaports with their respective captive markets and a common inland market for which the ports compete. The ports and the inland belong to three independent regional governments, each making investment decisions on accessibility for its own region. We find that there is a conflict of interest between the port governments and inland government in terms of their jointly making accessibility investment decisions, and that each region's preference over various coalitions is highly affected by ownership type of the competing ports. For public ports, the inland may compensate the port regions to achieve the grand coalition that maximizes total welfare but requires a sizable investment in the port regions. For private ports, however, the port regions benefit from coordinating with the inland and hence may be able to compensate the inland to form the grand coalition.

Exploring alternative service schemes for busy transit corridors

- Transportation Research Part B: Methodological---2016---Weihua Gu,Zahra Amini,Michael J. Cassidy

Transit systems in which buses or trains always visit each and every stop along corridors are compared against those that feature two alternative vehicle-dispatching schemes. The alternatives entail so-called skip-stop and express/local services. Continuous models found in the literature are expanded so that the alternatives could be compared under a wider array of options. Comparisons are separately drawn for systems that feature buses, BRT and metro-rail trains, both for cities that are wealthy and for those that are not. Idealizations in regard to travel demand and route symmetry are assumed in pursuit of insights useful for high-level planning.

A method of integrating correlation structures for a generalized recursive route choice model

- Transportation Research Part B: Methodological---2016---Tien Mai

We propose a way to estimate a generalized recursive route choice model. The model generalizes other existing recursive models in the literature, i.e., (Fosgerau et al., 2013b; Mai et al., 2015c), while being more flexible since it allows the choice at each stage to be any member of the network multivariate extreme value (network MEV) model (Daly and Bierlaire, 2006). The estimation of the generalized model requires defining a contraction mapping and performing contraction iterations to solve the Bellman's equation. Given the fact that the contraction mapping is defined based on the choice probability generating functions (CPGF) (Fosgerau et al., 2013b) generated by the network MEV models, and these CPGFs are complicated, the generalized model becomes difficult to estimate. We deal with this challenge by proposing a novel method where the network of correlation structures and the structure parameters given by the network MEV models are integrated into the transport network. The approach allows to simplify the contraction mapping and to make the estimation practical on real data.

Introducing relations between activities and goods consumption in microeconomic time use models

- Transportation Research Part B: Methodological---2016---Sergio R. Jara-Díaz,Sebastian Astroza,Chandra R. Bhat,Marisol Castro

We present a microeconomic model for time use and consumption for workers with an improved treatment of the (technical) relations between goods and time. In addition to the traditional time and income constraints, an improved set of restrictions involving explicit relations between consumption of goods and time assigned to activities is included in two versions. In each version, a system of equations involving a subset of the consumer's decision variables is obtained, including (1) work time, (2) activities that are assigned more time than the minimum, and (3) goods that are consumed above the minimum. The system cannot be solved explicitly in the endogenous decision variables but is used to set a stochastic system for econometric estimation through maximum likelihood. The models are applied to analyze weekly time use and consumption data from Netherlands for year 2012. The results obtained by this new "goods and time" framework are compared with previous research in terms of the value of leisure and the value of work, showing substantial differences in the valuation of time.

Reliability-based stochastic transit assignment: Formulations and capacity paradox

- Transportation Research Part B: Methodological---2016---Y. Jiang,W.Y. Szeto

This study develops link-based and approach-based variational inequality (VI) formulations for the frequency-based transit assignment with supply uncertainty, where link flows and flow on each outgoing link from each node are decision variables, respectively. Both the mean and variance of travel cost, including the covariance of in-vehicle travel costs, are captured in both formulations. To address the covariance of in-vehicle travel costs between different links on the same transit line, an augmented route-section network representation is developed, allowing us to apply the dynamic programming method to compute the value of the mapping function of the VI. The approach-based formulation can be solved by an extragradient method that only requires mild assumptions for convergence. It is found that the number of links carrying flow and equilibrium cost can be underestimated if supply uncertainty is not considered.

The impact of travel time variability and travelers' risk attitudes on the values of time and reliability

- Transportation Research Part B: Methodological---2016---Mickael Beaud,Thierry Blayac,Maïté Stéphan

In this paper, we derive implementable measures of travelers' willingness to pay to save travel time (vot) and to improve the reliability (vor) of a given trip. We set out a simple microeconomic model of transport mode choice in which each trip is fully characterized by its price and the statistical distribution of its random travel time, assuming that travelers have expected utility preferences over the latter. We then explore how the vot and vor are affected by the statistical distribution of travel time and by travelers' preferences towards travel time variability.

Capacitated transit service network design with boundedly rational agents

- Transportation Research Part B: Methodological---2016---Jiangtao Liu,Xuesong Zhou

This paper proposes a new alternative modeling framework to systemically account for boundedly rational decision rules of travelers in a dynamic transit service network with tight capacity constraints. Within a time-discretized space-time network, the time-dependent transit services are characterized by traveling arcs and waiting arcs with constant travel times. Instead of using traditional flow-based formulations, an agent-based integer linear formulation is proposed to represent boundedly rational decisions under strictly imposed capacity constraints, due to vehicle carrying capacity and station storage capacity. Focusing on a viable and limited sets of space-time path alternatives, the proposed single-level optimization model can be effectively decomposed to a time-dependent routing sub-problem for individual agents and a knapsack sub-problem for service arc selections through the Lagrangian decomposition. In addition, several practically important modeling issues are discussed, such as dynamic and personalized transit pricing, passenger inflow control as part of network restraint strategies, and penalty for early/late arrival. Finally, numerical experiments are performed to demonstrate the methodology and computational efficiency of our proposed model and algorithm.

Setting lines frequency and capacity in dense railway rapid transit networks with simultaneous passenger assignment

- Transportation Research Part B: Methodological---2016---David Canca,Eva Barrena,Alicia De-Los-Santos,José Luis Andrade-Pineda

We propose a Mixed Integer Non-Linear Programming (MINLP) model in order to determine optimal line frequencies and capacities in dense railway rapid transit (RRT) networks in which typically several lines can run over the same open tracks. Given a certain demand matrix, the model determines the most appropriate frequency and train capacity for each line taking into account infrastructure capacity constraints, allocating lines to tracks while assigning passengers to lines. The service provider and the user points of view are simultaneously taken into account. The first one is considered by selecting the most convenient set of frequencies and capacities and routing passengers from their origins to their destinations while minimizing the average trip time. The second one by minimizing operation, maintenance and fleet acquisition costs. Due to the huge number of variables and constraints appearing in real size instances, a preprocessing phase determining the best k-paths linking origin and destination stations is followed. Then, the best paths are used to define sparse index sets in order to drastically reduce the size of the problem. As illustration, the model is applied to a simplified version of the Madrid Metropolitan Railway network.

Joint design of parking capacities and fleet size for one-way station-based carsharing systems with road congestion constraints

- Transportation Research Part B: Methodological---2016---Lu Hu,Yang Liu

This paper formulates one-way station-based carsharing systems as a mixed queuing network model and proposes a profit-maximization model for the joint design of fleet size and station capacities. We explicitly model the road congestion by formulating each route as a queue where the travel time is an increasing function of the state. The booking process is also modeled in the rental station queue so that the efficiency loss caused by the reservation policy can be captured. The mixed queuing network falls into Baskett, Chandy, Muntz and Palacios (BCMP) networks with unique product-form equilibrium distribution. We derive the asymptotic behavior as the parking capacities and fleet size grows, and show that the performance of carsharing systems will be proportionally bounded by that of the bottleneck route. The exact mean value analysis (MVA) algorithm and the approximate Schweitzer-Bard mean value analysis (SB-MVA) algorithm are extended here to solve networks with different sizes. The numerical experiments reveal some interesting findings: (1) The higher customer service rate (the smaller pick-up time window) will generate the optimal design with lower parking capacities and lower fleet size; (2) Neglecting the efficiency loss due to reservation will lead to an overestimate of the profit and other system performances as well; and (3) Given different levels of congestion on the existing road network (the non-shared car traffic), the net revenue is maximized when the existing traffic congestion is moderate.

Bus bunching along a corridor served by two lines

- Transportation Research Part B: Methodological---2016---Jan-Dirk Schmöcker,Wenzhe Sun,Achille Fonzone,Ronghui Liu

Headway fluctuations and "bus bunching" are well known phenomena on many bus routes where an initial delay to one service can disturb the whole schedule due to resulting differences in dwell times of subsequent buses at stops. This paper deals with the influence of a frequent but so far largely neglected characteristic of bus networks on bus bunching, that is the presence of overtaking and common lines. A set of discrete state equations is implemented to obtain the departure times of a group of buses following the occurrence of an exogenous delay to one bus at a bus stop. Two models are distinguished depending on whether overtaking at stops is possible or not. If two buses board simultaneously and overtaking is not possible, passengers will board the front bus. If overtaking is possible, passengers form equilibrium queues in order to minimise their waiting times. Conditions for equilibrium queues among passengers with different choice sets are formulated. With a case study we then illustrate that, if overtaking is not allowed, the presence of common lines worsens the service regularity along the corridor. Conversely, common lines have positive effects when overtaking is possible. We suggest hence that appropriate network design is important to reduce the negative effects of delay-prone lines on the overall network performance.

Modeling the decoy effect with context-RUM Models: Diagrammatic analysis and empirical evidence from route choice SP and mode choice RP case studies

- Transportation Research Part B: Methodological---2016---Cristian Guevara,Mitsuyoshi Fukushi

Evidence outside transportation has suggested that the introduction of a decoy to the choice-set could increase the share of other alternatives. This evidence breaks the regularity assumption, which is at the root of the classical Random Utility Maximization (RUM) model with utilities that ignore the choice context. This article assesses the suitability of various context-RUM choice models that could overcome this limitation. For this we use a diagrammatic analysis, as well as Stated Preference (SP) and Revealed Preference (RP) transportation choice evidence. We begin confirming that the reported decoy outcomes cannot be replicated with the classical RUM models and that such a goal could be achieved instead using a set of five context-RUM models. We then show, for the first time, that the Asymmetrically Dominated (AD) and Compromise (CP) decoy effects were present in an SP route choice setting. We also show that, for a subset of individuals, the relative strength of the different decoy types was coherent with a Data Generation Process (DGP) defined by the Random Regret Minimization (RRM) or by the Regret by Aspects (RBA) parsimonious models. Then, we use cross-validation analysis where we found that RRM and RBA were superior to a classical Logit for all decoy types. Nevertheless, the ad-hoc Emergent Value (EV) model was consistently superior to all models suggesting that, although the parsimonious models may in theory replicate all decoy types, they seem to still make an incomplete representation of the DGP behind the overall decoy effect. We finally consider an RP mode choice experiment with which we detect, for the first time, an AD decoy effect in this choice setting. We also use this experiment to illustrate how to handle the decoy phenomena in a real context with various alternatives and variables. The article concludes summarizing the main contributions of this research and suggesting future lines of investigation for it.

Empirical analysis and simulation of the concave growth pattern of traffic oscillations

- Transportation Research Part B: Methodological---2016---Junfang Tian,Rui Jiang,Bin Jia,Ziyou Gao,Shoufeng Ma

This paper has investigated the growth pattern of traffic oscillations in the NGSIM vehicle trajectories data, via measuring the standard deviation of vehicle velocity involved in oscillations. We found that the standard deviation of the velocity increases in a concave way along vehicles in the oscillations. Moreover, all datasets collapse into a single concave curve, which indicates a universal evolution law of oscillations. A comparison with traffic experiment shows that the empirical and the experimental results are highly compatible and can be fitted by a single concave curve, which demonstrates that qualitatively the growth pattern of oscillations is not affected by type of bottleneck and lane changing behavior. We have shown theoretically that small disturbance with an angular frequency ω increases in a convex way in the initial stage in the traditional models presuming a unique relationship between speed and density, which obviously deviates from our findings. Simulations show that stochastic models in which the traffic state dynamically spans a 2D region in the speed-spacing plane can qualitatively or even quantitatively reproduce the concave growth pattern of traffic oscillations.

Testing for regularity and stochastic transitivity using the structural parameter of nested logit

- Transportation Research Part B: Methodological---2016---Richard Batley,Stephane Hess

We introduce regularity and stochastic transitivity as necessary and well-behaved conditions respectively, for the consistency of discrete choice preferences with the Random Utility Model (RUM). For the specific case of a three-alternative nested logit (NL) model, we synthesise these conditions in the form of a simple two-part test, and reconcile this test with the conventional zero-one bounds on the structural ('log sum') parameter within this model, i.e. $0 < \theta \leqslant 1$, where θ denotes the structural parameter. We show that, whilst regularity supports the lower bound of zero, moderate and strong stochastic transitivity may, for some preference orderings, give rise to a lower bound greater than zero, i.e. impose a constraint $l \leqslant \theta$, where $l > 0$. On the other hand, we show that neither regularity nor stochastic transitivity constrain the upper bound at one. Therefore, if the conventional zero-one bounds are imposed in model estimation, preferences which violate regularity and/or stochastic transitivity may either go undetected (if the 'true' structural parameter is less than zero) and/or be unknowingly admitted (if the 'true' lower bound is greater than zero), and preferences which comply with regularity and stochastic transitivity may be excluded (if the 'true' upper bound is greater than one). Against this background, we show that imposition of the zero-one bounds may compromise model fit, inferences of willingness-to-pay, and forecasts of choice behaviour. Finally, we show that where the 'true' structural parameter is negative (thereby violating RUM – at least when choosing the 'best' alternative), positive starting values for the structural parameter in estimation may prevent the exposure of regularity and stochastic transitivity failures.

A multiphase optimal control method for multi-train control and scheduling on railway lines

- Transportation Research Part B: Methodological---2016---Hongbo Ye,Ronghui Liu

We consider a combined train control and scheduling problem involving multiple trains in a railway line with a predetermined departure/arrival sequence of the trains at stations and meeting points along the line. The problem is formulated as a multiphase optimal control problem while incorporating complex train running conditions (including undulating track, variable speed restrictions, running resistances, speed-dependent maximum tractive/braking forces) and practical train operation constraints on departure/arrival/running/dwell times. Two case studies are conducted. The first case illustrates the control and scheduling problem of two trains in a small artificial network with three nodes, where one train follows and overtakes the other. The second case optimises the control and timetable of a single train in a subway line. The case studies demonstrate that the proposed framework can provide an effective approach in solving the combined train scheduling and control problem for reducing energy consumption in railway operations.

A polynomial-time algorithm for sailing speed optimization with containership resource sharing

- Transportation Research Part B: Methodological---2016---Shuaian Wang,Xinchang Wang

The sailing speed optimization problem aims to determine the optimal cruising speeds of ships by balancing the number of ships required on services, the fuel consumption, and the level of service provided for customers. The level of service can be incorporated into a sailing speed optimization model from the perspective of supply chain management or from the perspective of shipping lines. We design a polynomial-time algorithm workable to solve the two models based on bi-section search methods. The novelties of the algorithm include constructing a new parameter on which the bi-section search will be executed and deriving a near-optimal solution by taking advantage of the problem structure. We also provide theoretical results that guarantee the validity of the polynomial-time algorithm.

New insights and improvements of using paired alternative segments for traffic assignmentAuthor-Name: Xie, Jun

- Transportation Research Part B: Methodological---2016---Chi Xie

The recent literature observes that the development of advanced algorithms for the traffic assignment problem (TAP) heavily relies on the proper use of some specific topological structures. This paper focuses on discussing a particular topological structure named paired alternative segment (PAS), which consists of two path segments sharing the same starting and ending nodes but no other common nodes. We first present two alternative conditions that establish an equivalency relationship between user equilibrium (UE) flows and PAS structures. Starting from the traffic assignment method by paired alternative segments (TAPAS), we then examine the utilization of PASs for TAP and explore some algorithmic and implementation issues, which leads to the birth of an improved TAPAS procedure (termed iTAPAS in this paper). Compared to the original TAPAS, iTAPAS enhances the algorithmic efficiency in two aspects: (1) a more effective PAS identification method is used; (2) each PAS is set as being associated with only one origin in the UE-finding process. Some analytical results based on the new PAS identification method are presented to justify the convergence and efficiency of iTAPAS. A simplified post-process procedure is also presented to achieve the proportionality for iTAPAS. Numerical results obtained from applying the new and original algorithms for several large networks reveal that iTAPAS is nearly two times faster than TAPAS in achieving highly precise link flow solutions while it is practically identical to TAPAS in finding stable path flow solutions that meet consistency and proportionality.

Rescheduling a metro line in an over-crowded situation after disruptions

- Transportation Research Part B: Methodological---2016---Yuan Gao,Leo Kroon,Marie Schmidt,Lixing Yang

In the case of a metro disruption, the planned timetable cannot be operated and a large number of passengers are left stranded in the stations. When the disruption is over, some stations may be skipped in the recovery period, which speeds up the circulation of trains and makes the number of stranded passengers reduce faster. Considering an over-crowded and time-dependent passenger flow, this paper proposes an optimization model to reschedule a metro line. To achieve a balance between theoretical validity and computational convenience, the optimization model is decomposed, and an iterative algorithm is proposed to solve the model. Numerical experiments based on the Beijing Metro are carried out, the results of which verify the effectiveness and efficiency of our method.

Dynamic collective routing using crowdsourcing data

- Transportation Research Part B: Methodological---2016---Siyuan Liu,Qiang Qu

With the development of information technology, crowdsourcing data from a crowd of cooperative vehicles and online social platforms have been becoming available. The crowdsourcing data, reflecting real-time context of road segments in transportation systems, enable vehicles to be routed adaptively in uncertain and dynamic traffic environments. We consider the problem of adaptively routing a fleet of cooperative vehicles within a road network. To tackle this problem, we first propose a Crowdsourcing Dynamic Congestion Model. The model is based on topic-aware Gaussian Process considering the crowdsourced data collected from social platforms and probing vehicle traces that can effectively characterize both the dynamics and the uncertainty of road conditions. Our model is efficient and thus facilitates real-time adaptive routing in the face of uncertainty. Using this congestion model, we develop efficient algorithms for non-myopic adaptive routing to minimize the collective travel time of all vehicles in the entire transportation system. A key property of our approach is the ability to efficiently reason about the long-term value of exploration, which enables collectively balancing the exploration/exploitation trade-off for entire fleets of vehicles. Our approach is validated by real-life traffic and geo-tagged social network data from two large cities. Our congestion model is shown to be effective in modeling dynamic congestion conditions. Our routing algorithms also generate significantly faster routes compared to standard baselines, and approximate optimal performance compared to an omniscient routing algorithm. We also present the results from a preliminary field study, which showcases the efficacy of our approach.

Modeling the morning commute for urban networks with cruising-for-parking: An MFD approach

- Transportation Research Part B: Methodological---2016---Wei Liu,Nikolas Geroliminis

This study focuses on the morning commute problem with explicit consideration of cruising-for-parking, and its adverse impacts on traffic congestion. The cruising-for-parking is modeled through a dynamic aggregated traffic model for networks: the Macroscopic Fundamental Diagram (MFD). Firstly, we formulate the commuting equilibrium in a congested downtown network where travelers have to cruise for curbside parking spaces. The cruising-for-parking would yield longer trip distance and smaller network outflow, and thus can induce severe congestion and lengthen the morning peak. We then develop a dynamic model of pricing for the network to reduce total social cost, which includes cruising time cost, moving time cost (moving or in-transit time, which is the duration during which vehicles move close to the destination but do not cruise for parking yet), and schedule delay cost. We show that under specific assumptions, at the system optimum, the downtown network should be operating at the maximum production of its MFD. However, the cruising effect is not fully eliminated. We also show that the time-dependent toll to support the system optimum has a different shape than the classical fine toll in Vickrey's bottleneck model. In the end, analytical results are illustrated and verified with numerical experiments.

Designing robust schedule coordination scheme for transit networks with safety control margins

- Transportation Research Part B: Methodological---2016---Weitiao Wu,Ronghui Liu,Wenzhou Jin

We propose a robust schedule coordination scheme which combines timetable planning with a semi-flexible departure delayed control strategy in case of disruptions. The flexibility is provided by allowing holding for the late incoming bus within a safety control margin (SCM). In this way, the stochastic travel time is addressed by the integration of real-time control and slacks at the planning phase. The schedule coordination problem then jointly optimises the planning headways and slack times in the timetable subject to SCM. Analytical formulations of cost functions are derived for three types of operating modes: uncoordinated operation, departure punctual control and departure delayed control. The problem is formulated as a stochastic mixed integer programming model and solved by a branch-and-bound algorithm. Numerical results provide an insight into the interaction between SCM and slack times, and demonstrate that the proposed model leads to cost saving and higher efficiency when SCM is considered. Compared to the conventional operating modes, the proposed method also presents advantages in transfer reliability and robustness to delay and demand variation.

Modeling flight delay propagation: A new analytical-econometric approach

- Transportation Research Part B: Methodological---2016---Nabin Kafle,Bo Zou

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

On the equivalence between continuum and car-following models of traffic flow

- Transportation Research Part B: Methodological---2016---Wen-Long Jin

Recently different formulations of the first-order Lighthill-Whitham-Richards (LWR) model have been identified in different coordinates and state variables. However, relationships between higher-order continuum and car-following traffic flow models are still not well understood. In this study, we first categorize traffic flow models according to their coordinates, state variables, and orders in the three-dimensional representation of traffic flow and propose a unified approach to convert higher-order car-following models into continuum models and vice versa. The conversion method consists of two steps: equivalent transformations between the secondary Eulerian (E-S) formulations and the primary Lagrangian (L-P) formulations, and approximations of L-P derivatives with anisotropic (upwind) finite differences. We use the method to derive continuum models from general second- and third-order car-following models and derive car-following models from second-order continuum models. Furthermore, we demonstrate that corresponding higher-order continuum and car-following models have the same fundamental diagrams, and that the string stability conditions for vehicle-continuous car-following models are the same as the linear stability conditions for the corresponding continuum models. A numerical example verifies the analytical results. In a sense, we establish a weak equivalence between continuum and car-following models, subject to errors introduced by the finite difference approximation. Such an equivalence relation can help us to pick out anisotropic solutions of higher-order models with non-concave fundamental diagrams.

Cellular automaton model simulating spatiotemporal patterns, phase transitions and concave growth pattern of oscillations in traffic flow

- Transportation Research Part B: Methodological---2016---Junfang Tian,Guangyu Li,Martin

Treiber,Rui Jiang,Ning Jia,Shoufeng Ma

This paper firstly shows that a recent model (Tian et al., Transpn. Res. B 71, 138–157, 2015) is not able to replicate well the concave growth pattern of traffic oscillations (i.e., the standard deviation of speed is a concave function of the vehicle number in the platoon) observed from car following experiments. We propose an improved model by introducing a safe speed and the logistic function for the randomization probability. Simulations show that the improved model can reproduce well the metastable state, the spatiotemporal patterns, and the phase transitions of traffic flow. Calibration and validation results show that the concave growth pattern of oscillations and the empirical detector data can be simulated with a quantitative agreement.

Discrete choice models with q-product random utilities

- Transportation Research Part B: Methodological---2016---Makoto Chikaraishi,Shoichiro Nakayama

While most existing closed-form discrete choice models can be regarded as special cases of McFadden's generalized extreme value model, recently, alternative frameworks of McFadden's generalized extreme value model, which maintain closed-form expressions, have been proposed; these include the weibit model, which uses the Weibull distribution for its random component. In this paper, we develop a generalized closed-form discrete choice model which include both logit and weibit models as special cases, by introducing the q-product random utility, in which the relationship between the systematic component and the random component can be either additive, multiplicative, or in-between, depending on the value of the parameter q. We show that, when imposing the Gumbel distribution on its error component (instead of assuming the additive case as the logit model), the parameter q depicts decision maker's risk attitude in the sense of the Arrow–Pratt measure of relative risk aversion, which would be a behavioral foundation of the model. We also show that the model can be straightforwardly extended to incorporate statistical dependence across alternatives. The performance of the proposed model is examined by using two case studies; one on travel-route choices and the other on transport-mode choices.

Private parking slot sharing

- Transportation Research Part B: Methodological---2016---Su Xiu Xu,Meng Cheng,Xiang T.R. Kong,Hai Yang,George Q. Huang

This paper addresses the private parking slot sharing problem during regular working hours in a big city. Our results extend the existing market design theory so that money flow is allowed in the matching mechanisms. We consider two cases of money flow: (i) one agent who fails to exchange his parking slot can join the leasing mechanism as a lessor; and (ii) one agent who fails in parking slot exchange can always “transfer” (rent) his parking slots to the platform. Each agent is self-interested. We propose the (price-compatible) top trading cycles and deals (TTCD) mechanism for case (i) and the price-compatible top trading cycles and chains (PC-TTCC) mechanism for case (ii). Both mechanisms are effective in terms of the compatibility with money flow, agents' welfare, and strategy-proofness. Our experimental results further show that the proposed mechanisms would result in remarkable social welfare, and (ex post) budget balance for the platform in a big city with large population. In some realistic settings, our proposed mechanisms can almost realize cost saving of 60% and make more than 50% of agents strictly better off. There is no private parking slot sharing in the benchmark case. Overall, this paper opens the door to the solutions of a host of price-compatible matching problems.

Pavement systems reconstruction and resurfacing policies for minimization of life-cycle costs under greenhouse gas emissions constraints

- Transportation Research Part B: Methodological---2016---Jinwoo Lee,Samer Madanat,Darren Reger

Pavement management systems, designed to minimize total lifecycle costs, will need to evolve to meet the needs of the future. Environmental concerns are likely to add an additional consideration for the state DOTs when allocating their financial resources. Transportation agencies will be concerned with determining maintenance, resurfacing and reconstruction policies for pavement segments in their systems while also addressing the environmental impact of these activities.

A comparison of three idling options in long-haul truck scheduling

- Transportation Research Part B: Methodological---2016---Çağrı Koç,Tolga Bektaş,Ola Jabali,Gilbert Laporte

This paper studies the Truck Driver Scheduling Problem with Idling Options (TDSP-IO), an extension of the long-haul truck driver scheduling problem with a more comprehensive objective function that accounts for driving cost, fuel cost, and idling cost. The best-known idling option is the widespread practice of keeping the vehicle engine running while the vehicle is not moving, which primarily stems from the drivers' desire to keep their vehicle at an adequate comfort level during breaks. Here, we explore two additional cleaner idling options: resting at an Electrified Parking Space (EPS) or using an Auxiliary Power Unit (APU) while idling. We also account for the initial investments associated with the equipment required for the use of these technologies. We formulate a mathematical model for the TDSP-IO under these three idling options, and we perform extensive computational experiments on realistic benchmark instances. The paper sheds light on the trade-offs between various performance indicators and offers several managerial and policy insights. Our analyses quantify the advantages of using EPSs and APUs, and show that they yield both economical and environmental benefits.

An integrated algorithm for the optimal design of stated choice experiments with partial profiles

- Transportation Research Part B: Methodological---2016---Daniel Palhazi Cuervo,Roselinde Kessels,Peter Goos,Kenneth Sörensen

Stated choice experiments are conducted to identify the attributes that drive people's preferences when choosing between competing options. They are widely used in transportation in order to support the decision making of companies and governmental authorities. A large number of attributes might increase the complexity of the choice task in a choice experiment, and have a detrimental effect on the quality of the results obtained. In order to reduce the cognitive effort required by the experiment, researchers may resort to experimental designs where the levels of some attributes are held constant within a choice situation. These designs are called partial profile designs. In this paper, we propose an integrated algorithm for the generation of D-optimal designs for stated choice experiments with partial profiles. This algorithm optimizes the set of constant attributes and the levels of the varying attributes simultaneously. An extensive computational experiment shows that the designs produced by the integrated algorithm outperform those obtained by existing algorithms, and match the optimal designs that have been analytically derived for a number of benchmark instances. Additionally, we evaluate the performance of the algorithm under varying experimental conditions and study the structure of the designs generated. We also revisit two stated choice experiments in transportation, and describe how the integrated algorithm could help to improve their designs.

A Benders decomposition approach for the charging station location problem with plug-in hybrid electric vehicles

- Transportation Research Part B: Methodological---2016---Okan Arslan,Oya Ekin Karaşan

The flow refueling location problem (FRLP) locates p stations in order to maximize the flow volume that can be accommodated in a road network respecting the range limitations of the vehicles. This paper introduces the charging station location problem with plug-in hybrid electric vehicles (CSLP-PHEV) as a generalization of the FRLP. We consider not only the electric vehicles but also the plug-in hybrid electric vehicles when locating the stations. Furthermore, we accommodate multiple types of these vehicles with different ranges. Our objective is to maximize the vehicle-miles-traveled using electricity and thereby minimize the total cost of transportation under the existing cost structure between electricity and gasoline. This is also indirectly equivalent to maximizing the environmental benefits. We present an arc-cover formulation and a Benders decomposition algorithm as exact solution methodologies to solve the CSLP-PHEV. The decomposition algorithm is accelerated using Pareto-optimal cut generation schemes. The structure of the formulation allows us to construct the subproblem solutions, dual solutions and nondominated Pareto-optimal cuts as closed form expressions without having to solve any linear programs. This increases the efficiency of the decomposition algorithm by orders of magnitude and the results of the computational studies show that the proposed algorithm both accelerates the solution process and effectively handles instances of realistic size for both CSLP-PHEV and FRLP.

Special issue on within-day dynamics

- Transportation Research Part B: Methodological---2016---Giulio E. Cantarella,Michiel Bliemer,Chris Tampère

2016

Solving a Dynamic User Equilibrium model based on splitting rates with Gradient Projection algorithms

- Transportation Research Part B: Methodological---2016---Guido Gentile

This article shows how Gradient Projection (GP) algorithms are capable of solving with high precision a Dynamic User Equilibrium (UE) model based on Splitting Rates, i.e. turning movements fractions by destination.

Optimal queue placement in dynamic system optimum solutions for single origin-destination traffic networks

- Transportation Research Part B: Methodological---2016---D. Ngoduy,N.H. Hoang,H.L. Vu,D. Watling

The Dynamic System Optimum (DSO) traffic assignment problem aims to determine a time-dependent routing pattern of travellers in a network such that the given time-dependent origin-destination demands are satisfied and the total travel time is at a minimum, assuming some model for dynamic network loading. The network kinematic wave model is now widely accepted as such a model, given its realism in reproducing phenomena such as transient queues and spillback to upstream links. An attractive solution strategy for DSO based on such a model is to reformulate as a set of side constraints apply a standard solver, and to this end two methods have been previously proposed, one based on the discretisation scheme known as the Cell Transmission Model (CTM), and the other based on the Link Transmission Model (LTM) derived from variational theory. In the present paper we aim to combine the advantages of CTM (in tracking time-dependent congestion formation within a link) with those of LTM (avoiding cell discretisation, providing a more computationally attractive with much fewer constraints). The motivation for our work is the previously-reported possibility for DSO to have multiple solutions, which differ in where queues are formed and dissipated in the network. Our aim is to find DSO solutions that optimally distribute the congestion over links inside the network which essentially eliminate avoidable queue spillbacks. In order to do so, we require more information than the LTM can offer, but wish to avoid the computational burden of CTM for DSO. We thus adopt an extension of the LTM called the Two-regime Transmission Model (TTM), which is consistent with LTM at link entries and exits but which is additionally able to accurately track the spatial and temporal formation of the congestion boundary within a link (which we later show to be a critical element, relative to LTM). We set out the theoretical background necessary for the formulation of the network-level TTM as a set of linear side constraints. Numerical experiments are used to illustrate the application of the method to determine DSO solutions avoiding spillbacks, reduce/eliminate the congestion and to show the distinctive elements of adopting TTM over LTM. Furthermore, in comparison to a fine-level CTM-based DSO method, our formulation is seen to significantly reduce the number of linear constraints while maintaining a reasonable accuracy.

An efficient iterative link transmission model

- Transportation Research Part B: Methodological---2016---Willem Himpe,Ruben Corthout,M.J. Chris Tampère

In this paper a novel iterative algorithm is presented for the link transmission model, a fast macroscopic dynamic network loading scheme. The algorithm's solutions are defined on a space–time discretized grid. Unlike previous numerical schemes there is no hard upper limit on the time step size for the algorithm to be numerically stable, leaving only the trade-off between accuracy and interpolation errors. This is a major benefit because mandatory small time steps in existing algorithm (required for numerical tractability) are undesirable in most strategic analyses. They lead to highly increased memory costs on larger network instances and unnecessary complex behaviour. In practice results are often aggregated for storage or analysis, which leads to the loss of computationally expensive detailed information and to the introduction of inconsistencies. The novel iterative scheme is consistent with the modelling assumptions independent of the numerical time step. A second contribution of the iterative procedure is the smart handling of repeated runs, which can be initialized (or warm started) by an earlier solution. For applications, repeatedly loading a network is often needed when evaluating traffic states under changing variables or adjusted parameter settings, or in optimization and equilibration procedures. In these cases the iterative algorithm is initialized with the solution of a previous run and iterations are performed to find a new consistent solution. Pseudo-code is provided for both a basic upwind iterative scheme and an extended algorithm that significantly accelerates convergence. The most important computational gains are achieved by ordering and reducing calculations to that part of the network which has changed (most). The properties of the algorithm are demonstrated on a theoretical network as well as on some real-world networks.

An efficient and exact event-based algorithm for solving simplified first order dynamic network loading problems in continuous time

- Transportation Research Part B: Methodological---2016---Mark P.H. Raadsen,Michiel Bliemer,Michael G.H. Bell

In this paper a novel solution algorithm is proposed for exactly solving simplified first order dynamic network loading (DNL) problems for any generalised network. This DNL solution algorithm, termed eLTM (event-based Link Transmission Model), is based on the seminal Lighthill–Witham–Richards (LWR) model, adopts a triangular fundamental diagram and includes a generalised first order node model formulation. Unlike virtually all DNL solution algorithms, eLTM does not rely on time discretisation, but instead adopts an event based approach. The main advantage of this approach is the possibility of yielding exact results. Furthermore, an approximate version of the same algorithm is introduced. The user can configure an a-priori threshold that dictates the approximation error (measurable a-posteriori). Using this approximation the computational effort required decreases significantly, making it especially suitable for large scale applications. The computational complexity is investigated and results are demonstrated via theoretical and real world case studies. Fixed periods of stationary demands are included adopting a matrix demand profile to mimic basic departure time demand fluctuations. Finally, the information loss of the approximate solution is assessed under different configurations.

Continuity of the path delay operator for dynamic network loading with spillback

- Transportation Research Part B: Methodological---2016---Ke Han,Benedetto Piccoli,Terry L. Friesz

This paper establishes the continuity of the path delay operators for dynamic network loading (DNL) problems based on the Lighthill–Whitham–Richards model, which explicitly capture vehicle spillback. The DNL describes and predicts the spatial-temporal evolution of traffic flow and congestion on a network that is consistent with established route and departure time choices of travelers. The LWR-based DNL model is first formulated as a system of partial differential algebraic equations. We then investigate the continuous dependence of merge and diverge junction models with respect to their initial/boundary conditions, which leads to the continuity of the path delay operator through the wave-front tracking methodology and the generalized tangent vector technique. As part of our analysis leading up to the main continuity result, we also provide an estimation of the minimum network supply without resort to any numerical computation. In particular, it is shown that gridlock can never occur in a finite time horizon in the DNL model.

Demand responsive transit systems with time-dependent demand: User equilibrium, system optimum, and management strategyAuthor-Name: Amirgholy, Mahyar

- Transportation Research Part B: Methodological---2016---Eric J. Gonzales

The operating cost of a demand responsive transit (DRT) system strictly depends on the quality of service that it offers to its users. An operating agency seeks to minimize operating costs while maintaining the quality of service while users experience costs associated with scheduling, waiting, and traveling within the system. In this paper, an analytical model is employed to approximate the agency's operating cost for running a DRT system with dynamic demand and the total generalized cost that users experience as a result of the operating decisions. The approach makes use of Vickrey's (1969) congestion theory to model the dynamics of the DRT system in the equilibrium condition and approximate the generalized cost for users when the operating capacity is inadequate to serve the time-dependent demand over the peak period without excess delay. The efficiency of the DRT system can be improved by optimizing one of three parameters that define the agency's operating decision: (1) the operating capacity of the system, (2) the number of passengers that have requested a pick-up and are awaiting service, and (3) the distribution of requested times for service from the DRT system. A schedule management strategy and dynamic pricing strategies are presented that can be implemented to manage demand and reduce the total cost of the DRT system by keeping the number of waiting requests optimized over the peak period. In the end, proposed optimization strategies are compared using a numerical example.

Editorial: Day-to-day dynamics in transportation networksAuthor-Name: Lo, Hong K

- Transportation Research Part B: Methodological---2016---David P. Watling,Giulio E. Cantarella

2016

A general stochastic process for day-to-day dynamic traffic assignment: Formulation, asymptotic behaviour, and stability analysis

- Transportation Research Part B: Methodological---2016---Giulio E. Cantarella,David P. Watling

This paper presents a general modelling approach to day-to-day dynamic assignment to a congested network through discrete-time stochastic and deterministic process models including an explicit modelling of users' habit as a part of route choice behaviour, through an exponential smoothing filter, and of their memory of network conditions on past days, through a moving average or an exponentially smoothing filter. An asymptotic analysis of the mean process is carried out to provide a better insight. Results of such analyses are also used for deriving conditions, about values of the system parameters, assuring that the mean process is dissipative and/or converges to some kind of attractor. Numerical small examples are also provided in order to illustrate the theoretical results obtained.

Statistical methods for comparison of day-to-day traffic models

- Transportation Research Part B: Methodological---2016---Martin L. Hazelton,Katharina Parry

Day-to-day dynamic traffic models have considerable potential as tools for transport network management and planning, and also for the study of traveller behaviour. However, their efficacy for these purposes is dependent on appropriate model selection. In particular, while it can be tempting to incorporate sophisticated and intricate representations of traveller learning in day-to-day models, it is important to ask whether the available data are able to support such a level of model complexity. To this end, our overall aim is to investigate the extent to which it is possible to learn about day-to-day traveller behaviour from observations on traffic counts collected over a sequence of days. The paper makes two specific contributions. The first is the development of a principled Bayesian methodology for comparing day-to-day models using link count data, and a description of how it may be implemented in practice using Markov chain Monte Carlo methods. The second contribution is a suite of simulation studies that examine whether these techniques can select the correct model within a set of alternatives with a variety of complexities of behavioural representation. We find that successful model choice based on link count data is often possible when travellers are relatively sensitive to differences in route utilities.

Sensitivity analysis based approximation models for day-to-day link flow evolution process

- Transportation Research Part B: Methodological---2016---Jian Wang,Xiaozheng He,Srinivas Peeta

Compared with path-based day-to-day (DTD) traffic evolution models, link-based DTD traffic evolution models are easier to calibrate and validate. However, the inherent network loading sub-problem in link-based DTD models induces high computational burden which precludes their broad practical applicability. To address this challenge, this study proposes three approximation models for the DTD traffic flow evolution process based on the sensitivity analysis of the network loading sub-problem in a link-based DTD model. In particular, a first-order approximation (FOA) model is formulated based on the derivative of link flow solutions with respect to perturbations on network characteristics. To improve the approximation accuracy of the FOA model, a second-order approximation (SOA) model and a variable reduced approximation (VRA) model are developed. The applicability conditions of the proposed approximation models are derived. A small numerical example demonstrates that the FOA model performs well when perturbations are small and the approximation accuracy reduces as the scale of perturbations increases. The SOA and VRA models can improve the approximation accuracy of the FOA model, at the cost of computing the second-order derivative and the reference link flow pattern, respectively.

Day-to-day departure time modeling under social network influence

- Transportation Research Part B: Methodological---2016---Yu Xiao,Hong K. Lo

With the prevalence of social media and location-aware mobile devices, travelers may make travel decisions not only by referring to their own experiences and conventional travel information, but also information shared on their social media. This study investigates the influence of this novel information on commuters' day-to-day departure time choices. We introduce a general framework for departure time choice with information sharing via social networks, which can be applied to any social network structure and is flexible for future extensions. The key in the framework, the learning process from friends' information in decision-making, is modeled based on the Bayesian learning theory. The properties of this learning model and the dynamics of the day-to-day departure time choice are analyzed. We further propose an agent-based approach to simulate travelers' choices. The parameters in the learning model are estimated based on an experimental data set. The agent-based approach is applied to validate the model and examine the effect of different social network structures, in terms of both travel choices and transportation system performance.

Advanced traveller information systems under recurrent traffic conditions: Network equilibrium and stability

- Transportation Research Part B: Methodological---2016---Gennaro N. Bifulco,Giulio E. Cantarella,Fulvio Simonelli,Pietro Velonà

In this paper the stability of traffic equilibrium is analysed by using a framework where advanced traveller information systems (ATIS) are explicitly modelled. The role played by information in traffic networks is discussed, with particular reference to the day-to-day dynamics of the traffic network and to system stability at equilibrium. The perspective adopted is that of transportation planning under recurrent network conditions. The network is considered to be in equilibrium, viewed as a fixed-point state of a day-to-day deterministic process, here modelled as a time-discrete non-linear Markovian dynamic system. In discussing the effects generated by the introduction of ATIS, the paper examines: changes in the fixed point(s) with respect to the absence of ATIS, how the theoretical conditions for fixed-point existence and uniqueness are affected, and the impact on the stability properties and the stability region at equilibrium. Most of the analyses are carried out with explicit theoretical considerations. Moreover, a toy network is also employed to explore numerically the effects of removing some assumptions concerning the accuracy of ATIS.

Day-to-day dynamical model incorporating an explicit description of individuals' information collection behaviour

- Transportation Research Part B: Methodological---2016---Takamasa Iryo

To forecast the performance of a congested transport system, it is necessary to model how transport system users adjust their day-to-day choice behaviour in an equilibration process. Although there are various ways of constructing a day-to-day dynamical model, the model should explicitly reflect the microscopic day-to-day adjustment behaviour of individual users to clarify which behavioural factors are incorporated in the model. From this point of view, existing day-to-day dynamical models seems not to contain sufficiently explicit mechanisms for the information collection behaviour. Several existing models implicitly incorporate user behaviour under imperfect information, but not in a way that can be explicitly related to the microscopic information acquisition processes of individual users. The present study proposes a continuous and deterministic day-to-day dynamical model that explicitly incorporates microscopic user behaviour about the information collection and can be handled easily in a mathematical manner. A microscopic model describing individuals' day-to-day adjustment process is first constructed. Then, introducing the mean-field approximation and assuming the large number of users, a macroscopic model that does not contain any disaggregated variable is derived as an ordinary differential equation. Convergence towards a user equilibrium solution is globally or locally guaranteed for utility functions associated with a potential function and those of monotonically decreasing regardless of the variety of information collection behaviour considered by the proposed model. On the other hand, results of numerical examples imply that the variety of information collection behaviour affects how a system behaves in a transient status of the dynamics, including how the system oscillates when it does not converge to an equilibrium point.

Dynamic pricing in discrete time stochastic day-to-day route choice models

- Transportation Research Part B: Methodological---2016---Tarun Rambha,Stephen D. Boyles

The traffic assignment problem is primarily concerned with the study of user equilibrium and system optimum and it is often assumed that travelers are perfectly rational and have a complete knowledge of network conditions. However, from an empirical standpoint, when a large number of selfish users travel in a network, the chances of reaching an equilibrium are slim. User behavior in such settings can be modeled using probabilistic route choice models which define when and how travelers switch paths. This approach results in stochastic processes with steady state distributions containing multiple states in their support. In this paper, we propose an average cost Markov decision process model to reduce the expected total system travel time of the logit route choice model using dynamic pricing. Existing dynamic pricing methods in day-to-day network models are formulated in continuous time. However, the solutions from these methods cannot be used to set tolls on different days in the network. We hence study dynamic tolling in a discrete time setting in which the system manager collects tolls based on the state of the system on previous day(s). In order to make this framework practical, approximation schemes for handling a large number of users are developed. A simple example to illustrate the application of the exact and approximate methods is also presented.

A class of RUM choice models that includes the model in which the utility has logistic distributed errors

- Transportation Research Part B: Methodological--2016---J.M. del Castillo

A class of random utility maximization (RUM) models is introduced. For these RUM models the utility errors are the sum of two independent random variables, where one of them follows a Gumbel distribution. For this class of RUM models an integral representation of the choice probability generating function has been derived which is substantially different from the usual integral representation arising from the RUM theory. Four types of models belonging to the class are presented. Thanks to the new integral representation, a closed-form expression for the choice probability generating function for these four models may be easily obtained. The resulting choice probabilities are fairly manageable and this fact makes the proposed models an interesting alternative to the logit model. The proposed models have been applied to two samples of interurban trips in Japan and some of them yield a better fit than the logit model. Finally, the concavity of the log-likelihood of the proposed models with respect to the utility coefficients is also analyzed.

Speed or spacing? Cumulative variables, and convolution of model errors and time in traffic flow models validation and calibration

- Transportation Research Part B: Methodological--2016---Vincenzo Punzo,Marcello Montanino

This paper proves that in traffic flow model calibration and validation the cumulative sum of a variable has to be preferred to the variable itself as a measure of performance. As shown through analytical relationships, model residuals dynamics are preserved if discrepancy measures of a model against reality are calculated on a cumulative variable, rather than on the variable itself. Keeping memory of model residuals occurrence times is essential in traffic flow modelling where the ability of reproducing the dynamics of a phenomenon – as a bottleneck evolution or a vehicle deceleration profile – may count as much as the ability of reproducing its order of magnitude. According to the aforesaid finding, in a car-following models context, calibration on travelled space is more robust than calibration on speed or acceleration. Similarly in case of macroscopic traffic flow models validation and calibration, cumulative flows are to be preferred to flows. Actually, the findings above hold for any dynamic model.

A scenario-based planning for the pickup and delivery problem with time windows, scheduled lines and stochastic demands

- Transportation Research Part B: Methodological--2016---Veaceslav Ghilas,Emrah Demir,Tom Van Woensel

The Pickup and Delivery Problem with Time Windows, Scheduled Lines and Stochastic Demands (PDPTW-SLSD) concerns scheduling a set of vehicles to serve a set of requests, whose expected demands are known in distribution when planning, but are only revealed with certainty upon the vehicles' arrival. In addition, a part of the transportation plan can be carried out on limited-capacity scheduled public transportation line services. This paper proposes a scenario-based sample average approximation approach for the PDPTW-SLSD. An adaptive large neighborhood search heuristic embedded into sample average approximation method is used to generate good-quality solutions. Computational results on instances with up to 40 requests (i.e., 80 locations) reveal that the integrated transportation networks can lead to operational cost savings of up to 16% compared with classical pickup and delivery systems.

Incorporating a multiple discrete-continuous outcome in the generalized heterogeneous data model: Application to residential self-selection effects analysis in an activity time-use behavior model

- Transportation Research Part B: Methodological---2016---Chandra R. Bhat,Sebastian Astroza,Aarti C. Bhat,Kai Nagel

This paper makes both a methodological contribution as well as an empirical contribution. From a methodological perspective, we propose a new econometric approach for the estimation of joint mixed models that include a multiple discrete choice outcome and a nominal discrete outcome, in addition to the count, binary/ordinal outcomes, and continuous outcomes considered in traditional structural equation models. These outcomes are modeled together by specifying latent underlying unobserved individual lifestyle, personality, and attitudinal factors that impact the many outcomes, and generate the jointness among the outcomes. From an empirical perspective, we analyze residential location choice, household vehicle ownership choice, as well as time-use choices, and investigate the extent of association versus causality in the effects of residential density on activity participation and mobility choices. The sample for the empirical application is drawn from a travel survey conducted in the Puget Sound Region in 2014. The results show that residential density effects on activity participation and motorized auto ownership are both associative as well as causal, emphasizing that accounting for residential self-selection effects are not simply esoteric econometric pursuits, but can have important implications for land-use policy measures that focus on neo-urbanist design.

Heterogeneous sensor location model for path reconstruction

- Transportation Research Part B: Methodological---2016---Chenyi Fu,Ning Zhu,Shuai Ling,Shoufeng Ma,Yongxi Huang

A new traffic sensor location problem is developed and solved by strategically placing both passive and active sensors in a transportation network for path reconstruction. Passive sensors simply count vehicles, while active sensors can recognize vehicle plates but are more expensive. We developed a two-stage heterogeneous sensor location model to determine the most cost-effective strategies for sensor deployment. The first stage of the model adopts the path reconstruction model defined by Castillo et al. (2008b) to determine the optimal locations of active sensors in the network. In the second stage, an algebraic framework is developed to strategically replace active sensors so that the total installation cost can be reduced while maintaining path flow observation quality. Within the algebraic framework, a scalar product operator is introduced to calculate path flows. An extension matrix is generated and used to determine if a replacement scheme is able to reconstruct all path flows. A graph model is then constructed to determine feasible replacement schemes. The problem of finding the optimal replacement scheme is addressed by utilizing the theory of maximum clique to obtain the upper bound of the number of replaced sensors and then revising this upper bound to generate the optimal replacement scheme. A polynomial-time algorithm is proposed to solve the maximum clique problem, and the optimal replacement scheme can be obtained accordingly. Three numerical experiments show that our proposed two-stage method can reduce the total costs of transportation surveillance systems without affecting the system monitor quality. The locations of the active sensors play a more critical role than the locations of the passive sensors in the number of reconstructed paths.

Parking as a loss leader at shopping malls

- Transportation Research Part B: Methodological---2016---Fulya Yuksel Ersoy,Kevin Hasker,Eren Inci

This paper investigates the pricing of malls in an environment where shoppers choose between a car and public transportation in getting to a suburban mall. The mall implicitly engages in mixed bundling; it sells goods bundled with parking to shoppers who come by car, and only goods to shoppers who come by public transportation. There are external costs of discomfort in public transportation due to crowdedness. Thus, shoppers using public transportation deter each other. The mall internalizes these external costs, much like a policy maker. To do so, it raises the sales price of the good and sets a parking fee less than parking' s marginal cost. Hence, parking is always a loss leader. Surprisingly, this pricing scheme is not necessarily distortionary.

Profit maximization by a private toll road with cars and trucks

- Transportation Research Part B: Methodological---2016---Xiaolei Guo,Da Xu

This paper examines the profit maximizing behavior of a private firm which operates a toll road competing against a free alternative in presence of cars and trucks. Trucks differ from cars in value of time (VOT), congestion externality, pavement damage, and link travel time function. We find that the firm takes either a car-strategy or a truck-strategy for profit maximization. For a traffic mix with relatively large car volume and small truck volume, the car-strategy results in no trucks using the toll road, while the truck-strategy results in all trucks using the toll road. We derive the equilibrium flow pattern under any combination of car-toll and truck-toll, based on which we identify a profit-maximizing frontier and a strategy-switching frontier in the car-toll and truck-toll two-dimensional space. By geometrically comparing the two frontiers, we establish general conditions under which each strategy will be taken, which suggest that the truck-to-car VOT ratio, the total traffic demand, and the difference in travel distance between the two roads are critical in shaping the firm's strategy.

On the flexibility of using marginal distribution choice models in traffic equilibrium

- Transportation Research Part B: Methodological---2016---Selin Damla Ahipaşaoğlu,Uğur Arıkan,Karthik Natarajan

Traffic equilibrium models are fundamental to the analysis of transportation systems. The stochastic user equilibrium (SUE) model which relaxes the perfect information assumption of the deterministic user equilibrium is one such model. The aim of this paper is to develop a new user equilibrium model, namely the MDM-SUE model, that uses the marginal distribution model (MDM) as the underlying route choice model. In this choice model, the marginal distributions of the path utilities are specified but the joint distribution is not. By focusing on the joint distribution that maximizes expected utility, we show that MDM-SUE exists and is unique under mild assumptions on the marginal distributions. We develop a convex optimization formulation for the MDM-SUE. For specific choices of marginal distributions, the MDM-SUE model recreates the optimization formulation of logit SUE and weibit SUE. Moreover, the model is flexible since it can capture perception variance scaling at the route level and allows for modeling different user preferences by allowing for skewed distributions and heavy tailed distributions. The model can also be generalized to incorporate bounded support distributions and discrete distributions which allows to distinguish between used and unused routes within the SUE framework. We adapt the method of successive averages to develop an efficient approach to compute MDM-SUE traffic flows. In our numerical experiments, we test the ability of MDM-SUE to relax the assumption that the error terms are independently and identically distributed random variables as in the logit models and study the additional modeling flexibility that MDM-SUE provides on small-sized networks as well as on the large network of the city of Winnipeg. The results indicate that the model provides both modeling flexibility and computational tractability in traffic equilibrium.

Instantaneous multihop connectivity of one-dimensional vehicular ad hoc networks with general distributions of communication nodes

- Transportation Research Part B: Methodological---2016---Wen-Long Jin,Wilfred W. Recker,Xiubin B. Wang

Connected and automated vehicle technologies hold great promises for improving the safety, efficiency, and environmental impacts of the transportation sector. In this study we are concerned with multihop connectivity of instantaneous vehicular one-dimensional ad hoc networks (VANETs) formed by connected vehicles along a communication path in a road network with given either vehicle locations or traffic densities, market penetration rates, and transmission ranges. We first define a new random variable for the location of the end node of a communication chain, which is a discrete random variable with given vehicle locations and a mixed random variable with given traffic densities. Then recursive, iterative, or differential equation models of instantaneous multihop connectivity between two communication nodes are derived from the relationships between end node probability mass or density function and connectivity. Assuming a simple communication model, the new models are applicable for general distribution patterns of vehicles and communication nodes, including non-evenly placed vehicles and nonhomogeneous Poisson distributions of nodes. With given vehicle locations, the computational cost for this new model is linear to the number of vehicles; with given traffic densities, we derive a new closed-form connectivity model for homogeneous Poisson distributions of communication nodes and an approximate closed-form model when distribution patterns of communication nodes are given by spatial renewal processes. We then apply the models to evaluate impacts on connectivity of traffic patterns, including shock waves, and road-side stations. The connectivity model could be helpful for designing routing protocols in VANETs and developing their applications in transportation systems.

Energy-efficient metro train rescheduling with uncertain time-variant passenger demands: An approximate dynamic programming approach

- Transportation Research Part B: Methodological---2016---Jiateng Yin,Tao Tang,Lixing Yang,Ziyou Gao,Bin Ran

In a heavily congested metro line, unexpected disturbances often occur to cause the delay of the traveling passengers, infeasibility of the current timetable and reduction of the operational efficiency. Due to the uncertain and dynamic characteristics of passenger demands, the commonly used method to recover from disturbances in practice is to change the timetable and rolling stock manually based on the experiences and professional judgements. In this paper, we develop a stochastic programming model for metro train rescheduling problem in order to jointly reduce the time delay of affected passengers, their total traveling time and operational costs of trains. To capture the complexity of passenger traveling characteristics, the arriving ratio of passengers at each station is modeled as a non-homogeneous poisson distribution, in which the intensity function is treated as time-varying origin-to-destination passenger demand matrices. By considering the number of on-board passengers, the total energy usage is modeled as the difference between the tractive energy consumption and the regenerative energy. Then, we design an approximate dynamic programming based algorithm to solve the proposed model, which can obtain a high-quality solution in a short time. Finally, numerical examples with real-world data sets are implemented to verify the effectiveness and robustness of the proposed approaches.

The time dimension of parking economics

- Transportation Research Part B: Methodological---2016---Roman Zakharenko

A model of demand for parking, evolving over time, is proposed. The model features both extensive (whether to park) and intensive (for how long to park) margins of parking demand, allows multidimensional heterogeneity of parkers, and evolution of demand throughout the day. I show that the optimal price for parking is proportional to the rate of arrival of new parkers and is inversely related to the square of the occupancy rate, which is different from previously discussed pricing methods. I show that the primary purpose of pricing is to regulate departures, rather than arrivals, of parkers. I also find that asymmetric information about parkers' characteristics does not prevent the parking authority from achieving the social optimum. A numerical example compares the optimal policy against the alternatives.

Node modeling for congested urban road networks

- Transportation Research Part B: Methodological---2016---Saif Eddin Jabari

First-order network flow models are coupled systems of differential equations which describe the build-up and dissipation of congestion along network road segments, known as link models. Models describing flows across network junctions, referred to as node models, play the role of the coupling between the link models and are responsible for capturing the propagation of traffic dynamics through the network. Node models are typically stated as optimization problems, so that the coupling between the link dynamics is not known explicitly. This renders network flow models analytically intractable. This paper examines the properties of node models for urban networks. Solutions to node models that are free of traffic holding, referred to as holding-free solutions, are formally defined and it is shown that flow maximization is only a sufficient condition for holding-free solutions. A simple greedy algorithm is shown to produce holding-free solutions while also respecting the invariance principle. Staging movements through nodes in a manner that prevents conflicting flows from proceeding through the nodes simultaneously is shown to simplify the node models considerably and promote unique solutions. The staging also models intersection capacities in a more realistic way by preventing unrealistically large flows when there is ample supply in the downstream and preventing artificial blocking when some of the downstream supplies are restricted.

Clustering of heterogeneous networks with directional flows based on "Snake" similarities

- Transportation Research Part B: Methodological---2016---Mohammadreza Saeedmanesh,Nikolas Geroliminis

Aggregated network level modeling and control of traffic in urban networks have recently gained a lot of interest due to unpredictability of travel behaviors and high complexity of physical modeling in microscopic level. Recent research has shown the existence of well-defined Macroscopic Fundamental Diagrams (MFDs) relating average flow and density in homogeneous networks. The concept of MFD allows to design real-time traffic control schemes specifically hierarchical perimeter control approaches to alleviate or postpone congestion. Considering the fact that congestion is spatially correlated in adjacent roads and it propagates spatiotemporaly with finite speed, describing the main pockets of congestion in a heterogeneous city with small number of clusters is conceivable. In this paper, we propose a three-step clustering algorithm to partition heterogeneous networks into connected homogeneous regions, which makes the application of perimeter control feasible. The advantages of the proposed method compared to the existing ones are the ability of finding directional congestion within a cluster, robustness with respect to parameters calibration, and its good performance for networks with low connectivity and missing data. Firstly, we start to find a connected homogeneous area around each road of the network in an iterative way (i.e. it forms a sequence of roads). Each sequence of roads, defined as 'snake' , is built by starting from a single road and iteratively adding one adjacent road based on its similarity to join previously added roads in that sequence. Secondly, based on the obtained sequences from the first step, a similarity measure is defined between each pair of the roads in the network. The similarities are computed in a way that put more weight on neighboring roads and facilitate connectivity of the clusters. Finally, Symmetric Non-negative Matrix Factorization (SNMF) framework is utilized to assign roads to proper clusters with high intra-similarity and low inter-similarity. SNMF partitions the data by providing a lower rank approximation of the similarity matrix. The proposed clustering framework is applied in medium and large-size networks based on micro-simulation and empirical data from probe vehicles. In addition, the extension of the algorithm is proposed to deal with the networks with sparse measurements where information of some links is missing. The results show the effectiveness and robustness of the extended algorithm applied to simulated network under different penetration rates (percentage of links with data).

Inferring origin-destination pairs and utility-based travel preferences of shared mobility system users in a multi-modal environment

- Transportation Research Part B: Methodological---2016---Anshuman Anjani Kumar,Jee Eun Kang,Changhyun Kwon,Alexander Nikolaev

This paper presents a methodological framework to identify population-wide traveler type distribution and simultaneously infer individual travelers' Origin-Destination (OD) pairs, based on the individual records of a shared mobility (bike) system use in a multimodal travel environment. Given the information about the travelers' outbound and inbound bike stations under varied price settings, the developed Selective Set Expectation Maximization (SSEM) algorithm infers an underlying distribution of travelers over the given traveler "types," or "classes," treating each traveler's OD pair as a latent variable; the inferred most likely traveler type for each traveler then informs their most likely OD pair. The experimental results based on simulated data demonstrate high SSEM learning accuracy both on the aggregate and dissagregate levels.

Pareto-improving transportation network design and ownership regimes

- Transportation Research Part B: Methodological---2016---Zhijia Tan,Hai Yang,Wei Tan,Zhichun Li

Private provision of public roads signifies co-existence of free, public-tolled and private-tolled roads. This paper investigates the Pareto-improving transportation network design problem under various ownership regimes by allowing joint choice of road pricing and capacity enhancement on free links. The problem of interest is formulated as a bi-objective mathematical programming model that considers the travel cost of road users in each origin-destination pair and the investment return of the whole network. The non-dominated Pareto-improving solutions of toll and/or capacity enhancement schemes are sought for achieving a win-win situation. A sufficient condition is provided for the existence of the non-dominated Pareto-improving schemes and then the properties of those schemes are analyzed. It is found that, under some mild assumptions, the optimal capacity enhancement is uniquely determined by the link flow under any non-dominated Pareto-improving scheme. As a result, the joint road pricing and capacity enhancement problem reduces to a bi-objective second-best road pricing problem. A revenue distribution mechanism with return rate guarantee is proposed to implement the non-dominated Pareto-improving schemes.

Optimal allocation of limited and random network resources to discrete stochastic demands for standardized cargo transportation networks

- Transportation Research Part B: Methodological---2016---Xinchang Wang

We consider the resource allocation problem with discrete random demands and discrete random resource capacities for standardized cargo transportation networks, in which a freight operator needs to determine the integral quantity of booking requests to be accepted for each product to maximize the expected profit. We formulate the problem as a stochastic integer programming model and provide theoretical results that completely characterize the optimal solution to the stochastic model under a special case. We present a progressive augmentation algorithm and a sampling based method for solving the stochastic model under a general case. We also offer numerical experiments to test the two methods and shed light on their performances.

Travel itinerary problem

- Transportation Research Part B: Methodological---2016---Xiang Li,Jiandong Zhou,Xiande Zhao

In this study, we propose a travel itinerary problem (TIP) which aims to find itineraries with the lowest cost for travelers visiting multiple cities, under the constraints of time horizon, stop times at cities and transport alternatives with fixed departure times, arrival times, and ticket prices. First, we formulate the TIP into a 0–1 integer programming model. Then, we decompose the itinerary optimization into a macroscopic tour (i.e., visiting sequence between cities) selection process and a microscopic number (i.e., flight number, train number for each piece of movement) selection process, and use an implicit enumeration algorithm to solve the optimal combination of tour and numbers. By integrating the itinerary optimization approach and Web crawler technology, we develop a smart travel system that is able to capture online transport data and recommend the optimal itinerary that satisfies travelers’ preferences in departure time, arrival time, cabin class, and transport mode. Finally, we present case studies based on real-life transport data to illustrate the usefulness of itinerary optimization for minimizing travel cost, the computational efficiency of the implicit enumeration algorithm, and the feasibility of the smart travel system.

Optimal deployment of charging lanes for electric vehicles in transportation networks

- Transportation Research Part B: Methodological---2016---Zhibin Chen,Fang He,Yafeng Yin

Given the rapid development of charging-while-driving technology, we envision that charging lanes for electric vehicles can be deployed in regional or even urban road networks in the future and thus attempt to optimize their deployment in this paper. We first develop a new user equilibrium model to describe the equilibrium flow distribution across a road network where charging lanes are deployed. Drivers of electric vehicles, when traveling between their origins and destinations, are assumed to select routes and decide battery recharging plans to minimize their trip times while ensuring to complete their trips without running out of charge. The battery recharging plan will dictate which charging lane to use, how long to charge and at what speed to operate an electric vehicle. The speed will affect the amount of energy recharged as well as travel time. With the established user equilibrium conditions, we further formulate the deployment of charging lanes as a mathematical program with complementarity constraints. Both the network equilibrium and design models are solved by effective solution algorithms and demonstrated with numerical examples.

Creating complex congestion patterns via multi-objective optimal freeway traffic control with application to cyber-security

- Transportation Research Part B: Methodological---2016---Jack Reilly,Sébastien Martin,Mathias Payer,Alexandre M. Bayen

This article presents a study on freeway networks instrumented with coordinated ramp metering and the ability of such control systems to produce arbitrarily complex congestion patterns within the dynamical limits of the traffic system. The developed method is used to evaluate the potential for an adversary with access to control infrastructure to enact high-level attacks on the underlying freeway system. The attacks are executed using a predictive, coordinated ramp metering controller based on finite-horizon optimal control and multi-objective optimization techniques. The efficacy of the control schemes in carrying out the prescribed attacks is determined via simulations of traffic network models based on the cell transmission model with onramps modeled as queue buffers. Freeway attacks with high-level objectives are presented on two illustrative examples: congestion-on-demand, which aims to create precise, user-specified pockets of congestion, and catch-me-if-you-can, which attempts to aid a fleeing vehicle from pursuant vehicles.

On the morning commute problem with carpooling behavior under parking space constraint

- Transportation Research Part B: Methodological---2016---Ling-Ling Xiao,Tian-Liang Liu,Hai-Jun Huang

Morning commuters choose their departure times and travel modes based on a combinational evaluation of factors associated with the chances of running into bottleneck congestion, likely schedule delays, parking space availability as well as monetary costs of traveling and parking. This study investigates a morning commute problem with carpooling behavior under parking space constraint at destination. We consider such a scenario that as a competing mode of the transit line, the highway contains a carpool lane only used by carpoolers while all solo drivers are forced to use a general purpose (GP) lane. Unlike the standard bottleneck model, the rush-hour dynamic departure patterns with a binding parking supply vary with the relative proportion of the two lanes' capacities. The possible departure pattern domain with different parking supply and lane capacity allocation is explored in terms of the relative extra carpool cost and distinguished between the bi-mode and multi-mode equilibria. It is found that compared with solo drivers, carpoolers have shorter rush hour in order to smooth the extra carpool cost. With the decrease of parking spots, the number of solo drivers cuts down gradually, whilst the number of carpoolers climbs up firstly and then declines in the multi-mode system. Under mild assumptions, the best system performance can be realized with the joint consideration of total travel cost and vehicle emission cost through optimizing the lane capacity allocation and the parking supply.

Network based temporary facility location for the Emergency Medical Services considering the disaster induced demand and the transportation infrastructure in disaster response

- Transportation Research Part B: Methodological---2016---Albert Y. Chen,Ting-Yi Yu

Pre-hospital Emergency Medical Service (EMS) provides the immediate and appropriate aid to patients in emergencies. As part of the traditional triad of first responders, EMS plays an important role in disaster response. In this work, the transportation infrastructure, which the EMS is dependent on, is considered. The objective of this research is to improve the effectiveness of EMS after the disaster by applying integer programming and the network-based partitioning to determine temporary locations for on-post EMS facilities. Integer Programming problems are formed for the optimization problem in different scales, and the Lagrangian Relaxation is adapted to extend the problem further into larger scale. Network based partitioning of demands are also proposed and tested. Numerical results are provided, and a case study is presented. In the case study, the facility location problem takes into consideration of both disaster triggered and usual EMS demand that forms a worst-case scenario. The analytical results are expected to facilitate decision making, and to serve as benchmarks for the planning of post-disaster EMS.

A stochastic model for the integrated optimization on metro timetable and speed profile with uncertain train mass

- Transportation Research Part B: Methodological---2016---Xin Yang,Anthony Chen,Bin Ning,Tao Tang

The integrated timetable and speed profile optimization model has recently attracted more attention because of its good achievements on energy conservation in metro systems. However, most previous studies often ignore the spatial and temporal uncertainties of train mass, and the variabilities of tractive force, braking force and basic running resistance on energy consumption in order to simplify the model formulation and solution algorithm. In this paper, we develop an integrated metro timetable and speed profile optimization model to minimize the total tractive energy consumption, where these real-world operating conditions are explicitly considered in the model formulation and solution algorithm. Firstly, we formulate a two-phase stochastic programming model to determine the timetable and speed profile. Given the speed profile, the first phase determines the timetable by scheduling the arrival and departure times for each station, and the second phase determines the speed profile for each inter-station with the scheduled arrival and departure times. Secondly, we design a simulation-based genetic algorithm procedure incorporated with the optimal train control algorithm to find the optimal solution. Finally, we present a simple example and a real-world example based on the operation data from the Beijing Metro Yizhuang Line in Beijing, China. The results of the real-world example show that, during peak hours, off-peak hours and night hours, the total tractive energy consumptions can be reduced by: (1) 10.66%, 9.94% and 9.13% in comparison with the current timetable and speed profile; and (2) 3.35%, 3.12% and 3.04% in comparison with the deterministic model.

Convexity and robustness of dynamic traffic assignment and freeway network control

- Transportation Research Part B: Methodological---2016---Giacomo Como,Enrico Lovisari,Ketan Savla

We study the use of the System Optimum (SO) Dynamic Traffic Assignment (DTA) problem to design optimal traffic flow controls for freeway networks as modeled by the Cell Transmission Model, using variable speed limit, ramp metering, and routing. We consider two optimal control problems: the DTA problem, where turning ratios are part of the control inputs, and the Freeway Network Control (FNC), where turning ratios are instead assigned exogenous parameters. It is known that relaxation of the supply and demand constraints in the cell-based formulations of the DTA problem results in a linear program. However, solutions to the relaxed problem can be infeasible with respect to traffic dynamics. Previous work has shown that such solutions can be made feasible by proper choice of ramp metering and variable speed limit control for specific traffic networks. We extend this procedure to arbitrary networks and provide insight into the structure and robustness of the proposed optimal controllers. For a network consisting only of ordinary, merge, and diverge junctions, where the cells have linear demand functions and affine supply functions with identical slopes, and the cost is the total traffic volume, we show, using the Pontryagin maximum principle, that variable speed limits are not needed in order to achieve optimality in the FNC problem, and ramp metering is sufficient. We also prove bounds on perturbation of the controlled system trajectory in terms of perturbations in initial traffic volume and exogenous inflows. These bounds, which leverage monotonicity properties of the controlled trajectory, are shown to be in close agreement with numerical simulation results.

Subsidizing and pricing private toll roads with noncontractible service quality: A relational contract approach

- Transportation Research Part B: Methodological---2016---Zhuo Feng,Shui-Bo Zhang,Ying Gao,Shuai-Jun Zhang

In private toll roads, some elements of the private operator's performance are noncontractible. As a result, the government cannot motivate the private operator to improve them through a formal contract but through a self-enforcing contract that both parties are unwilling to deviate unilaterally. In this paper, we use noncontractible service quality to capture these performance elements. By employing a relational contract approach, we aim to investigate the optimal subsidy plan to provide incentives for quality improvement. We show that government subsidy is feasible in quality improvement when the discount factor is sufficiently high and marginal cost of public funds is sufficiently small. Under feasible government subsidy, we have demonstrated the optimal subsidy plans in different scenarios. Moreover, some comparative statics are presented. Based on the derived subsidy plans, we further investigate the optimal toll price. We find that the optimal toll price generates zero surplus for the private operator and positive surplus for consumers. We then make two extensions of our model to re-investigate the government's optimal decisions on subsidy plan and toll price when her decision sequence is changed and when government compensation is present upon termination of the relationship. Some implications for practice have been derived from our model results.

Modeling unobserved heterogeneity using finite mixture random parameters for spatially correlated discrete count data

- Transportation Research Part B: Methodological---2016---Prasad Buddhavarapu,James G. Scott,Jorge A. Prozzi

Road segments with identical site-specific attributes often exhibit significantly different crash counts due to unobserved reasons. The extent of unobserved heterogeneity associated with a road feature is to be estimated prior to selecting the relevant safety treatment. Moreover, crash count data is often over-dispersed and spatially correlated. This paper proposes a spatial negative binomial specification with random parameters for modeling crash counts of contiguous road segments. The unobserved heterogeneity is incorporated using a finite multi-variate normal mixture prior on the random parameters; this allows for non-normality, skewness in the distribution of the random parameters, facilitates correlation across the random parameters, and relaxes any distributional assumptions. The model extracts the inherent groups of road segments with crash counts that are equally sensitive to the road attributes on an average; the heterogeneity within these groups is also allowed in the proposed framework. The specification simultaneously accounts for potential spatial correlation of the crash counts from neighboring road segments. A Gibbs sampling framework is proposed that leverages recent theoretical developments on data-augmentation algorithms, and elegantly sidesteps many of the computational difficulties usually associated with Bayesian inference of count models. Empirical results suggests the presence of two latent groups and spatial correlation within the study road network. Road features with significantly different effect on crash counts across two latent groups of road segments were identified.

Understanding urban mobility patterns with a probabilistic tensor factorization framework

- Transportation Research Part B: Methodological---2016---Lijun Sun,Kay W. Axhausen

The rapid developments of ubiquitous mobile computing provide planners and researchers with new opportunities to understand and build smart cities by mining the massive spatial-temporal mobility data. However, given the increasing complexity and volume of the emerging mobility datasets, it also becomes challenging to build novel analytical framework that is capable of understanding the structural properties and critical features. In this paper, we introduce an analytical framework to deal with high-dimensional human mobility data. To this end, we formulate mobility data in a probabilistic setting and consider each record a multivariate observation sampled from an underlying distribution. In order to characterize this distribution, we use a multi-way probabilistic factorization model based on the concept of tensor decomposition and probabilistic latent semantic analysis (PLSA). The model provides us with a flexible approach to understand multi-way mobility involving higher-order interactions —which are difficult to characterize with conventional approaches—using simple latent structures. The model can be efficiently estimated using the expectation maximization (EM) algorithm. As a numerical example, this model is applied on a four-way dataset recording 14 million public transport journeys extracted from smart card transactions in Singapore. This framework can shed light on the modeling of urban structure by understanding mobility flows in both spatial and temporal dimensions.

Traffic state estimation through compressed sensing and Markov random field

- Transportation Research Part B: Methodological---2016---Zuduo Zheng,Dongcai Su

This study focuses on information recovery from noisy traffic data and traffic state estimation. The main contributions of this paper are: i) a novel algorithm based on the compressed sensing theory is developed to recover traffic data with Gaussian measurement noise, partial data missing, and corrupted noise; ii) the accuracy of traffic state estimation (TSE) is improved by using Markov random field and total variation (TV) regularization, with introduction of smoothness prior; and iii) a recent TSE method is extended to handle traffic state variables with high dimension. Numerical experiments and field data are used to test performances of these proposed methods; consistent and satisfactory results are obtained.

The cost of travel time variability: Three measures with properties

- Transportation Research Part B: Methodological---2016---Leonid Engelson,Mogens Fosgerau

This paper explores the relationships between three types of measures of the cost of travel time variability: measures based on scheduling preferences and implicit departure time choice, Bernoulli type measures based on a univariate function of travel time, and mean-dispersion measures. We characterise measures that are both scheduling measures and mean-dispersion measures and measures that are both Bernoulli and mean-dispersion. There are no measures that are both scheduling and Bernoulli. We consider the impact of requiring that measures are additive or homogeneous, proving also a new strong result on the utility rates in an additive scheduling measure. These insights are useful for selecting cost measures to use in applications.

A container loading algorithm with static mechanical equilibrium stability constraints

- Transportation Research Part B: Methodological---2016---A. Galrão Ramos,José F. Oliveira,José F. Gonçalves,Manuel P. Lopes

The Container Loading Problem (CLP) literature has traditionally guaranteed cargo static stability by imposing the full support constraint for the base of the box. Used as a proxy for real-world static stability, this constraint excessively restricts the container space utilization and has conditioned the algorithms developed for this problem. In this paper we propose a container loading algorithm with static stability constraints based on the static mechanical equilibrium conditions applied to rigid bodies, which derive from Newton's laws of motion. The algorithm is a multi-population biased random-key genetic algorithm, with a new placement procedure that uses the maximal-spaces representation to manage empty spaces, and a layer building strategy to fill the maximal-spaces. The new static stability criterion is embedded in the placement procedure and in the evaluation function of the algorithm. The new algorithm is extensively tested on well-known literature benchmark instances using three variants: no stability constraint, the classical full base support constraint and with the new static stability constraint—a comparison is then made with the state-of-the-art algorithms for the CLP. The computational experiments show that by using the new stability criterion it is always possible to achieve a higher percentage of space utilization than with the classical full base support constraint, for all classes of problems, while still guaranteeing static stability. Moreover, for highly heterogeneous cargo the new algorithm with full base support constraint outperforms the other literature approaches, improving the best solutions known for these classes of problems.

Hidden Markov Model-based population synthesis

- Transportation Research Part B: Methodological---2016---Ismaïl Saadi,Ahmed Mustafa,Jacques Teller,Bilal Farooq,Mario Cools

Micro-simulation travel demand and land use models require a synthetic population, which consists of a set of agents characterized by demographic and socio-economic attributes. Two main families of population synthesis techniques can be distinguished: (a) fitting methods (iterative proportional fitting, updating) and (b) combinatorial optimization methods. During the last few years, a third outperforming family of population synthesis procedures has emerged, i.e., Markov process-based methods such as Monte Carlo Markov Chain (MCMC) simulations. In this paper, an extended Hidden Markov Model (HMM)-based approach is presented, which can serve as a better alternative than the existing methods. The approach is characterized by a great flexibility and efficiency in terms of data preparation and model training. The HMM is able to reproduce the structural configuration of a given population from an unlimited number of micro-samples and a marginal distribution. Only one marginal distribution of the considered population can be used as a boundary condition to "guide" the synthesis of the whole population. Model training and testing are performed using the Survey on the Workforce of 2013 and the Belgian National Household Travel Survey of 2010. Results indicate that the HMM method captures the complete heterogeneity of the micro-data contrary to standard fitting approaches. The method provides accurate results as it is able to reproduce the marginal distributions and their corresponding multivariate joint distributions with an acceptable error rate (i.e., SRSME=0.54 for 6 synthesized attributes). Furthermore, the HMM outperforms IPF for small sample sizes, even though the amount of input data is less than that for IPF. Finally, simulations show that the HMM can merge information provided by multiple data sources to allow good population estimates.

Strategic maritime container service design in oligopolistic markets

- Transportation Research Part B: Methodological---2016---Panagiotis Angeloudis,Luciano Greco,Michael G.H. Bell

This paper considers the maritime container assignment problem in a market setting with two competing firms. Given a series of known, exogenous demands for service between pairs of ports, each company is free to design liner services connecting a subset of the ports and demand, subject to the size of their fleets and the potential for profit. The model is designed as a three-stage complete information game: in the first stage, the firms simultaneously invest in their fleet; in the second stage, they individually design their services and solve the route assignment problem with respect to the transport demand they expect to serve, given the fleet determined in the first stage; in the final stage, the firms compete in terms of freight rates on each origin–destination movement. The game is solved by backward induction. Numerical solutions are provided to characterize the equilibria of the game.

The Time Dependent Traveling Salesman Planning Problem in Controlled Airspace

- Transportation Research Part B: Methodological---2016---Fabio Furini,Carlo Alfredo Persiani,Paolo Toth

The integration of drones into civil airspace is one of the most challenging problems for the automation of the controlled airspace, and the optimization of the drone route is a key step for this process. In this paper, we optimize the route planning of a drone mission that consists of departing from an airport, flying over a set of mission way points and coming back to the initial airport. We assume that during the mission a set of piloted aircraft flies in the same airspace and thus the cost of the drone route depends on the air traffic and on the avoidance maneuvers used to prevent possible conflicts. Two air traffic management techniques, i.e., routing and holding, are modeled in order to maintain a minimum separation between the drone and the piloted aircraft. The considered problem, called the Time Dependent Traveling Salesman Planning Problem in Controlled Airspace (TDTSPPCA), relates to the drone route planning phase and aims to minimize the total operational cost. Two heuristic algorithms are proposed for the solution of the problem. A mathematical formulation based on a particular version of the Time Dependent Traveling Salesman Problem, which allows holdings at mission way points, and a Branch and Cut algorithm are proposed for solving the TDTSPPCA to optimality. An additional formulation, based on a Travelling Salesman Problem variant that uses specific penalties to model the holding times, is proposed and a Cutting Plane algorithm is designed. Finally, computational experiments on real-world air traffic data from Milano Linate Terminal Maneuvering Area are reported to evaluate the performance of the proposed formulations and of the heuristic algorithms.

Traffic flow on signalized streets

- Transportation Research Part B: Methodological---2016---Carlos F. Daganzo,Lewis J. Lehe

This paper considers a signalized street of uniform width and blocks of various lengths. Its signals are pre-timed in an arbitrary pattern, and traffic on it behaves as per the kinematic-wave/variational theory with a triangular fundamental diagram. It is shown that the long run average flow on the street when the number of cars on the street (i.e. the street' s density) is held constant is given by the solution of a linear program (LP) with a finite number of variables and constraints. This defines a point on the street' s macroscopic fundamental diagram. For the homogeneous special case where the block lengths and signal timings are identical, all the LP constraints but one are redundant and the result has a closed form. In this case, the LP recipe matches and simplifies the so-called "method of cuts" . This establishes that the method of cuts is exact for homogeneous problems. However, in the more realistic inhomogeneous case the difference between the two methods can be arbitrarily large.

Willingness to board: A novel concept for modeling queuing up passengersAuthor-Name: Liu, Zhiyuan

- Transportation Research Part B: Methodological---2016---Shuaian Wang,Weijie Chen,Yuan Zheng

This paper addresses an innovative concept, termed as queuing passengers' willingness to board (WTB) the transit vehicles. In the peak hours, some queuing passengers cannot board a crowded bus/train, but when the same vehicle arrives at the next stop, some other passengers could still get on. This phenomenon reflects that passengers at different queuing locations have heterogeneous level of ambitions to board. A methodological framework is proposed for the quantitative investigation of WTB. First, a general model is proposed, together with a new least square method (LSM) for the calibration. Then, a parametric model is developed, which is also calibrated by the LSM. To refine the calibration method and deal with the biasness of survey data, a weighted least square method is further developed. Based on real survey data, the calibration results clearly support the existence of WTB, which can be used to estimate the capacity of transit vehicles. This paper also sheds some lights on the practical applications of the quantitative WTB.

Modeling of yard congestion and optimization of yard template in container ports

- Transportation Research Part B: Methodological---2016---Lu Zhen

As a tactical-level plan, a yard template determines the assignment of spaces in a container port yard for arriving vessels. This paper investigates the concept of yard congestion quantitatively in the context of yard truck interruptions, and develops a combination of probabilistic and physics-based models for truck interruptions. The above work enables us to exactly evaluate the expected link travel time, which then acts as the basis for proposing a mixed-integer programming model that minimizes the total expected travel time of moving containers around the yard. A Squeaky Wheel Optimization based meta-heuristic is developed to solve the model. Experiments are also conducted to validate the effectiveness of the model and the solution method.

Analysis of timer-based message dissemination protocols for inter-vehicle communications

- Transportation Research Part B: Methodological---2016---Andrea Baiocchi

Message dissemination protocols are a key component of the communication infrastructure of the Intelligent Transportation System. They have been targeted by several research and standardization efforts. An especially interesting class of dissemination protocols are so called timer (or delay) based ones. The recently standardized GeoBroadcast service of the GeoNetworking protocol of ETSI falls into this category. This work lays out an analytical model of message coverage distance and delivery delay with timer-based dissemination protocols in a highway environment. The model is based on the assumption of (possibly non homogeneous) Poisson vehicle spatial distribution. The model results are compared with computer simulations and measured data driven experiments, including scenarios with traffic discontinuities (signalized intersections). The limits of applicability of the proposed model are assessed, showing that it provides accurate predictions with a wide range of system parameters for highway scenarios. It is also shown that one of the most popular timer-based dissemination protocols achieves the same connectivity and coverage performance of the ideal message flooding.

Liner container assignment model with transit-time-sensitive container shipment demand and its applicationsAuthor-Name: Wang, Shuaian

- Transportation Research Part B: Methodological---2016---Qiang Meng,Chung-Yee Lee

This paper proposes a practical tactical-level liner container assignment model for liner shipping companies, in which the container shipment demand is a non-increasing function of the transit time. Given the transit-time-sensitive demand, the model aims to determine which proportion of the demand to fulfill and how to transport these containers in a liner shipping network to maximize the total profit. Although the proposed model is similar to multi-commodity network-flow (MCNF) with side constraints, unlike the MCNF with time delay constraints or reliability constraints that is NP-hard, we show that the liner container assignment model is polynomially solvable due to its weekly schedule characteristics by developing two link-based linear programing formulations. A number of practical extensions and applications are analyzed and managerial insights are discussed. The polynomially solvable liner container assignment model is then applied to address several important decision problems proposed by a global liner shipping company.

Determining structural route components from GPS traces

- Transportation Research Part B: Methodological---2016---Luk Knapen,Irith Ben-Arroyo Hartman,Daniel Schulz,Tom Bellemans,Davy Janssens,Geert Wets

Analysis of GPS traces shows that people often do not use the least cost path through the transportation network while making trips. This leads to the question which structural path characteristics can be used to construct realistic route choice sets for use in traffic simulation models. In this paper, we investigate the hypothesis that, for utilitarian trips, the route between origin and destination consists of a small number of concatenated least cost paths. The hypothesis is verified by analyzing routes extracted from large sets of recorded GPS traces which constitute revealed preference information. Trips have been extracted from the traces and for each trip the path in the transportation network is determined by map matching. This is followed by a path decomposition phase for which the algorithm constitutes the first contribution of this paper. There are multiple ways to split a given path in a directed graph into a minimal number of subpaths of minimal cost. By calculating two specific path splittings, it is possible to identify subsets of the vertices (splitVertexSuites) that can be used to generate every possible minimum path splitting by taking one vertex from each such subset. As a second contribution, we show how the extracted information is used in microscopic travel simulation. The distribution for the size of the minimum decomposition, extracted from the GPS traces, can be used in constrained enumeration methods for route choice set generation. The sets of vertices that can act as boundary vertices separating consecutive route parts contain way points (landmarks) having a particular meaning to their user. The paper explains the theoretical aspects of route splitting as well as the process to extract splitVertexSuites from big data. It reports statistical distributions extracted from sets of GPS traces for both multimodal person movements and unimodal car trips.

Enhanced cooperative car-following traffic model with the combination of V2V and V2I communication

- Transportation Research Part B: Methodological---2016---Dongyao Jia,Dong Ngoduy

Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication are emerging components of intelligent transport systems (ITS) based on which vehicles can drive in a cooperative way and, hence, significantly improve traffic flow efficiency. However, due to the high vehicle mobility, the unreliable vehicular communications such as packet loss and transmission delay can impair the performance of the cooperative driving system (CDS). In addition, the downstream traffic information collected by roadside sensors in the V2I communication may introduce measurement errors, which also affect the performance of the CDS. The goal of this paper is to bridge the gap between traffic flow modelling and communication approaches in order to build up better cooperative traffic systems. To this end, we aim to develop an enhanced cooperative microscopic (car-following) traffic model considering V2V and V2I communication (or V2X for short), and investigate how vehicular communications affect the vehicle cooperative driving, especially in traffic disturbance scenarios. For these purposes, we design a novel consensus-based vehicle control algorithm for the CDS, in which not only the local traffic flow stability is guaranteed, but also the shock waves are supposed to be smoothed. The IEEE 802.11p, the defacto vehicular networking standard, is selected as the communication protocols, and the roadside sensors are deployed to collect the average speed in the targeted area as the downstream traffic reference. Specifically, the imperfections of vehicular communication as well as the measured information noise are taken into account. Numerical results show the efficiency of the proposed scheme. This paper attempts to theoretically investigate the relationship between vehicular communications and cooperative driving, which is needed for the future deployment of both connected vehicles and infrastructure (i.e. V2X).

How, when and why integrated choice and latent variable models are latently useful

- Transportation Research Part B: Methodological---2016---Akshay Vij,Joan L. Walker

Integrated Choice and Latent Variable (ICLV) models are an increasingly popular extension to discrete choice models that attempt explicitly to model the cognitive process underlying the formation of any choice. This study was born from the discovery that an ICLV model can in many cases be reduced to a choice model without latent variables that fits the choice data at least as well as the original ICLV model from which it was obtained. The failure of past studies to recognize this fact raised concerns about other benefits that have been claimed with regards to the framework. With the objective of addressing these concerns, this study undertakes a systematic comparison between the ICLV model and an appropriately specified reduced form choice model. We derive analytical proofs regarding the benefits of the framework and use synthetic datasets to corroborate any conclusions drawn from the analytical proofs. We find that the ICLV model can under certain conditions lead to an improvement in the analyst's ability to predict outcomes to the choice data, allow for the identification of structural relationships between observable and latent variables, correct for bias arising from omitted variables and measurement error, reduce the variance of parameter estimates, and abet practice and policy, all in ways that would not be possible using the reduced form choice model. We synthesize these findings into a general process of evaluation that can be used to assess what gains, if any, might be had from developing an ICLV model in a particular empirical context.

Holding decisions for correlated vehicle arrivals at intermodal freight transfer terminals

- Transportation Research Part B: Methodological---2016---Yanshuo Sun,Paul Schonfeld

We propose a vehicle holding method for mitigating the effect of service disruptions on coordinated intermodal freight operations. We extend existing studies mainly by (1) modeling correlations among vehicle arrivals and (2) considering decision risks with a mean-standard deviation optimization model. We prove that the expected value of the total cost in our proposed formulation is not affected by the correlations, while the variance can be miscomputed when arrival correlations are neglected. We also identify some implications of delay propagation when optimizing vehicle holding decisions in real-time. We provide general criteria for determining the boundary of the affected region and length of the numerical search, based on the frequency of information updates. Theoretical analyses are supported by three numerical examples.

Estimation of urban bus transit marginal cost without cost data

- Transportation Research Part B: Methodological--2016---Marco Batarce

We develop a method to study the industrial structure of urban bus transit without using cost data. To do so, we estimate the marginal cost function under the assumption that firms compete on frequency and adjust frequency to maximize profits. Our methodology is applied to Santiago, Chile. In this case, demand is modeled with a simplified model of transit network assignment. The goal is to consider how frequency, capacity, and on-board passengers affect the bus line’s demand. The marginal cost function is estimated by using the first-order conditions of the firm’s profit maximization problem, using the results of the demand model as data. We conclude that the urban bus transit industry in Santiago exhibits increasing returns to scale for low levels of demand and that these returns are exhausted rapidly at a moderate demand level. Additionally, firms exhibit economies of network expansion, on average.

A multiple type bike repositioning problem

- Transportation Research Part B: Methodological--2016---Yanfeng Li,W.Y. Szeto,Jiancheng Long,C.S. Shui

This paper investigates a new static bicycle repositioning problem in which multiple types of bikes are considered. Some types of bikes that are in short supply at a station can be substituted by other types, whereas some types of bikes can occupy the spaces of other types in the vehicle during repositioning. These activities provide two new strategies, substitution and occupancy, which are examined in this paper. The problem is formulated as a mixed-integer linear programming problem to minimize the total cost, which consists of the route travel cost, penalties due to unmet demand, and penalties associated with the substitution and occupancy strategies. A combined hybrid genetic algorithm is proposed to solve this problem. This solution algorithm consists of (i) a modified version of a hybrid genetic search with adaptive diversity control to determine routing decisions and (ii) a proposed greedy heuristic to determine the loading and unloading instructions at each visited station and the substitution and occupancy strategies. The results show that the proposed method can provide high-quality solutions with short computing times. Using small examples, this paper also reveals problem properties and repositioning strategies in bike sharing systems with multiple types of bikes.

Nonlinear pricing for stochastic container leasing system

- Transportation Research Part B: Methodological--2016---Wen Jiao,Hong Yan,King-Wah Pang

With the substantial upsurge of container traffic, the container leasing company thrives on the financial benefits and operational flexibility of leasing containers requested by shippers. In practice, container lease pricing problem is different from the consumer product pricing in consideration of the fair value of container, limited customer types and monopolistic supply market. In view of the durability of container and the diversified lease time and quantity, the pricing is a challenging task for the leasing company. This paper examines the monopolist’s nonlinear pricing problems in static and dynamic environments. In particular, the leasing company designs and commits a menu of price and hire quantity/time pairs to maximize the expected profit and in turn customers choose hire quantities/time to maximize their surpluses according to their hire preferences. In a static environment, closed-form solutions are obtained for different groups of customers with multiple types subject to capacity constraint. In a dynamic environment, we address two customer types and derive closed-form solutions for the problem of customers with hire time preference. Further, we show that the effect of the capacity constraint increases with time of the planning horizon when customers have the same hire time preference; while in the case with different hire time preferences, the capacity constraint has opposite effects on the low and high type customers. Last, the case of customers with hire quantity preference is discussed. We focus on the lease with alternative given sets of hire time and use dynamic programming to derive the numerical optimal hire time sequence.

Finding optimal solutions for vehicle routing problem with pickup and delivery services with time windows: A dynamic programming approach based on state–space–time network representations

- Transportation Research Part B: Methodological---2016---Monirehalsadat Mahmoudi,Xuesong Zhou

Optimization of on-demand transportation systems and ride-sharing services involves solving a class of complex vehicle routing problems with pickup and delivery with time windows (VRPPDTW). This paper first proposes a new time-discretized multi-commodity network flow model for the VRPPDTW based on the integration of vehicles’ carrying states within space–time transportation networks, so as to allow a joint optimization of passenger-to-vehicle assignment and turn-by-turn routing in congested transportation networks. Our three-dimensional state–space–time network construct is able to comprehensively enumerate possible transportation states at any given time along vehicle space–time paths, and further allows a forward dynamic programming solution algorithm to solve the single vehicle VRPPDTW problem. By utilizing a Lagrangian relaxation approach, the primal multi-vehicle routing problem is decomposed to a sequence of single vehicle routing subproblems, with Lagrangian multipliers for individual passengers’ requests being updated by sub-gradient-based algorithms. We further discuss a number of search space reduction strategies and test our algorithms, implemented through a specialized program in C++, on medium-scale and large-scale transportation networks, namely the Chicago sketch and Phoenix regional networks.

A dynamic stochastic model for evaluating congestion and crowding effects in transit systems

- Transportation Research Part B: Methodological---2016---Oded Cats,Jens West,Jonas Eliasson

One of the most common motivations for public transport investments is to reduce congestion and increase capacity. Public transport congestion leads to crowding discomfort, denied boardings and lower service reliability. However, transit assignment models and appraisal methodologies usually do not account for the dynamics of public transport congestion and crowding and thus potentially underestimate the related benefits.

Probabilistic speed–density relationship for pedestrian traffic

- Transportation Research Part B: Methodological---2016---Marija Nikolić,Michel Bierlaire,Bilal Farooq,Matthieu de Lapparent

We propose a probabilistic modeling approach to represent the speed–density relationship of pedestrian traffic. The approach is data-driven, and it is motivated by the presence of high scatter in the raw data that we have analyzed. We show the validity of the proposed approach, and its superiority compared to deterministic approaches from the literature using a dataset collected from a real scene and another from a controlled experiment.

Vehicle identification sensor models for origin–destination estimation

- Transportation Research Part B: Methodological---2016---Majid Hadavi,Yousef Shafahi

The traditional approach to origin–destination (OD) estimation based on data surveys is highly expensive. Therefore, researchers have attempted to develop reasonable low-cost approaches to estimating the OD vector, such as OD estimation based on traffic sensor data. In this estimation approach, the location problem for the sensors is critical. One type of sensor that can be used for this purpose, on which this paper focuses, is vehicle identification sensors. The information collected by these sensors that can be employed for OD estimation is discussed in this paper. We use data gathered by vehicle identification sensors that include an ID for each vehicle and the time at which the sensor detected it. Based on these data, the subset of sensors that detected a given vehicle and the order in which they detected it are available. In this paper, four location models are proposed, all of which consider the order of the sensors. The first model always yields the minimum number of sensors to ensure the uniqueness of path flows. The second model yields the maximum number of uniquely observed paths given a budget constraint on the sensors. The third model always yields the minimum number of sensors to ensure the uniqueness of OD flows. Finally, the fourth model yields the maximum number of uniquely observed OD flows given a budget constraint on the sensors. For several numerical examples, these four models were solved using the GAMS software. These numerical examples include several medium-sized examples, including an example of a real-world large-scale transportation network in Mashhad.

Passenger centric train timetabling problem

- Transportation Research Part B: Methodological---2016---Tomáš Robenek,Yousef Maknoon,Shadi Sharif Azadeh,Jianghang Chen,Michel Bierlaire

The aim of this paper is to analyze and to improve the current planning process of the passenger railway service in light of the recent railway market changes. In order to do so, we introduce the Passenger Centric Train Timetabling Problem. The originality of our approach is that we account for the passenger satisfaction in the design of the timetable. We consider both types of timetable(s): cyclic and non-cyclic. The problem is modeled as a Mixed Integer Linear Programming (MILP) problem with an objective of maximizing the train operating company’s profit while maintaining ε level of passenger satisfaction. The model does not take into account conflicts between trains and does not adjust dwell times at stopping stations among the lines. By solving the model for various values of ε, the approximated Pareto frontier is constructed. The analysis, based on an experiment using realistic data, shows that an improvement of passenger satisfaction while maintaining a low profit loss for the railway company can be achieved. A sensitivity analysis on passenger congestion illustrates a quantitative evidence that the non-cyclic timetables can account better for high density demand in comparison to cyclic timetables.

A coordinated location-inventory problem in closed-loop supply chain

- Transportation Research Part B: Methodological---2016---Zhi-Hai Zhang,Avinash Unnikrishnan

This paper considers a coordinated location-inventory model under uncertain demands for a closed loop supply chain comprising of one plant, forward and reverse distribution centers, and retailers. The inventory of new and returned products is managed at forward and reverse distribution centers respectively through a periodic review policy. The proposed model determines the location of forward and reverse distribution centers and the associated capacities, the review intervals of the inventory policy at distribution centers, and the assignments of retailers to the distribution centers. We model six different coordination strategies. All the models are formulated as nonlinear integer programs with chance constraints and transformed to conic quadratic mixed-integer programs that can be efficiently solved by CPLEX. An outer approximation based solution algorithm is developed to solve the conic quadratic mixed-integer program. The benefit of different types of coordination strategies is shown through extensive computational testing.

Can you ever be certain? Reducing hypothetical bias in stated choice experiments via respondent reported choice certaintyAuthor-Name: Beck, Matthew J

- Transportation Research Part B: Methodological---2016---Simon Fifer,John M. Rose

Stated choice experiments are a preeminent method for researchers and practitioners who seek to examine the behavior of consumers. However, the extent to which these experiments can replicate real markets continues to be debated in the literature, with particular reference to the potential for biased estimates as a result of the hypothetical nature of such experiments. In this paper, a first in the transportation literature, we compare stated choice responses to revealed preference behavior and examine three methods proposed in the literature for calibrating choice experiments via reported choice certainty. In doing so we provide evidence that the incorrect calibration of responses can produce stated choice results that are more biased than doing nothing at all, however we show that by jointly estimating choice and choice certainty there is a significant reduction in hypothetical bias such that stated choice responses more directly replicate real behavior.

Symmetries in the kinematic wave model and a parameter-free representation of traffic flow

- Transportation Research Part B: Methodological---2016---Jorge A. Laval,Bhargava R. Chilukuri

This paper identifies a family of linear transformations where conservation laws are invariant. In the case of a triangular fundamental diagram, it is shown that for a subset of these transformations, flow, total distance traveled and total delay are invariant. This means that for capacity or delay computations one may choose the transformation—i.e., the shape of the triangular diagram—that simplifies the problem the most, which does not require knowing the actual fundamental diagram. This is appealing also for delay-optimizing control problems since they may be solved using an isosceles fundamental diagram, which provides the most efficient numerical methods. Examples are given.

Market mechanism design for profitable on-demand transport services

- Transportation Research Part B: Methodological---2016---Malcolm Egan,Michal Jakob

On-demand transport services in the form of dial-a-ride and taxis are crucial parts of the transport infrastructure in all major cities. However, not all on-demand transport services are equal: not-for-profit dial-a-ride services with coordinated drivers significantly differ from profit-motivated taxi services with uncoordinated drivers. In fact, there are two key threads of work on efficient scheduling, routing, and pricing for passengers: dial-a-ride services; and taxi services. Unfortunately, there has been only limited development of algorithms for joint optimization of scheduling, routing, and pricing; largely due to the widespread assumption of fixed pricing. In this paper, we introduce another thread: profit-motivated on-demand transport services with coordinated drivers. To maximize provider profits and the efficiency of the service, we propose a new market mechanism for this new thread of on-demand transport services, where passengers negotiate with the service provider. In contrast to previous work, our mechanism jointly optimizes scheduling, routing, and pricing. Ultimately, we demonstrate that our approach can lead to higher profits and reduced passenger prices, compared with standard fixed price approaches, while also improving efficiency.

Robust network sensor location for complete link flow observability under uncertaintyAuthor-Name: Xu, Xiangdong

- Transportation Research Part B: Methodological---2016---Hong K. Lo,Anthony Chen,Enrique Castillo

The link observability problem is to identify the minimum set of links to be installed with sensors that allow the full determination of flows on all the unobserved links. Inevitably, the observed link flows are subject to measurement errors, which will accumulate and propagate in the inference of the unobserved link flows, leading to uncertainty in the inference process. In this paper, we develop a robust network sensor location model for complete link flow observability, while considering the propagation of measurement errors in the link flow inference. Our model development relies on two observations: (1) multiple sensor location schemes exist for the complete inference of the unobserved link flows, and different schemes can have different accumulated variances of the inferred flows as propagated from the measurement errors. (2) Fewer unobserved links involved in the nodal flow conservation equations will have a lower chance of accumulating measurement errors, and hence a lower uncertainty in the inferred link flows. These observations motivate a new way to formulate the sensor location problem. Mathematically, we formulate the problem as min–max and min–sum binary integer linear programs. The objective function minimizes the largest or cumulative number of unobserved links connected to each node, which reduces the chance of incurring higher variances in the inference process. Computationally, the resultant binary integer linear program permits the use of a number of commercial software packages for its globally optimal solution. Furthermore, considering the non-uniqueness of the minimum set of observed links for complete link flow observability, the optimization programs also consider a secondary criterion for selecting the sensor location scheme with the minimum accumulated uncertainty of the complete link flow inference.

Design framework of large-scale one-way electric vehicle sharing systems: A continuum approximation model

- Transportation Research Part B: Methodological---2016---Xiaopeng Li,Jiaqi Ma,Jianxun Cui,Amir Ghiasi,Fang Zhou

This paper proposes a Continuum Approximation (CA) model for design of a one-way Electrical Vehicle (EV) sharing system that serves a metropolitan area. This model determines the optimal EV sharing station locations and the corresponding EV fleet sizes to minimize the comprehensive system cost, including station construction investment, vehicle charging, transportation and vehicle balancing, under stochastic and dynamic trip demands. This is a very complex problem due to the NP-hard nature of location design, the large number of individual users, and the stochasticity and dynamics of generated trips. Further, the considerable charging time required by EVs distinguishes this problem from traditional car sharing problems where a vehicle is immediately available for pickup after being dropped at a station. We find that the CA approach can overcome these modeling challenges by decomposing the studied area into a number of small neighborhoods that each can be approximated by an Infinite Homogeneous Plane (IHP). We find that the system cost of an IHP is a unimodal function of the station service area size and can be efficiently solved in a sub-linear time by the bisection algorithm. Then integrating the solutions of all IHPs yields an approximate solution to the original heterogeneous area. With numerical experiments, we show that the CA solution is able to estimate the total system cost of the discrete counterpart solution efficiently with good accuracy, even for large-scale heterogeneous problems. This implies that the proposed CA approach is capable of providing a near-optimum solution to the comprehensive design of a practical large-scale EV sharing system. With this model, we also conduct sensitivity analysis to reveal insights into how cost components and system design vary with key parameter values. As far as the author’s knowledge, this study is the first work that addresses design of an EV sharing system considering both longer-term location and fleet size planning and daily vehicle operations. The proposed CA model also extends the CA methodology literature from traditional location problems with stationary demand, single-facility based service to EV sharing problems considering dynamic demands, OD trips, and nonlinear vehicle charging times.

Service type assignment and container routing with transit time constraints and empty container repositioning for liner shipping service networks

- Transportation Research Part B: Methodological---2016---M. Hakan Akyüz,Chung-Yee Lee

A decision tool is developed for a liner shipping company to deploy its fleet considering vessel speeds and to find routes for cargos with repositioning of empty containers and transit time constraints. This problem is referred as the simultaneous Service type Assignment and container Routing Problem (SARP) in the sequel. A path-flow based mixed-integer linear programming formulation is suggested for the SARP. A Branch and Bound (BB) algorithm is used to solve the SARP exactly. A Column Generation (CG) procedure, embedded within the BB framework, is devised to solve the linear programming relaxation of the SARP. The CG subproblems arises as Shortest Path Problems (SPP). Yet incorporating transit time requirements yields constrained SPP which is NP-hard and solved by a label correcting algorithm. Computational experiments are performed on randomly generated test instances mimicking real life. The BB algorithm yields promising solutions for the SARP. The SARP with and without transit time constraints is compared with each other. Our results suggest a potential to increase profit margins of liner shipping companies by considering transit time requirements of cargos.

Biased standard error estimations in transport model calibration due to heteroscedasticity arising from the variability of linear data projection

- Transportation Research Part B: Methodological---2016---Wai Wong,S.C. Wong

Reliable transport models calibrated from accurate traffic data are crucial for predicating transportation system performance and ensuring better traffic planning. However, due to the impracticability of collecting data from an entire population, methods of data inference such as the linear data projection are commonly adopted. A recent study has shown that systematic bias may be embedded in the parameters calibrated due to linearly projected data that do not account for scaling factor variability. Adjustment factors for reducing such biases in the calibrated parameters have been proposed for a generalized multivariate polynomial model. However, the effects of linear data projection on the dispersion of and confidence in the adjusted parameters have not been explored. Without appropriate statistics examining the statistical significance of the adjusted model, their validity in applications remains unknown and dubious. This study reveals that heteroscedasticity is inherently introduced by data projection with a varying scaling factor. Parameter standard errors that are estimated by linearly projected data without any appropriate treatments for non-homoscedasticity are definitely biased, and possibly above or below their true values. To ensure valid statistical tests of significance and prevent exposure to uninformed and unnecessary risk in applications, a generic analytical distribution-free (ADF) method and an equivalent scaling factor (ESF) method are proposed to adjust the parameter standard errors for a generalized multivariate polynomial model, based on the reported residual sum of squares. The ESF method transforms a transport model into a linear function of the scaling factor before calibration, which provides an alternative solution path for achieving unbiased parameter estimations. Simulation results demonstrate the robustness of the ESF method compared with the ADF method at high model nonlinearity. Case studies are conducted to illustrate the applicability of the ESF method for the parameter standard error estimations of six Macroscopic Bureau of Public Road functions, which are calibrated using real-world global positioning system data obtained from Hong Kong.

The economics of workplace charging

- Transportation Research Part B: Methodological---2016---Gebeyehu Fetene,Georg Hirte,Sigal Kaplan,Carlo G. Prato,Stefan Tscharaktschiew

To overcome the range-anxiety problem and further shortcomings associated with electric vehicles, workplace charging (WPC) is gaining increasing attention.

We propose a microeconomic model of WPC and use the approach to shed light on the incentives and barriers employees and employers face when deciding on demand for and supply of WPC. It is shown that under market conditions there is no WPC contract an employer is willing to offer and at the same time the majority of employees is willing to accept. To overcome the lack of demand or underprovision of WPC we discuss various ‘remedies’, involving subsidies to charging facility costs and adjustments in electricity tariffs or loading technologies. We find that direct subsidies to WPC facilities or subsidies combined with specific energy price policies could be a way to foster WPC provision. In contrast measures on the employee side that may help to stimulate the demand for WPC turn out to be less feasible. Hence, our results suggest that in order to promote WPC it is more promising to support employers in offering WPC contracts than to provide employees an incentive to accept WPC contracts. The study therefore gives a rationale for public initiatives being undertaken to boost WPC provision, as e.g. in the case of the US.

Effect of stochastic transition in the fundamental diagram of traffic flow

- Transportation Research Part B: Methodological---2016---Adriano F. Siqueira,Carlos J.T. Peixoto,Chen Wu,Wei-Liang Qian

In this work, we propose an alternative stochastic model for the fundamental diagram of traffic flow with minimal number of parameters. Our approach is based on a mesoscopic viewpoint of the traffic system in terms of the dynamics of vehicle speed transitions. A key feature of the present approach lies in its stochastic nature which makes it possible to study not only the flow-concentration relation, namely, the fundamental diagram, but also its uncertainty, namely, the variance of the fundamental diagram—an important characteristic in the observed traffic flow data. It is shown that in the simplified versions of the model consisting of only a few speed states, analytic solutions for both quantities can be obtained, which facilitate the discussion of the corresponding physical content. We also show that the effect of vehicle size can be included into the model by introducing the maximal congestion density kmax. By making use of this parameter, the free flow region and congested flow region are naturally divided, and the transition is characterized by the capacity drop at the maximum of the flow-concentration relation. The model parameters are then adjusted to the observed traffic flow on the I-80 Freeway Dataset in the San Francisco area from the NGSIM program, where both the fundamental diagram and its variance are reasonably reproduced. Despite its simplicity, we argue that the current model provides an alternative description for the fundamental diagram and its uncertainty in the study of traffic flow.

An integrated micro–macro approach to robust railway timetabling

- Transportation Research Part B: Methodological---2016---Nikola Bešinović,Rob M.P. Goverde,Egidio Quaglietta,Roberto Roberti

With the increasing demand for railway transportation infrastructure managers need improved automatic timetabling tools that provide feasible timetables with enhanced performance in short computation times. This paper proposes a hierarchical framework for timetable design which combines a microscopic and a macroscopic model of the network. The framework performs an iterative adjustment of train running and minimum headway times until a feasible and stable timetable has been generated at the microscopic level. The macroscopic model optimizes a trade-off between minimal travel times and maximal robustness using an Integer Linear Programming formulation which includes a measure for delay recovery computed by an integrated delay propagation model in a Monte Carlo setting. The application to an area of the Dutch railway network shows the ability of the approach to automatically compute a feasible, stable and robust timetable. Practitioners can use this approach both for effective timetabling and post-evaluation of existing timetables.

A self-adaptive method to equalize headways: Numerical analysis and comparison

- Transportation Research Part B: Methodological---2016---Shidong Liang,Shuzhi Zhao,Chunxiu Lu,Minghui Ma

In uncontrolled bus systems, buses tend to bunch due to the stochastic nature of traffic flows and passenger demand at bus stops. Although schedules and priori target methods introduce slack time to delay buses at control points to maintain constant headways between successive buses, too much slack required delay passengers on-board. In addition, these methods focus on regular headways and do not consider the rates of convergence of headways after disturbances. We propose a self-adaptive control scheme to equalize the headways of buses with little slack in a single line automatically. The proposed method only requires the information from the current bus at the control point and both its leading and following buses. This elegant method is shown to regulate headways faster than existing methods. In addition, compared to previous self-equalizing methods, the proposed method can improve the travel time of buses by about 12%, while keeping the waiting time of passengers almost the same.

Stochastic Poisson game for an online decentralized and coordinated parking mechanism

- Transportation Research Part B: Methodological---2016---Lili Du,Siyuan Gong

This paper proposes a decentralized and coordinated online parking mechanism (DCPM), which seeks to reduce parking congestion at multiple parking facilities in a central business district (CBD) through guiding the parking decisions of a parking coordination group. To establish this DCPM, this study develops a stochastic Poisson game to model the competitions among parking vehicles en route at multiple parking facilities. The equilibrium condition for the proposed stochastic Poisson game is formulated through involving travelers' parking choice behavior described by multinomial logit model. Furthermore, we prove that the stochastic Poisson game is a potential game with a unique equilibrium. A simultaneously updating distributed algorithm is developed to search the equilibrium solution of the DCPM. Its convergence is proved by both mathematical analysis and numerical experiments. The numerical experiments are conducted to test the efficiency of the DCPM, based on a real-world CBD covering Guicheng Community, Nanhai District at Foshan in China. The performance of the DCPM is compared to three greedy strategies following the nearest first, cheapest first, and least cruise first policies, respectively. The experimental results demonstrate that the DCPM significantly reduces cruise vehicles and average cruise distance per vehicle from all other three greedy strategies; the least cruise first strategy, which takes advantage of the real-time open spots information at parking facilities, performs better than the nearest first and the cheapest first strategies without the access to real-time information. The DCPM can further improve the benefit of the real-time information. Additionally, in terms of walking distance and parking cost, the DCPM provide a trade-off solution between the nearest first and the cheapest first strategies.

Solving the User Optimum Privately Owned Automated Vehicles Assignment Problem (UO-POAVAP): A model to explore the impacts of self-driving vehicles on urban mobility

- Transportation Research Part B: Methodological---2016---Gonçalo Homem de Almeida Correia,Bart van Arem

Interest in vehicle automation has been growing in recent years, especially with the very visible Google car project. Although full automation is not yet a reality there has been significant research on the impacts of self-driving vehicles on traffic flows, mainly on interurban roads. However, little attention has been given to what could happen to urban mobility when all vehicles are automated. In this paper we propose a new method to study how replacing privately owned conventional vehicles with automated ones affects traffic delays and parking demand in a city. The model solves what we designate as the User Optimum Privately Owned Automated Vehicles Assignment Problem (UO-POAVAP), which dynamically assigns family trips in their automated vehicles in an urban road network from a user equilibrium perspective where, in equilibrium, households with similar trips should have similar transport costs. Automation allows a vehicle to travel without passengers to satisfy multiple household trips and, if needed, to park itself in any of the network nodes to benefit from lower parking charges. Nonetheless, the empty trips can also represent added congestion in the network. The model was applied to a case study based on the city of Delft, the Netherlands. Several experiments were done, comparing scenarios where parking policies and value of travel time (VTT) are changed. The model shows good equilibrium convergence with a small difference between the general costs of traveling for similar families. We were able to conclude that vehicle automation reduces generalized transport costs, satisfies more trips by car and is associated with increased traffic congestion because empty vehicles have to be relocated. It is possible for a city to charge for all street parking and create free central parking lots that will keep total transport costs the same, or reduce them. However, this will add to congestion as traffic competes to access those central nodes. In a scenario where a lower VTT is experienced by the travelers, because of the added comfort of vehicle automation, the car mode share increases. Nevertheless this may help to reduce traffic congestion because some vehicles will reroute to satisfy trips which previously were not cost efficient to be done by car. Placing the free parking in the outskirts is less attractive due to the extra kilometers but with a lower VTT the same private vehicle demand would be attended with the advantage of freeing space in the city center.

A rough-cut approach for evaluating location-routing decisions via approximation algorithms

- Transportation Research Part B: Methodological--2016---Mozart B.C. Menezes,Diego Ruiz-Hernández,Vedat Verter

The first step in most location-routing projects involves bringing the primary stakeholders on board and securing funding for implementation of the required changes. To this end, practitioners often need a good feasible solution together with a lower bound on the cost of any solution to the problem at hand, rather than exact solutions based on detailed and accurate parameter estimates. In this article, we present a simple methodology for assessing the quality of the current distribution network as well as for identifying opportunities for improvement. We incorporate the potential use of different transportation technologies at different layers of the network. We demonstrate the versatility of the proposed rough-cut approach by means of two real life implementations: (i) redesigning the supply network of the Casino Group, a supermarket chain in southeast France, and (ii) redesigning the household material recycling network of the city of Calgary, in Canada.

Information metrics for improved traffic model fidelity through sensitivity analysis and data assimilation

- Transportation Research Part B: Methodological--2016---A. Sopasakis,M.A. Katsoulakis

We develop theoretical and computational tools which can appraise traffic flow models and optimize their performance against current time-series traffic data and prevailing conditions. The proposed methodology perturbs the parameter space and undertakes path-wise analysis of the resulting time series. Most importantly the approach is valid even under non-equilibrium conditions and is based on procuring path-space (time-series) information. More generally we propose a mathematical methodology which quantifies traffic information loss.

Transportation service procurement problem with transit time

- Transportation Research Part B: Methodological--2016---Qian Hu,Zhenzhen Zhang,Andrew Lim

In this work, we investigate transit time in transportation service procurement, which is conducted by shippers using auctions to purchase transportation service from carriers in the planning stage. Besides cost, we find that many shippers are most concerned with transit time in practice; shorter transit time indicates better transportation service. To minimize both the total cost and transit time, the problem faced by shippers is the biobjective transportation service procurement problem with transit time. To solve the problem, we introduce a biobjective integer programming model that can also accommodate some important business constraints. A biobjective branch-and-bound algorithm that finds all extreme supported nondominated solutions is developed. To speed up the algorithm, two fast feasibility checks, a network flow model for particular subproblems, and lower bounds from relaxation are proposed. In addition, a sophisticated heuristic is introduced to meet shipper’s requirements in some situations. Computational experiments on evaluating the performance of the algorithms are conducted on a set of test instances that are generated from practical data.

Collaborative truck scheduling and appointments for trucking companies and container terminals

- Transportation Research Part B: Methodological---2016---Mai-Ha Phan,Kap Hwan Kim

Appointment systems for truck arrivals at container terminals have been applied in many ports to reduce truck congestion. This study suggests a new appointment process by which trucking companies and terminals collaboratively determine truck operation schedules and truck arrival appointments. This study formulates a mathematical model involving a sub-problem for each trucking company to determine the optimal dispatching schedules for trucks and the other sub-problem for the terminal to estimate the expected truck system time in each time interval. An iterative collaboration process is proposed based on a decomposed mathematical formulation. Numerical experiments are conducted to investigate the performance of the decision process and the robustness of the process in practical operation conditions.

The design of capacitated intermodal hub networks with different vehicle types

- Transportation Research Part B: Methodological---2016---Elif Zeynep Serper,Sibel A. Alumur

In this study, we allow using alternative transportation modes and different types of vehicles in the hub networks to be designed. The aim of the problem is to determine the locations and capacities of hubs, which transportation modes to serve at hubs, allocation of non-hub nodes to hubs, and the number of vehicles of each type to operate on the hub network to route the demand between origin-destination pairs with minimum total cost. Total cost includes fixed costs of establishing hubs with different capacities, purchasing and operational costs of vehicles, transportation costs, and material handling costs. A mixed-integer programming model is developed and a variable neighborhood search algorithm is proposed for the solution of this problem. The heuristic algorithm is tested on instances from the Turkish network and CAB data set. Extensive computational analyzes are conducted in order to observe the effects of changes in various problem parameters on the resulting hub networks.

Robust intermodal hub location under polyhedral demand uncertainty

- Transportation Research Part B: Methodological---2016---Merve Meraklı,Hande Yaman

In this study, we consider the robust uncapacitated multiple allocation p-hub median problem under polyhedral demand uncertainty. We model the demand uncertainty in two different ways. The hose model assumes that the only available information is the upper limit on the total flow adjacent at each node, while the hybrid model additionally imposes lower and upper bounds on each pairwise demand. We propose linear mixed integer programming formulations using a minmax criteria and devise two Benders decomposition based exact solution algorithms in order to solve large-scale problems. We report the results of our computational experiments on the effect of incorporating uncertainty and on the performance of our exact approaches.

Physics of day-to-day network flow dynamicsAuthor-Name: Xiao, Feng

- Transportation Research Part B: Methodological---2016---Hai Yang,Hongbo Ye

This paper offers a new look at the network flow dynamics from the viewpoint of physics by demonstrating that the traffic system, in terms of the aggregate effects of human behaviors, may exhibit like a physical system. Specifically, we look into the day-to-day evolution of network flows that arises from travelers’ route choices and their learning behavior on perceived travel costs. We show that the flow dynamics is analogous to a damped oscillatory system. The concepts of energies are introduced, including the potential energy and the kinetic energy. The potential energy, stored in each link, increases with the traffic flow on that link; the kinetic energy, generated by travelers’ day-to-day route swapping, is proportional to the square of the path flow changing speed. The potential and kinetic energies are converted to each other throughout the whole flow evolution, and the total system energy keeps decreasing owing to travelers’ tendency to stay on their current routes, which is analogous to the damping of a physical system. Finally, the system will approach the equilibrium state with minimum total potential energy and zero kinetic energy. We prove the stability of the day-to-day dynamics and provide numerical experiments to elucidate the interesting findings.

The Downs–Thomson paradox with imperfect mode substitutes and alternative transit administration regimes

- Transportation Research Part B: Methodological---2016---Fangni Zhang,Charles Lindsey,Hai Yang

The Downs–Thomson paradox (D–T paradox) occurs when expansion of a congested and untolled highway undermines scale economies of a competing transit service, leaving users of both modes worse off. The standard analysis of the D–T paradox is based on several stringent assumptions: fixed total travel demand, perfect substitutability between automobile and transit trips, and no transit crowding. This paper re-examines the paradox when these assumptions are relaxed while retaining the usual assumption that there is no congestion interaction between the modes. It also broadens consideration to alternative transit administration regimes. In the standard treatment the transit operator is obliged to cover its costs. In this paper we also study two other regimes: transit profit maximization, and system-wide welfare maximization with no financing constraint. We examine how the transit system operator responds to highway capacity expansion in each regime, and how this affects welfare for drivers and transit users. We show that in all regimes the full price of transit declines only if the full price of driving falls as well. Thus, drivers are more likely to benefit from highway expansion than transit riders. The D–T paradox cannot occur in the profit maximization or unconstrained welfare maximization regimes. In the traditional self-financing regime transit service deteriorates, but the D–T paradox is not inevitable. Numerical analysis suggests that it can occur only when automobile and transit trips are nearly perfect substitutes.

Long-term planning for ring-radial urban rail transit networksAuthor-Name: Saidi, Saeid

- Transportation Research Part B: Methodological---2016---S.C. Wirasinghe,Lina Kattan

Extensive work exists on regular rail network planning. However, few studies exist on the planning and design of ring-radial rail transit systems. With more ring transit lines being planned and built in Asia, Europe and the America’s, a detailed study on ring transit lines is timely. An analytical model to find the optimal number of radial lines in a city for any demand distribution is first introduced. Secondly, passenger route choice for different rail networks is analyzed, for a many-to-many Origin-Destination (OD) demand distribution, based on a total travel time cost per passenger basis. The routes considered are: (1) radial lines only; (2) ring line only or radial lines and ring line combined; or (3) direct access to a destination without using the rail system. Mathematica and Matlab are used to code the route choice model. A cost-benefit optimization model to identify the feasibility and optimality of a ring line is proposed. Unlike simulations and agent-based models, this model is shown to be easily transferable to many ring-radial transit networks. The City of Calgary is used as an example to illustrate the applicability of each model. The existing urban rail network and trip distribution are major influencing factors in judging the feasibility and optimal location of the ring line. This study shows the potential net benefit of introducing a ring line by assessing changes in passengers' costs. The changes in passenger cost parameters, such as ride cost and access cost, are shown to greatly influence the feasibility of a ring line.

Miles, speed, and technology: Traffic safety under oligopolistic insurance

- Transportation Research Part B: Methodological---2016---Maria Dementyeva,Erik Verhoef

We study road safety when insurance companies have market power, and can influence drivers' behavior via insurance premiums. We obtain first- and second-best premiums for different insurance market structures. The insurance program consists of an insurance premium, and marginal dependencies of that premium on speed and own safety technology choice of drivers. A private monopolist internalizes collision externalities up to the point where compensations to users' benefit matches the full (intangible) costs; in oligopolistic markets, insurers do not fully internalize collision externalities. Analytical results demonstrate how insurance firms' incentives to influence traffic safety coincide with or deviate from socially optimal incentives. Our results may be useful for design of pay-as-you-speed and alike insurances as well as policies related to driving safety.

The electric vehicle touring problem

- Transportation Research Part B: Methodological---2016---Chung-Shou Liao,Shang-Hung Lu,Zuo-Jun Max Shen

The increasing concern over global warming has led to the rapid development of the electric vehicle industry. Electric vehicles (EVs) have the potential to reduce the greenhouse effect and facilitate more efficient use of energy resources. In this paper, we study several EV route planning problems that take into consideration possible battery charging or swapping operations. Given a road network, the objective is to determine the shortest (travel time) route that a vehicle with a given battery capacity can take to travel between a pair of vertices or to visit a set of vertices with several stops, if necessary, at battery switch stations. We present polynomial time algorithms for the EV shortest travel time path problem and the fixed tour EV touring problem, where the fixed tour problem requires visiting a set of vertices in a given order. Based on the result, we also propose constant factor approximation algorithms for the EV touring problem, which is a generalization of the traveling salesman problem.

Infrastructure maintenance, regeneration and service quality economics: A rail example

- Transportation Research Part B: Methodological---2016---Marc Gaudry,Bernard Lapeyre,Émile Quinet

This paper proposes a formalized framework for the joint economic optimization of continuous maintenance and periodic regeneration of rail transport infrastructure taking into account output consisting not only in traffic levels but also in track service quality. In contrast with much optimization work pertaining to spatially contiguous maintenance works, its principal economic emphasis and objective focus are centered on the optimal allocation of current maintenance and periodic renewal expenses, on their yearly distribution among large network partitions, and on infrastructure pricing. The model equations are based on very simple assumptions of infrastructure degradation laws and on a manager's objective function optimized through optimal control procedures. Equations are tested on national French rail track segment databases using Box–Cox transformations and match rail regeneration and maintenance practices prevailing in France. More generally, the paper makes a broad contribution to capital theory, on the optimal maintenance and renewal of equipment, and defines a method applicable not only to other transport infrastructure but to a wide range of capital goods, including housing, cars and industrial machines.

Traffic flow on pedestrianized streets

- Transportation Research Part B: Methodological---2016---Carlos F. Daganzo,Victor L. Knoop

Giving pedestrians priority to cross a street enhances pedestrian life, especially if crosswalks are closely spaced. Explored here is the effect of this management decision on car traffic. Since queuing theory suggests that for a given pedestrian flux the closer the crosswalk spacing the lower the effect of pedestrians on cars, scenarios where pedestrians can cross anywhere should be best for both cars and pedestrians. This is the kind of pedestrianization studied.

On allowing a general form for unobserved heterogeneity in the multiple discrete–continuous probit model: Formulation and application to tourism travelAuthor-Name: Bhat, Chandra R

- Transportation Research Part B: Methodological---2016---Sebastian Astroza,Aarti C. Bhat

This paper proposes a new econometric formulation and an associated estimation method for a finite discrete mixture of normals (FDMN) version of the multiple discrete–continuous probit (MDCP) model. To our knowledge, this is the first such formulation and application of an MDCP model in the econometric literature. Using the New Zealand Domestic Travel Survey data set, the model is applied to analyze individual-level decisions regarding recreational destination locations and the number of trips to each destination. The results provide insights into the demographic and other factors that influence individuals' preferences for different destinations, and show that the FDMN MDCP model is able to identify different segments of the sample, each one of them with different effects of the exogenous variables on destination choice.

Reinforcement learning approach for train rescheduling on a single-track railway

- Transportation Research Part B: Methodological---2016---D. Šemrov,R. Marsetič,M. Žura,L. Todorovski,A. Srdic

Optimal rail network infrastructure and rolling stock utilization can be achieved with use of different scheduling tools by extensive planning a long time before actual operations. The initial train timetable takes into account possible smaller disturbances, which can be compensated within the schedule. Bigger disruptions, such as accidents, rolling stock breakdown, prolonged passenger boarding, and changed speed limit cause delays that require train rescheduling. In this paper, we introduce a train rescheduling method based on reinforcement learning, and more specifically, Q-learning. We present here the Q-learning principles for train rescheduling, which consist of a learning agent and its actions, environment and its states, as well as rewards. The use of the proposed approach is first illustrated on a simple rescheduling problem comprising a single-lane track with three trains. The evaluation of the approach is performed on extensive set of experiments carried out on a real-world railway network in Slovenia. The empirical results show that Q-learning lead to rescheduling solutions that are at least equivalent and often superior to those of several basic rescheduling methods that do not rely on learning agents. The solutions are learned within reasonable computational time, a crucial factor for real-time applications.

Continuum modelling of spatial and dynamic equilibrium in a travel corridor with heterogeneous commuters—A partial differential complementarity system approach

- Transportation Research Part B: Methodological---2016---David Z.W. Wang,Bo Du

This paper studies on modelling and solving spatial and dynamic equilibrium travel pattern in a travel corridor. Consider a travel corridor connecting continuously distributed commuters to the city centre. The traffic is subject to flow congestion and the commuter heterogeneity is captured. The traffic flow dynamics is described by flow continuity equation and the equilibrium travel pattern is assumed to follow trip-timing condition. The continuous spatial and dynamic equilibrium travel pattern is formulated into a partial differential complementarity system, which is then solved through Godunov scheme. The proof of solution existence is provided, and a set of numerical experiments are demonstrated.

A probabilistic model for vehicle scheduling based on stochastic trip times

- Transportation Research Part B: Methodological---2016---Yindong Shen,Jia Xu,Jingpeng Li

Vehicle scheduling plays a profound role in public transit planning. Traditional approaches for the Vehicle Scheduling Problem (VSP) are based on a set of predetermined trips in a given timetable. Each trip contains a departure point/time and an arrival point/time whilst the trip time (i.e. the time duration of a trip) is fixed. Based on fixed durations, the resulting schedule is hard to comply with in practice due to the variability of traffic and driving conditions. To enhance the robustness of the schedule to be compiled, the VSP based on stochastic trip times instead of fixed ones is studied. The trip times follow the probability distributions obtained from the data captured by Automatic Vehicle Locating (AVL) systems. A network flow model featuring the stochastic trips is devised to better represent this problem, meanwhile the compatibility of any pair of trips is redefined based on trip time distributions instead of fixed values as traditionally done. A novel probabilistic model of the VSP is proposed with the objectives of minimizing the total cost and maximizing the on-time performance. Experiments show that the probabilistic model may lead to more robust schedules without increasing fleet size.

Pricing and competition in a shipping market with waste shipments and empty container repositioning

- Transportation Research Part B: Methodological---2016---Rongying Chen,Jing-Xin Dong,Chung-Yee Lee

In this paper, we study a shipping market with carriers providing services between two locations. Shipments are classified into two categories: goods and waste. Trade imbalance allows low-valued waste to be shipped at bargain rates. If imbalance persists, empty containers must be repositioned from a surplus location to a shortage location. Carriers decide prices, which will affect the demand. We build a monopoly and a duopoly model to find the optimal pricing strategy for carriers. We also analyze how the profit of a carrier is affected by price sensitivity, cost structure and competition intensity.

Optimal choice of capacity, toll and government guarantee for build-operate-transfer roads under asymmetric cost informationAuthor-Name: Shi, Shasha

- Transportation Research Part B: Methodological---2016---Yafeng Yin,Xiaolei Guo

The private provision of public roads via the build-operate-transfer (BOT) mode has been increasingly used around the world. By viewing a BOT contract as a combination of road capacity, toll and government guarantee, this paper investigates optimal concession contract design under both symmetric and asymmetric information about the marginal maintenance cost of private investors. Under asymmetric information, the government guarantee serves as an instrument to induce a private investor to reveal his true cost information. Compared with the situation under symmetric information, the government will suffer a loss of social welfare; the private investor will charge a higher toll that increases in his reported marginal maintenance cost, and specify a lower capacity that decreases with the reported cost. The results also show that the private investor obtains extra information rent beyond the reservation level of return and the rent decreases with his reported cost. However, the resulting volume-capacity ratios of the BOT road under both information structures are the same.

Disruption risk management in railroad networks: An optimization-based methodology and a case studyAuthor-Name: Azad, Nader

- Transportation Research Part B: Methodological---2016---Elkafi Hassini,Manish Verma

We propose an optimization-based methodology for recovery from random disruptions in service legs and train services in a railroad network. A network optimization model is solved for each service leg to evaluate a number of what-if scenarios. The solutions of these optimization problems are then used in a predictive model to identify the critical disruption factors and accordingly design a suitable mitigation strategy. A mitigation strategy, such as adding flexible or redundant capacity in the network, is an action that is deliberately taken by management in order to hedge against the cost and impact of disruption if it occurs. It is important that managers consider the trade-offs between the cost of mitigation strategy and the expected cost of disruption. The proposed methodology is applied to a case study built using the realistic infrastructure of a railroad network in the mid-west United States. The resulting analysis underscores the importance of accepting a slight increase in pre-disruption transportation costs, which in turn will enhance network resiliency by building dis-similar paths for train services, and by installing alternative links around critical service legs.

Ant colony optimization for the real-time train routing selection problem

- Transportation Research Part B: Methodological---2016---Marcella Samà,Paola Pellegrini,D’Ariano, Andrea,Joaquin Rodriguez,Dario Pacciarelli

This paper deals with the real-time problem of scheduling and routing trains in a railway network. In the related literature, this problem is usually solved starting from a subset of routing alternatives and computing the near-optimal solution of the simplified routing problem. We study how to select the best subset of routing alternatives for each train among all possible alternatives. The real-time train routing selection problem is formulated as an integer linear programming formulation and solved via an algorithm inspired by the ant colonies’ behavior. The real-time railway traffic management problem takes as input the best subset of routing alternatives and is solved as a mixed-integer linear program. The proposed methodology is tested on two practical case studies of the French railway infrastructure: the Lille terminal station area and the Rouen line. The computational experiments are based on several practical disturbed scenarios. Our methodology allows the improvement of the state of the art in terms of the minimization of train consecutive delays. The improvement is around 22% for the Rouen instances and around 56% for the Lille instances.

Should ports expand their facilities under congestion and uncertainty?

- Transportation Research Part B: Methodological---2016---Hsiao-Chi Chen,Shi-Miin Liu

This paper investigates simultaneous facility investments of risk-averse ports under congestion and uncertain market demand. We set up a two-period game, allowing two ports first choose their facility investment levels, and then decide their cargo-handling amounts and service prices. When investment costs of the two ports are large, the unique equilibrium is no investment. If investment costs of at least one port are small, then one or two ports will invest at equilibria. If both ports invest at equilibrium, they may become worse off than at non-equilibrium of no investment. This means that the ports may face a tradeoff between stability and efficiency. Moreover, we compare the behaviors of risk-averse and risk-neutral ports, as well as risk-averse ports’ behaviors under uncertainty and no-uncertainty. It is found that ports’ risk-averse degrees are the major factor determining their behaviors in different scenarios.

A route-swapping dynamical system and Lyapunov function for stochastic user equilibriumAuthor-Name: Smith, Michael J

- Transportation Research Part B: Methodological---2016---David P. Watling

An analysis of the continuous-time dynamics of a route-swap adjustment process is presented, which is a natural adaptation of that presented in Smith (1984) for deterministic choice problems, for a case in which drivers are assumed to make perceptual errors in their evaluations of travel cost according to a Random Utility Model. We show that stationary points of this system are stochastic user equilibria. A Lyapnuov function is developed for this system under the assumption of monotone, continuously differentiable and bounded cost-flow functions and a logit-based decision rule, establishing convergence and stability of trajectories of such a dynamical system with respect to a stochastic user equilibrium solution.

Boundedly rational route choice behavior: A review of models and methodologies

- Transportation Research Part B: Methodological---2016---Xuan Di,Henry X. Liu

Perfect rationality (PR) has been widely used in modeling travel behavior. As opposed to PR, bounded rationality (BR) has recently regained researchers' attention since it was first introduced into transportation science in the 1980s due to its power in more realistic travel behavior modeling and prediction. This paper provides a comprehensive survey on the models of BR route choice behavior, aiming to identify current research gaps and provide directions for future research. Despite a small but growing body of studies on employing bounded rationality principle, BR route choice behavior remains understudied due to the following reasons: (a) The existence of BR thresholds leads to mathematically intractable properties of equilibria; (b) BR parameters are usually latent and difficult to identify and estimate; and (c) BR is associated with human being's cognitive process and is challenging to model. Accordingly, we will review how existing literature addresses the aforementioned challenges in substantive and procedural bounded rationality models. Substantive bounded rationality models focus on choice outcomes while procedural bounded rationality models focus on the empirical studies of choice processes. Bounded rationality models in each category can be further divided based on whether time dimension is included. Accordingly, static and dynamic traffic assignment are introduced in substantive bounded rationality while two-stage cognitive models and day-to-day learning models in procedural bounded rationality are discussed. The methodologies employed in substantive bounded rationality include game theory and interactive congestion game, while those in procedural bounded rationality mainly adopt random utility and non- or semi-compensatory models. A comparison of all existing methodologies are given and bounded rationality models' scope and boundaries in terms of predictability, transferability, tractability, and scalability are discussed. Finally existing research gaps are presented and several promising future research directions are given.

Optimal location of advance warning for mandatory lane change near a two-lane highway off-ramp

- Transportation Research Part B: Methodological---2016---Siyuan Gong,Lili Du

Improper mandatory lane change (MLC) maneuvers in the vicinity of highway off-ramp will jeopardize traffic efficiency and safety. Providing an advance warning for lane change necessity is one of the efficient methods to perform systematic lane change management, which encourages smooth MLC maneuvers occurring at proper locations to mitigate the negative effects of MLC maneuvers on traffic flow nearby off-ramp. However, the state of the art indicates the lack of rigorous methods to optimally locate this advance warning so that the maximum benefit can be obtained. This research is motivated to address this gap. Specifically, the proposed approach considers that the area downstream of the advance warning includes two zones: (i) the green zone whose traffic ensures safe and smooth lane changes without speed deceleration (S-MLC); the start point of the green zone corresponding to the location of the advance warning; (ii) the yellow zone whose traffic leads to rush lane change maneuvers with speed deceleration (D-MLC). An optimization model is proposed to search for the optimal green and yellow zones. Traffic flow theory such as Greenshield model and shock wave analysis are used to analyze the impacts of the S-MLC and D-MLC maneuvers on the traffic delay. A grid search algorithm is applied to solve the optimization model. Numerical experiments conducted on the simulation model developed in Paramics 6.9.3 indicate that the proposed optimization model can identify the optimal location to set the advance MLC warning nearby an off-ramp so that the traffic delay resulting from lane change maneuvers is minimized, and the corresponding capacity drop and traffic oscillation can be efficiently mitigated. Moreover, the experiments validated the consistency of the green and yellow zones obtained in the simulation traffic flow and from the optimization model for a given optimally located MLC advance warning under various traffic regimes. The proposed approach can be implemented by roadside mobile warning facility or on-board GPS for human-driven vehicles, or embedded into lane change aid systems to serve connected and automated vehicles. Thus it will greatly contribute to both literature and engineering practice in lane change management.

Regulating inter-firm agreements: The case of airline codesharing in parallel networks

- Transportation Research Part B: Methodological---2016---Nicole Adler,Eran Hanany

We compare aviation markets under conditions of competition, codesharing contracts and anti-trust immune alliances, assuming that demand for flights depends on both fares and the level of frequency offered. Using a hybrid competitive/cooperative game theoretic framework, we show that the stronger the inter-airline agreement on overlapping routes, the higher the producer surplus. On the other hand, consumer surplus and overall social welfare are maximized under limited codesharing agreements. Partial mergers appear preferable to no agreement in ‘thin’ markets, in which both demand and profit margins are relatively low. Inter-governmental agreements are also analyzed and we show that bilaterals create the least favorable market outcomes for consumers and producers. Finally, a realistic case study demonstrates that under asymmetric and uncertain demand, codesharing on parallel links may be preferable to competitive outcomes for multiple consumer types.

Mechanisms that govern how the Price of Anarchy varies with travel demand

- Transportation Research Part B: Methodological---2016---O'Hare, Steven J.,Richard D. Connors,David P. Watling

Selfish routing, represented by the User-Equilibrium (UE) model, is known to be inefficient when compared to the System Optimum (SO) model. However, there is currently little understanding of how the magnitude of this inefficiency, which can be measured by the Price of Anarchy (PoA), varies across different structures of demand and supply. Such understanding would be useful for both transport policy and network design, as it could help to identify circumstances in which policy interventions that are designed to induce more efficient use of a traffic network, are worth their costs of implementation.

The impact of depot location, fleet composition and routing on emissions in city logistics

- Transportation Research Part B: Methodological---2016---Çağrı Koç,Tolga Bektaş,Ola Jabali,Gilbert Laporte

This paper investigates the combined impact of depot location, fleet composition and routing decisions on vehicle emissions in city logistics. We consider a city in which goods need to be delivered from a depot to customers located in nested zones characterized by different speed limits. The objective is to minimize the total depot, vehicle and routing cost, where the latter can be defined with respect to the cost of fuel consumption and CO_2 emissions. A new powerful adaptive large neighborhood search metaheuristic is developed and successfully applied to a large pool of new benchmark instances. Extensive analyses are performed to empirically assess the effect of various problem parameters, such as depot cost and location, customer distribution and heterogeneous vehicles on key performance indicators, including fuel consumption, emissions and operational costs. Several managerial insights are presented.

Optimization of incentive polices for plug-in electric vehicles

- Transportation Research Part B: Methodological--2016---Nie, Yu (Marco),Mehrnaz Ghamami,Ali Zockaie,Feng Xiao

High purchase prices and the lack of supporting infrastructure are major hurdles to the adoption of plug-in electric vehicles (PEVs). It is widely recognized that the government could help break these barriers through incentive policies, such as offering rebates to PEV buyers or funding charging stations. The objective of this paper is to propose a modeling framework that can optimize the design of such incentive policies. The proposed model characterizes the impact of the incentives on the dynamic evolution of PEV market penetration over a discrete set of time intervals, by integrating a simplified consumer vehicle choice model and a macroscopic travel and charging model. The optimization problem is formulated as a nonlinear and non-convex mathematical program and solved by a specialized steepest descent direction algorithm. We show that, under mild regularity conditions, the KKT conditions of the proposed model are necessary for local optimum. Results of numerical experiments indicate that the proposed algorithm is able to obtain satisfactory local optimal policies quickly. These optimal policies consistently outperform the alternative policies that mimic the state-of-the-practice by a large margin, in terms of both the total savings in social costs and the market share of PEVs. Importantly, the optimal policy always sets the investment priority on building charging stations. In contrast, providing purchase rebates, which is widely used in current practice, is found to be less effective.

Reducing the passenger travel time in practice by the automated construction of a robust railway timetable

- Transportation Research Part B: Methodological--2016---P. Sels,T. Dewilde,D. Cattrysse,P. Vansteenwegen

Automatically generating timetables has been an active research area for some time, but the application of this research in practice has been limited. We believe this is due to two reasons. Firstly, some of the models in the literature impose artificial upper bounds on time supplements. This causes a high risk of generating infeasibilities. Secondly, some models that leave out these upper bounds often generate solutions that contain some very large time supplements because these supplements are not penalised in the objective function. The reason is that these objective functions often do not completely correspond to the true goal of a timetable. We solve both problems by minimising our objective function: total passenger travel time, expected in practice. Since this function evaluates and indirectly steers all time related decision variables in the system, we do not need to further restrict the ranges of any of these variables. As a result, our model does not suffer from infeasibilities generated by such artificial upper bounds for supplements.

Two-phase stochastic program for transit network design under demand uncertainty

- Transportation Research Part B: Methodological--2016---Kun An,Hong K. Lo

This paper develops a reliability-based formulation for rapid transit network design under demand uncertainty. We use the notion of service reliability to confine the stochastic demand into a bounded uncertainty set that the rapid transit network is designed to cover. To evaluate the outcome of the service reliability chosen, flexible services are introduced to carry the demand overflow that exceeds the capacity of the rapid transit network such designed. A two-phase stochastic program is formulated, in which the transit line alignments and frequencies are determined in phase 1 for a specified level of service reliability; whereas in phase 2, flexible services are determined depending on the demand realization to capture the cost of demand overflow. Then the service reliability is optimized to minimize the combined rapid transit network cost obtained in phase 1, and the flexible services cost and passenger cost obtained in phase 2. The transit line alignments and passenger flows are studied under the principles of system optimal (SO) and user equilibrium (UE). We then develop a two-phase solution algorithm that combines the gradient method and neighborhood search and apply it to a series of networks. The results demonstrate the advantages of utilizing the two-phase formulation to determine the service reliability as compared with the traditional robust formulation that pre-specifies a robustness level.

Forecasting light-duty vehicle demand using alternative-specific constants for endogeneity correction versus calibration

- Transportation Research Part B: Methodological---2016---C. Grace Haaf,W. Ross Morrow,Inês M.L. Azevedo,Elea McDonnell Feit,Jeremy J. Michalek

We investigate parameter recovery and forecast accuracy implications of incorporating alternative-specific constants (ASCs) in the utility functions of vehicle choice models. We compare two methods of incorporating ASCs: (1) a maximum likelihood estimator that computes ASCs post-hoc as calibration constants (MLE-C) and (2) a generalized method of moments estimator that uses instrumental variables (GMM-IV) to correct for price endogeneity. In a synthetic study we observe significant coefficient bias with MLE-C when the price-ASC correlation (endogeneity) is large. GMM-IV successfully mitigates this bias given valid instruments but exacerbates the bias given invalid instruments. Despite greater coefficient bias, MLE-C yields better forecasts than GMM-IV with valid instruments in most of the cases examined, including most cases where the price-ASC correlation present in the estimation data is absent in the prediction data. In a market study of U.S. midsize sedan sales from 2002 – 2006 the GMM-IV model predicts the 1-year-forward market better, but the MLE-C model predicts the 5-year-forward market better. Including an ASC in predictions by any of the methods proposed improves share forecasts, and assuming that the ASC of each new vehicle matches that of its closest competitor vehicle yields the best long term forecasts. We find evidence that the instruments most frequently used in the automotive demand literature may be invalid.

A math-heuristic algorithm for the integrated air service recovery

- Transportation Research Part B: Methodological---2016---Dong Zhang,Chuhang Yu,Jitamitra Desai,H.Y.K. Henry Lau

A sophisticated flight schedule might be easily disrupted due to adverse weather, aircraft mechanical failures, crew absences, etc. Airlines incur huge costs stemming from such flight schedule disruptions in addition to the serious inconveniences experienced by passengers. Therefore, an efficient recovery solution that simultaneously decreases an airline's recovery cost while simultaneously mitigating passenger dissatisfaction is of great importance to the airline industry. In this paper, we study the integrated airline service recovery problem in which the aircraft and passenger schedule recovery problems are simultaneously addressed, with the objective of minimizing aircraft recovery and operating costs, passenger itinerary delay cost, and passenger itinerary cancellation cost.

A marginal utility day-to-day traffic evolution model based on one-step strategic thinkingAuthor-Name: He, Xiaozheng

- Transportation Research Part B: Methodological---2016---Srinivas Peeta

Most deterministic day-to-day traffic evolution models, either in continuous-time or discrete-time space, have been formulated based on a fundamental assumption on driver route choice rationality where a driver seeks to maximize her/his marginal benefit defined as the difference between the perceived route costs. The notion of rationality entails the exploration of the marginal decision rule from economic theory, which states that a rational individual evaluates his/her marginal utility, defined as the difference between the marginal benefit and the marginal cost, of each incremental decision. Seeking to analyze the marginal decision rule in the modeling of deterministic day-to-day traffic evolution, this paper proposes a modeling framework which introduces a term to capture the marginal cost to the driver induced by route switching. The proposed framework enables to capture both benefit and cost associated with route changes. The marginal cost is then formulated upon the assumption that drivers are able to predict other drivers' responses to the current traffic conditions, which is adopted based on the notion of strategic thinking of rational players developed in behavior game theory. The marginal cost based on 1-step strategic thinking also describes the "shadow price" of shifting routes, which helps to explain the behavioral tendency of the driver perceiving the cost-sensitivity to link/route flows. After developing a formulation of the marginal utility day-to-day model, its theoretical properties are analyzed, including the invariance property, asymptotic stability, and relationship with the rational behavioral adjustment process.

Integrating a heterogeneous fixed fleet and a flexible assignment of destination depots in the waste collection VRP with intermediate facilities

- Transportation Research Part B: Methodological--2016---Iliya Markov,Sacha Varone,Michel Bierlaire

We consider a complex recyclable waste collection problem that extends the class of vehicle routing problems with intermediate facilities by integrating a heterogeneous fixed fleet and a flexible assignment of destination depots. Several additional side constraints, such as a mandated break period contingent on tour start time, multiple vehicle capacities, and site dependencies are also included. This specific problem was inspired by a real-world application and does not appear in the literature. It is modeled as an MILP which is enhanced with several valid inequalities. Due to the rich nature of the problem, state-of-the-art solvers are only able to tackle instances of small to medium size. To solve realistic instances, we propose a multiple neighborhood search heuristic capable of systematically treating all problem features and general enough to respond to the varying characteristics of the case study regions for which it is intended. The results show that the heuristic achieves optimality on small instances, exhibits competitive performance in comparison to state-of-the-art solution methods for special cases of our problem, and leads to important savings in the state of practice. Moreover, it highlights and quantifies the savings from allowing a flexible depot assignment. The data from the state of practice comes from a company in the waste collection industry in Geneva, Switzerland.

Real-time holding control for high-frequency transit with dynamics

- Transportation Research Part B: Methodological--2016---G.E. Sánchez-Martínez,H.N. Koutsopoulos,N.H.M. Wilson

Operations control is an important means of improving service quality for high-frequency transit. Past research on real-time control has focused on developing and evaluating the effectiveness of different control strategies, largely relying on running times and demand which are assumed to be static. We formulate a mathematical model for holding control optimization that reflects dynamic running times and demand. The model can be used to produce a plan of holding times that accounts not only for the current state of the system, but also for expected changes in running times and demand. We evaluate the effectiveness of the model within a simulation environment. The results show that control based on dynamic inputs outperforms its static equivalent in high demand cases where passengers can be left behind at stops, and to a lesser extent in low to moderate demand cases with time-varying running times.

Regulating hazardous materials transportation by dual toll pricing

- Transportation Research Part B: Methodological---2016---Tolou Esfandeh,Changhyun Kwon,Rajan Batta

We investigate dual-toll setting as a policy tool to mitigate the risk of hazardous material (hazmat) shipment in road networks. We formulate the dual-toll problem as a bi-level program wherein the upper level aims at minimizing the risk, and the lower level explores the user equilibrium decision of the regular vehicles and hazmat carriers given the toll. When the upper level objective is to minimize the risk and all links are tollable, we decompose the formulation into first-stage and second-stage, and suggest a computational method to solve each stage. Our two-stage solution methodology guarantees nonnegative valid dual tolls regardless of the solution accuracy of the first-stage problem. We also consider a general dual-toll setting problem where the regulator rather wishes to minimize a combination of risk and the paid tolls and/or some links are untollable. To solve this truly bilevel problem, we provide heuristic algorithms that decompose the problem into subproblems each being solved by a line search. Case studies based on the Sioux Falls network illustrate the insights on the dual-toll policies.

Modeling and optimization of multimodal urban networks with limited parking and dynamic pricing

- Transportation Research Part B: Methodological---2016---Nan Zheng,Nikolas Geroliminis

Cruising-for-parking constraints mobility in urban networks. Car-users may have to cruise for on-street parking before reaching their destinations. The accessibility and the cost of parking significantly influence people's travel behavior (such as mode choice, or parking facility choice between on-street and garage). The cruising flow causes delays eventually to everyone, even users with destinations outside limited parking areas. It is therefore important to understand the impact of parking limitation on mobility, and to identify efficient parking policies for travel cost reduction. Most existing studies on parking fall short in reproducing the dynamic spatiotemporal features of traffic congestion in general, lack the treatment of dynamics of the cruising-for-parking phenomenon, or require detailed input data that are typically costly and difficult to collect. In this paper, we propose an aggregated and dynamic approach for modeling multimodal traffic with the treatment on parking, and utilize the approach to design dynamic parking pricing strategies. The proposed approach is based on the Macroscopic Fundamental Diagram (MFD), which can capture congestion dynamics at network-level for single-mode and bi-modal (car and bus) systems. A parsimonious parking model is integrated into the MFD-based multimodal modeling framework, where the dynamics of vehicular and passenger flows are considered with a change in the aggregated behavior (e.g. mode choice and parking facility choice) caused by cruising and congestion. Pricing strategies are developed with the objective of reducing congestion, as well as lowering the total travel cost of all users. A case study is carried out for a bi-modal city network with a congested downtown region. An elegant feedback dynamic parking pricing strategy can effectively reduce travel delay of cruising and the generic congestion. Remarkably, such strategy, which is applicable in real-time management with limited available data, is fairly as efficient as a dynamic pricing scheme obtained from system optimum conditions and a global optimization with full information about the future states of the system. Stackelberg equilibrium is also investigated in a competitive behavior between different parking facility operators. Policy indications on on-street storage capacity management and pricing are provided.

Bottleneck congestion: Differentiating the coarse charge

- Transportation Research Part B: Methodological---2016---Jasper Knockaert,Erik Verhoef,Jan Rouwendal

The traditional bottleneck model for road congestion promotes the implementation of a triangular, and time varying, charge as the optimal solution for the road congestion externality. However, cognitive and technological barriers put a practical limit to the degree of differentiation real world implementations can handle. The traditional approach to accommodate for this concern has been a step toll, with the single step coarse charge as its simplest case.

Second best toll pricing within the framework of bounded rationality

- Transportation Research Part B: Methodological---2016---Xuan Di,Henry X. Liu,Ban, Xuegang (Jeff)

The network design problem is usually formulated as a bi-level program, assuming the user equilibrium is attained in the lower level program. Given boundedly rational route choice behavior, the lower-level program is replaced with the boundedly rational user equilibria (BRUE). The network design problem with boundedly rational route choice behavior is understudied due to non-uniqueness of the BRUE. In this study, thus, we mainly focus on boundedly rational toll pricing (BR-TP) with affine link cost functions. The topological properties of the lower level BRUE set are first explored. As the BRUE solution is generally non-unique, urban planners cannot predict exactly which equilibrium flow pattern the transportation network will operate after a planning strategy is implemented. Due to the risk caused by uncertainty of people’s reaction, two extreme scenarios are considered: the traffic flow patterns with either the minimum system travel cost or the maximum, which is the “risk-prone” (BR-TP-RP) or the “risk-averse” (BR-TP-RA) scenario respectively. The upper level BR-TP is to find an optimal toll minimizing the total system travel cost, while the lower level is to find the best or the worst scenario. Accordingly BR-TP can be formulated as either a min –min or a min –max program. Solution existence is discussed based on the topological properties of the BRUE and algorithms are proposed. Two examples are accompanied to illustrate the proposed methodology.

E-commerce and traffic congestion: An economic and policy analysis

- Transportation Research Part B: Methodological---2016---Jing Shao,Hangjun Yang,Xiaoqiang Xing,Liu Yang

E-commerce, due to its ability to re-direct consumers from physical stores to online, can potentially alleviate traffic congestion. In this paper, we set up a theoretic model to analyze interactions between a firm’s distribution strategy and traffic congestion. In an unregulated economy, we first characterize the private firm’s optimal strategy concerning e-commerce under the influence of traffic congestion. We then examine a centralized economy where the firm is publicly owned and derive the distribution strategy that maximizes social welfare. Comparing the two cases, we show that the private firm’s incentives may deviate from the socially optimal decisions, which leads to inefficiency. We identify two effects, i.e., monopoly effect and congestion externality effect, which drive the private firm to deviate from the social optimum. Based on our analysis, we propose a differentiated tolls/rebates policy to achieve maximum social welfare. Under such a policy, the firm will not only adopt the socially optimal distribution strategy but offer the socially optimal quantities.

Activity imputation for trip-chains elicited from smart-card data using a continuous hidden Markov model

- Transportation Research Part B: Methodological---2016---Gain Han,Keemin Sohn

Although smart-card data were expected to substitute for conventional travel surveys, the reality is that only a few automatic fare collection (AFC) systems can recognize an individual passenger’s origin, transfer, and destination stops (or stations). The Seoul metropolitan area is equipped with a system wherein a passenger’s entire trajectory can be tracked. Despite this great advantage, the use of smart-card data has a critical limitation wherein the purpose behind a trip is unknown. The present study proposed a rigorous methodology to impute the sequence of activities for each trip chain using a continuous hidden Markov model (CHMM), which belongs to the category of unsupervised machine-learning technologies. Coupled with the spatial and temporal information on trip chains from smart-card data, land-use characteristics were used to train a CHMM. Unlike supervised models that have been mobilized to impute the trip purpose to GPS data, A CHMM does not require an extra survey, such as the prompted-recall survey, in order to obtain labeled data for training. The estimated result of the proposed model yielded plausible activity patterns that are intuitively accountable and consistent with observed activity patterns.

A conflict-based path-generation heuristic for evacuation planning

- Transportation Research Part B: Methodological--2016---Victor Pillac,Pascal Van Hentenryck,Caroline Even

Evacuation planning and scheduling is a critical aspect of disaster management and national security applications. This paper proposes a conflict-based path-generation approach for evacuation planning. Its key idea is to decompose the evacuation planning problem into a master and a subproblem. The subproblem generates new evacuation paths for each evacuated area, while the master problem optimizes the flow of evacuees and produce an evacuation plan. Each new path is generated to remedy conflicts in the evacuation flows and adds new columns and a new row in the master problem. The algorithm is applied to a set of large-scale evacuation scenarios ranging from the Hawkesbury-Nepean flood plain (West Sydney, Australia) which require evacuating in the order of 70,000 persons, to the New Orleans metropolitan area and its 1,000,000 residents. Experiments illustrate the scalability of the approach which is able to produce evacuation for scenarios with more than 1200 nodes, while a direct Mixed Integer Programming formulation becomes intractable for instances with more than 5 nodes. With this approach, realistic evacuations scenarios can be solved near-optimally in reasonable time, supporting both evacuation planning in strategic, tactical, and operational environments.

A heterogeneous reliable location model with risk pooling under supply disruptions

- Transportation Research Part B: Methodological--2016---Ying Zhang,Lawrence V. Snyder,Mingyao Qi,Lixin Miao

This paper investigates a facility location model that considers the disruptions of facilities and the cost savings from the inventory risk-pooling effect and economies of scale. Facilities may have heterogeneous disruption probabilities. When a facility fails, its customers may be reassigned to other surviving ones to hedge against lost-sales costs. We first develop both an exact and an approximate expression for the nonlinear inventory cost, and then formulate the problem as a nonlinear integer programming model. The objective is to minimize the expected total cost across all possible facility failure scenarios. To solve this problem, we design two methods, an exact approach using special ordered sets of type two (SOS2) and a heuristic based on Lagrangian relaxation. We test the model and algorithms on data sets with up to 150 nodes. Computational results show that the proposed algorithms can solve the problem efficiently in reasonable time. Managerial insights on the optimal facility deployment, customer assignments and inventory control strategies are also drawn.

The nonlinear equation system approach to solving dynamic user optimal simultaneous route and departure time choice problems

- Transportation Research Part B: Methodological--2016---Jiancheng Long,W.Y. Szeto,Ziyou Gao,Hai-Jun Huang,Qin Shi

Dynamic user optimal simultaneous route and departure time choice (DUO-SRDTC) problems are usually formulated as variational inequality (VI) problems whose solution algorithms generally require continuous and monotone route travel cost functions to guarantee convergence. However, the monotonicity of the route travel cost functions cannot be ensured even if the route travel time functions are monotone. In contrast to traditional formulations, this paper formulates a DUO-SRDTC problem (that can have fixed or elastic demand) as a system of nonlinear equations. The system of nonlinear equations is a function of generalized origin-destination (OD) travel costs rather than route flows and includes a dynamic user optimal (DUO) route choice subproblem with perfectly elastic demand and a quadratic programming (QP) subproblem under certain assumptions. This study also proposes a solution method based on the backtracking inexact Broyden–Fletcher–Goldfarb–Shanno (BFGS) method, the extragradient algorithm, and the Frank-Wolfe algorithm. The BFGS method, the extragradient algorithm, and the Frank-Wolfe algorithm are used to solve the system of nonlinear equations, the DUO route choice subproblem, and the QP subproblem, respectively. The proposed formulation and solution method can avoid the requirement of monotonicity of the route travel cost functions to obtain a convergent solution and provide a new approach with which to solve DUO-SRDTC problems. Finally, numeric examples are used to demonstrate the performance of the proposed solution method.

Shipping log data based container ship fuel efficiency modeling

- Transportation Research Part B: Methodological---2016---Qiang Meng,Yuquan Du,Yadong Wang

Container shipping lines have been initiating various ship fuel efficiency management programs because bunker fuel costs always dominate the daily operating costs of a container ship. As the basis of these kinds of programs, we develop a viable research methodology for modeling the relationship between the fuel consumption rate of a particular container ship and its determinants, including sailing speed, displacement, sea conditions and weather conditions, by using the shipping log data available in practice. The developed methodology consists of an outlier-score-based data preprocessing procedure to tackle the fuzziness, inaccuracy and limited information of shipping logs, and two regression models for container ship fuel efficiency. Real shipping logs from four container ships (two with 13000 TEUs and two with 5000 TEUs) over a six-month sailing period are used to exhibit the applicability and effectiveness of the proposed methodology. The empirical studies demonstrate the performance of three models for fitting the fuel consumption rate of a ship and the industrial merits of ship fuel efficiency management. In addition, we highlight the potential impacts of the models developed in this study on liner shipping network analysis, as these models can serve as base models for additionally considering the influence of displacement and weather conditions on ship fuel efficiency and exhaust emissions.

A driving force model for non-strict priority crossing behaviors of right-turn driversAuthor-Name: Lin, Dianchao

- Transportation Research Part B: Methodological---2016---Wanjing Ma,Li Li,Yinhai Wang

At urban intersections, conflicts between right-turn vehicles and through non-motorized vehicles are a critical cause of traffic congestion and safety challenges. Based on the fact that in different countries there is no strict priority in conflicts between motorized and non-motorized vehicles, this study focused on analysis of the inherent mechanism of this universal phenomenon. By the analogy of a force model for moving vehicles, this paper developed a micro driving force model, including the safety driving force and efficiency driving force, for right-turn drivers which constitute the dominant party during the non-strict priority crossing process. We further demonstrate that the strict priority crossing behavior is a special case of the proposed driving force model. All the parameters used in this model were calibrated through field data collected at twelve signalized intersection sites in Shanghai. Model validation results proved the accuracy and reliability of the proposed driving force model. The model was further proved that it can be used for right-turn vehicle's average crossing speed prediction. The sensitivity analysis identified the influence of vehicle type, non-motorized traffic flow rate, and non-motorized traffic speed on the average speed, and offered support for the rationality of the non-strict priority.

Improved models for technology choice in a transit corridor with fixed demand

- Transportation Research Part B: Methodological---2016---Luigi Moccia,Gilbert Laporte

We present three extensions to a base optimization model for a transit line which can be used to strategically evaluate technology choices. We add to the base model optimal stop spacing and train length, a crowding penalty, and a multi-period generalization. These extensions are analytically solvable by simple approximations and lead to meaningful insights. Their significance is illustrated by means of an example in which two road modes and two rail modes are defined by a set of techno-economical parameters. These parameters loaded in the base model yield dominance of road modes for all but the largest demand levels. We consistently keep this set of parameters for all models, and show how the break-even points between road and rail modes progressively recede toward lower demand levels when model refinements – not parameter changes – are applied. Scenario analyses of plausible parameter sets highlight the model' s versatility, and caution on general conclusions regarding technology dominance.

A two-stage stochastic optimization model for the transfer activity choice in metro networks

- Transportation Research Part B: Methodological---2016---Lixing Yang,Yan Zhang,Shukai Li,Yuan Gao

This research focuses on finding the best transfer schemes in metro networks. Using sample-based time-invariant link travel times to capture the uncertainty of a realistic network, a two-stage stochastic integer programming model with the minimized expected travel time and penalty value incurred by transfer activities is formulated. The first stage aims to find a sequence of potential transfer nodes (stations) that can compose a feasible path from origins to destinations in the transfer activity network, and the second stage provides the least time paths passing by the generated transfer stations in the first stage for evaluating the given transfer schemes and then outputs the best routing information. To solve our proposed model, an efficient hybrid algorithm, in which the label correcting algorithm is embedded into a branch and bound searching framework, is presented to find the optimal solutions of the considered problem. Finally, the numerical experiments are implemented in different scales of metro networks. The computational results demonstrate the effectiveness and performance of the proposed approaches even for the large-scale Beijing metro network.

Improved bush-based methods for network contraction

- Transportation Research Part B: Methodological---2016---Ehsan Jafari,Stephen D. Boyles

Calculating equilibrium sensitivity on a bush can be done very efficiently, and serve as the basis for a network contraction procedure. The contracted network (a simplified network with a few nodes and links) approximates the behavior of the full network but with less complexity. The network contraction method can be advantageous in network design applications where many equilibrium problems must be solved for different design scenarios. The network contraction procedure can also be used to increase the accuracy of subnetwork analysis. This method requires calculating travel time derivatives between two nodes, with respect to the demand between them, assuming that the flow distributes in a way that equilibrium is maintained. Previous research describes two methods for calculating these derivatives. This paper presents a third method, which is simpler, faster, and just as accurate. The method presented in this paper reformulates the linear system of equations defining these sensitivities as the solution to a convex programming problem, which can be solved by making minor modifications to static user equilibrium algorithms. In addition, the model is extended to capture the interactions between the path travel times and network flows, and a heuristic is proposed to compute these interactions. The accuracy and complexity of the proposed methodology are evaluated using the network of Barcelona, Spain. Further, numerical experiments on the Austin, Texas regional network validate its performance for subnetwork analysis applications.

Train commuters' scheduling preferences: Evidence from a large-scale peak avoidance experiment

- Transportation Research Part B: Methodological---2016---Stefanie Peer,Jasper Knockaert,Erik Verhoef

We study the trip scheduling preferences of train commuters in a real-life setting. The underlying data have been collected during large-scale peak avoidance experiment conducted in the Netherlands, in which participants could earn monetary rewards for traveling outside peak hours. The experiment included ca. 1000 participants and lasted for multiple months. Holders of an annual train pass were invited to join the experiment, and a customized smartphone app was used to measure the travel behavior of the participants. We find that compared to the pre-measurement, the relative share of peak trips decreased by 22% during the reward period, and by 10% during the post-measurement. By combining multiple complementary data sources, we are able to specify and estimate (MNL and panel latent class) departure time choice models. These yield plausible estimates for the monetary values that participants attach to reducing travel time, schedule delays, the number of transfers, crowdedness, and unreliability.

Revisiting the Task–Capability Interface model for incorporating human factors into car-following models

- Transportation Research Part B: Methodological---2015---Mohammad Saifuzzaman,Zuduo Zheng,Md. Mazharul Haque,Simon Washington

Human factors such as distraction, fatigue, alcohol and drug use are generally ignored in car-following (CF) models. Such ignorance overestimates driver capability and leads to most CF models' inability in realistically explaining human driving behaviors. This paper proposes a novel car-following modeling framework by introducing the difficulty of driving task measured as the dynamic interaction between driving task demand and driver capability. Task difficulty is formulated based on the famous Task–Capability Interface (TCI) model, which explains the motivations behind driver's decision making. The proposed method is applied to enhance two popular CF models: Gipps' model and IDM, and named as TDGipps and TDIDM respectively. The behavioral soundness of TDGipps and TDIDM are discussed and their stabilities are analyzed. Moreover, the enhanced models are calibrated with the vehicle trajectory data, and validated to explain both regular and human factor influenced CF behavior (which is distraction caused by hand-held mobile phone conversation in this paper). Both the models show better performance than their predecessors, especially in presence of human factors.

An evolutionary local search for the capacitated vehicle routing problem minimizing fuel consumption under three-dimensional loading constraints

- Transportation Research Part B: Methodological---2015---Zhenzhen Zhang,Lijun Wei,Andrew Lim

This study introduces a new practical variant of the combined routing and loading problem called the capacitated vehicle routing problem minimizing fuel consumption under three-dimensional loading constraints (3L-FCVRP). It presents a meta-heuristic algorithm for solving the problem. The aim is to design routes for a fleet of homogeneous vehicles that will serve all customers, whose demands are formed by a set of three-dimensional, rectangular, weighted items. Unlike the well-studied capacitated vehicle routing problem with 3D loading constraints (3L-CVRP), the objective of the 3L-FCVRP is to minimize total fuel consumption rather than travel distance. The fuel consumption rate is assumed to be proportionate to the total weight of the vehicle. A route is feasible only if a feasible loading plan to load the demanded items into the vehicle exists and the loading plan must satisfy a set of practical constraints.

The benefits of meeting points in ride-sharing systems

- Transportation Research Part B: Methodological--2015---Mitja Stiglic,Niels Agatz,Martin Savelsbergh,Mirko Gradisar

We investigate the potential benefits of introducing meeting points in a ride-sharing system. With meeting points, riders can be picked up and dropped off either at their origin and destination or at a meeting point that is within a certain distance from their origin or destination. The increased flexibility results in additional feasible matches between drivers and riders, and allows a driver to be matched with multiple riders without increasing the number of stops the driver needs to make. We design and implement an algorithm that optimally matches drivers and riders in large-scale ride-sharing systems with meeting points. We perform an extensive simulation study to assess the benefits of meeting points. The results demonstrate that meeting points can significantly increase the number of matched participants as well as the system-wide driving distance savings in a ride-sharing system.

Long queue estimation for signalized intersections using mobile data

- Transportation Research Part B: Methodological--2015---Peng Hao,Xuegang Ban

Queue length is one of the key measures in assessing arterial performances. Under heavy congestion, queues are difficult to estimate from either fixed-location sensors (such as loop detectors) or mobile sensors since they may exceed the region of detection, which is defined as long queue in the literature. While the long queue problem has been successfully addressed in the past using fixed-location sensors, whether this can be done using mobile traffic sensors remains unclear. In this paper, a queue length estimation method is proposed to solve this long queue problem using short vehicle trajectories obtained from mobile sensors. The method contains vehicle trajectory reconstruction models to estimate the missing deceleration or acceleration process of a vehicle. Long queue estimation models are then developed using the reconstructed vehicle trajectories. The proposed method can provide estimates of the queue profile and the maximum queue length of a cycle. The method is tested in a field experiment with reasonable results.

Speed-spacing dependency on relative speed from the adjacent lane: New insights for car following models

- Transportation Research Part B: Methodological--2015---Balaji Ponnu,Benjamin Coifman

This paper examines the traffic dynamics underlying a recently observed phenomenon, the so called “sympathy of speeds” whereby a high occupancy vehicle (HOV) lane seemingly exhibits lower vehicular capacity and lower flow at speeds throughout the congested regime compared to the adjacent general purpose (GP) lanes. Unlike previous studies this paper examines a time-of-day HOV lane. During the non-HOV periods the study lane reverts to a GP lane, thereby providing a control condition for the specific lane and location. This work uses the single vehicle passage (svp) method to group vehicle passages before measuring the traffic state and extends the svp to bin vehicles in the study lane based on the relative speed to the adjacent lane. The extended svp method allows the work to also study the impacts during the non-HOV periods when the study lane serves GP vehicles. This work finds that: (1) during the non-HOV periods the study lane exhibited behavior indistinguishable from the adjacent GP lane. (2) The sympathy of speeds persists throughout the day, even when the study lane serves GP vehicles. (3) The relative speed to the adjacent lane provided a better predictor of behavior than whether or not the HOV restriction is active. In short, the car following behavior that gives rise to the sympathy of speeds is unrelated to the HOV restriction per se, persisting under GP operations as well.

Airport congestion pricing and terminal investment: Effects of terminal congestion, passenger types, and concessionsAuthor-Name: Wan, Yulai

- Transportation Research Part B: Methodological---2015---Changmin Jiang,Anming Zhang

None of the airport-pricing studies have differentiated the congestion incurred in the terminals from the congestion incurred on the runways. This paper models and connects the two kinds of congestion in one joint model. This is done by adopting a deterministic bottleneck model for the terminal to describe passengers' behavior, and a simpler static congestion model for the runway. We find that different from the results obtained in the literature, uniform airfare does not yield the first-best outcome when terminal congestion is explicitly taken into account. In particular, business passengers are at first-best charged a higher fare than leisure passengers if and only if their relative schedule-delay cost is higher. We further identify circumstances under which passengers are, given a uniform airport charge scheme, under- or over-charged with respect to the terminal charge. Furthermore, when concession surplus is added to the analysis, the airport may raise (rather than reduce) the airport charge in order to induce more business passengers who in turn will lengthen leisure passengers' dwell time and hence increase their chance of purchasing concession goods. Finally, the impacts of terminal capacity expansion and time-varying terminal fine toll are discussed.

Integrated modeling of high performance passenger and freight train planning on shared-use corridors in the US

- Transportation Research Part B: Methodological---2015---Ahmadreza Talebian,Bo Zou

This paper studies strategic level train planning for high performance passenger and freight train operations on shared-use corridors in the US. We develop a hypergraph-based, two-level approach to sequentially minimize passenger and freight costs while scheduling train services. Passenger schedule delay and freight lost demand are explicitly modeled. We explore different solution strategies and conclude that a problem-tailored linearized reformulation yields superior computational performance. Using realistic parameter values, our numerical experiments show that passenger cost due to schedule delay is comparable to in-vehicle travel time cost and rail fare. In most cases, marginal freight cost increase from scheduling more passenger trains is higher than marginal reduction in passenger schedule delay cost. The heterogeneity of train speed reduces the number of freight trains that can run on a corridor. Greater tolerance for delays could reduce lost demand and overall cost on the freight side. The approach developed in the paper could be applied to other scenarios with different parameter values.

Liner container seasonal shipping revenue management

- Transportation Research Part B: Methodological---2015---Yadong Wang,Qiang Meng,Yuquan Du

This paper proposes a liner container seasonal shipping revenue management problem for a container shipping company. For a given weekly multi-type shipment demand pattern in a particular season, the proposed problem aims to maximize the total seasonal shipping profit by determining the number of multi-type containers to be transported and assigned on each container route, the number of containerships deployed on each ship route, and the sailing speed of containerships on each shipping leg subject to both the volume and capacity constraints of each containership. By adopting the realistic bunker consumption rate of a containership as a function of its sailing speed and payload (displacement), we develop a mixed-integer nonlinear programing with a nonconvex objective function for the proposed liner container seasonal shipping revenue management problem. A tailored branch and bound (B&B) method is designed to obtain the global ε-optimal solution of the model. Numerical experiments are finally conducted to assess the efficiency of the solution algorithm and to show the applicability of the developed model.

Dynamic activity-travel assignment in multi-state supernetworks

- Transportation Research Part B: Methodological---2015---Peng Liu,Feixiong Liao,Hai-Jun Huang,Harry Timmermans

The integration of activity-based modeling and dynamic traffic assignment for travel demand analysis has recently attracted ever-increasing attention. However, related studies have limitations either on the integration structure or the number of choice facets being captured. This paper proposes a formulation of dynamic activity-travel assignment (DATA) in the framework of multi-state supernetworks, in which any path through a personalized supernetwork represents a particular activity-travel pattern (ATP) at a high level of spatial and temporal detail. DATA is formulated as a discrete-time dynamic user equilibrium (DUE) problem, which is reformulated as an equivalent variational inequality (VI) problem. A generalized dynamic link disutility function is established with the accommodation of different characteristics of the links in the supernetworks. Flow constraints and non-uniqueness of equilibria are also investigated. In the proposed formulation, the choices of departure time, route, mode, activity sequence, activity and parking location are all unified into one time-dependent ATP choice. As a result, the interdependences among all these choice facets can be readily captured. A solution algorithm based on the route-swapping mechanism is adopted to find the user equilibrium. A numerical example with simulated scenarios is provided to demonstrate the advantages of the proposed approach.

Unified closed-form expression of logit and weibit and its extension to a transportation network equilibrium assignment

- Transportation Research Part B: Methodological---2015---Shoichiro Nakayama,Makoto Chikaraishi

This study proposes a generalized multinomial logit model that allows heteroscedastic variance and flexible utility function shape. The novelty of our approach is that the model is theoretically derived by applying a generalized extreme-value distribution to the random component of utility, while retaining its closed-form expression. In addition, the weibit model, in which the random utility is assumed to follow the Weibull distribution, is a special case of the proposed model. This is achieved by utilizing the q-generalization method developed in Tsallis statistics. Then, our generalized logit model is incorporated into a transportation network equilibrium model. The network equilibrium model with a generalized logit route choice is formulated as an optimization problem for uncongested networks. The objective function includes Tsallis entropy, a type of generalized entropy. The generalization of the Gumbel and Weibull distributions, logit and weibit models, and network equilibrium model are formulated within a unified framework with q-generalization or Tsallis statistics.

Modeling absolute and relative cost differences in stochastic user equilibrium problem

- Transportation Research Part B: Methodological---2015---Xiangdong Xu,Anthony Chen,Songyot Kitthamkesorn,Hai Yang,Hong K. Lo

This paper aims to develop a hybrid closed-form route choice model and the corresponding stochastic user equilibrium (SUE) to alleviate the drawbacks of both Logit and Weibit models by simultaneously considering absolute cost difference and relative cost difference in travelers' route choice decisions. The model development is based on an observation that the issues of absolute and relative cost differences are analogous to the negative exponential and power impedance functions of the trip distribution gravity model. Some theoretical properties of the hybrid model are also examined, such as the probability relationship among the three models, independence from irrelevant alternatives, and direct and indirect elasticities. To consider the congestion effect, we provide a unified modeling framework to formulate the Logit, Weibit and hybrid SUE models with the same entropy maximization objective but with different total cost constraint specifications representing the modelers' knowledge of the system. With this, there are two ways to interpret the dual variable associated with the cost constraint: shadow price representing the marginal change in the entropy level to a marginal change in the total cost, and dispersion/shape parameter representing the travelers' perceptions of travel costs. To further consider the route overlapping effect, a path-size factor is incorporated into the hybrid SUE model. Numerical examples are also provided to illustrate the capability of the hybrid model in handling both absolute and relative cost differences as well as the route overlapping problem in travelers' route choice decisions.

On multi-objective stochastic user equilibrium

- Transportation Research Part B: Methodological---2015---Matthias Ehrgott,Judith Y.T. Wang,David P. Watling

There is extensive empirical evidence that travellers consider many qualities (travel time, tolls, reliability, etc.) when choosing between alternative routes. Two main approaches exist to deal with this in network assignment models: Combine all qualities into a single (linear) utility function, or solve a multi-objective problem. The former has the advantages of a unique solution and efficient algorithms; the latter, however, is more general, but leads to many solutions and is difficult to implement in larger systems. In the present paper we present three alternative approaches for combining the principles of multi-objective decision-making with a stochastic user equilibrium model based on random utility theory. The aim is to deduce a tractable, analytic method. The three methods are compared both in terms of their theoretical principles, and in terms of the implied trade-offs, illustrated through simple numerical examples.

System dynamics of urban traffic based on its parking-related-states

- Transportation Research Part B: Methodological---2015---Jin Cao,Monica Menendez

The urban parking and the urban traffic systems are essential components of the overall urban transportation structure. The short-term interactions between these two systems can be highly significant and influential to their individual performance. The urban parking system, for example, can affect the searching-for-parking traffic, influencing not only overall travel speeds in the network (traffic performance), but also total driven distance (environmental conditions). In turn, the traffic performance can also affect the time drivers spend searching for parking, and ultimately, parking usage. In this study, we propose a methodology to model macroscopically such interactions and evaluate their effects on urban congestion.

Robust transit network design with stochastic demand considering development density

- Transportation Research Part B: Methodological---2015---Kun An,Hong K. Lo

This paper analyzes the influence of urban development density on transit network design with stochastic demand by considering two types of services, rapid transit services, such as rail, and flexible services, such as dial-a-ride shuttles. Rapid transit services operate on fixed routes and dedicated lanes, and with fixed schedules, whereas dial-a-ride services can make use of the existing road network, hence are much more economical to implement. It is obvious that the urban development densities to financially sustain these two service types are different. This study integrates these two service networks into one multi-modal network and then determines the optimal combination of these two service types under user equilibrium (UE) flows for a given urban density. Then we investigate the minimum or critical urban density required to financially sustain the rapid transit line(s). The approach of robust optimization is used to address the stochastic demands as captured in a polyhedral uncertainty set, which is then reformulated by its dual problem and incorporated accordingly. The UE principle is represented by a set of variational inequality (VI) constraints. Eventually, the whole problem is linearized and formulated as a mixed-integer linear program. A cutting constraint algorithm is adopted to address the computational difficulty arising from the VI constraints. The paper studies the implications of three different population distribution patterns, two CBD locations, and produces the resultant sequences of adding more rapid transit services as the population density increases.

Optimal transit service atop ring-radial and grid street networks: A continuum approximation design method and comparisons

- Transportation Research Part B: Methodological---2015---Haoyu Chen,Weihua Gu,Michael J. Cassidy,Carlos F. Daganzo

Two continuum approximation (CA) optimization models are formulated to design city-wide transit systems at minimum cost. Transit routes are assumed to lie atop a city' s street network. Model 1 assumes that the city streets are laid out in ring-radial fashion. Model 2 assumes that the city streets form a grid. Both models can furnish hybrid designs, which exhibit intersecting routes in a city' s central (downtown) district and only radial branching routes in the periphery. Model 1 allows the service frequency and the route spacing at a location to vary arbitrarily with the location' s distance from the center. Model 2 also allows such variation but in the periphery only.

Optimal multi-step toll design under general user heterogeneity

- Transportation Research Part B: Methodological---2015---Hongyu Chen,Nie, Yu (Marco),Yafeng Yin

This paper studies the optimal multi-step toll design problem for the bottleneck model with general user heterogeneity. The design model is formulated as a mathematical program with equilibrium constraints (MPEC), which is NP-hard due to non-convexity in both the objective function and the feasible set. An analytical method is proposed to solve the MPEC by decomposing it into smaller and easier quadratic programs, each corresponding to a unique departure order of different user classes. The quadratic programs are defined on a polyhedral set, which makes it easier to identify a local optimum. Importantly, each quadratic program is constrained by a set of linear feasibility cuts that define the presence of each user class in the arrival window. We prove that the proposed method ensures global optimality provided that each quadratic program can be solved globally. To obviate enumerating all departure orders, a heuristic method is developed to navigate through the solution space by using the multipliers associated with the feasibility cuts. Numerical experiments are conducted on several small examples to validate the proposed methodology. These experiments show that the proposed heuristic method is effective in finding near-optimal solutions within a relatively small number of iterations.

Learning marginal-cost pricing via a trial-and-error procedure with day-to-day flow dynamics

- Transportation Research Part B: Methodological---2015---Hongbo Ye,Hai Yang,Zhijia Tan

This paper investigates the convergence of the trial-and-error procedure to achieve the system optimum by incorporating the day-to-day evolution of traffic flows. The path flows are assumed to follow an 'excess travel cost dynamics' and evolve from disequilibrium states to the equilibrium day by day. This implies that the observed link flow pattern during the trial-and-error procedure is in disequilibrium. By making certain assumptions on the flow evolution dynamics, we prove that the trial-and-error procedure is capable of learning the system optimum link tolls without requiring explicit knowledge of the demand functions and flow evolution mechanism. A methodology is developed for updating the toll charges and choosing the inter-trial periods to ensure convergence of the iterative approach towards the system optimum. Numerical examples are given in support of the theoretical findings.

The corridor problem with discrete multiple bottlenecks

- Transportation Research Part B: Methodological---2015---Takashi Akamatsu,Kentaro Wada,Shunsuke Hayashi

This paper presents a transparent approach to the analysis of dynamic user equilibrium and clarifies the properties of a departure-time choice equilibrium of a corridor problem where discrete multiple bottlenecks exist along a freeway. The basis of our approach is the transformation of the formulation of equilibrium conditions in a conventional "Eulerian coordinate system" into one in a "Lagrangian-like coordinate system." This enables us to evaluate dynamic travel times easily, and to achieve a deep understanding of the mathematical structure of the problem, in particular, about the properties of the demand and supply (queuing) sub-models, relations with dynamic system optimal assignment, and differences between the morning and evening rush problems. Building on these foundations, we establish rigorous results on the existence and uniqueness of equilibria.

Bottleneck congestion and distribution of work start times: The economics of staggered work hours revisited

- Transportation Research Part B: Methodological---2015---Yuki Takayama

Since the seminal work of Henderson (Henderson, J.V., 1981. The economics of staggered work hours. Journal of Urban Economics 9 (3), 349–364), a number of studies have examined the effect of staggered work hours by analyzing models of work start time choice that consider the trade-off between negative congestion externalities and positive production externalities. However, these studies employed flow congestion models to describe traffic congestion. This study develops a model of work start time choice with bottleneck congestion and discloses the intrinsic properties of the model. To this end, this study extends Henderson's model to incorporate bottleneck congestion. By utilizing the properties of a potential game, we characterize equilibrium and optimal distributions of work start times. We also show that Pigouvian tax/subsidy policies generally yield multiple equilibria and that the first-best optimum must be a stable equilibrium under Pigouvian policies, whereas the second-best optimum in which policymakers cannot eliminate queuing congestion can be unstable.

Bounding tandem queuing system performance with variational theory

- Transportation Research Part B: Methodological---2015---Jia Li,H. Michael Zhang

Queuing models are often used for traffic analysis, but analytical results concerning a system of queues are rare, thanks to the interdependence between queues. In this paper, we present an analysis of queuing systems to obtain bounds of their performance without studying the details of individual queues. Queuing dynamics is formulated in continuous-time, subject to variations of demands and bottleneck capacities. Our analysis develops new techniques built on the closed-form solution to a generalized queuing model for a single bottleneck. Taking advantage of its variational structure, we derive the upper and lower bounds for the total queue length in a tandem bottleneck system and discuss its implication for the kinematic wave counterpart. Numerical experiments are conducted to demonstrate the appropriateness of the derived upper and lower bounds as approximations in a stochastic setting.

Traffic control and route choice: Capacity maximisation and stability

- Transportation Research Part B: Methodological---2015---M.J. Smith,R. Liu,R. Mounce

This paper presents idealised natural general and more special dynamical models of day-to-day re-routeing and of day to day green-time response. Both green-time response models are based on the responsive control policy P0 introduced in Smith (1979a, b, c, 1987). It is shown that, for any steady feasible demand within a flow model, if the general day to day re-routeing model is combined with the general day to day green-time response model then under natural conditions any (flow, green-time) solution trajectory cannot leave the region of supply-feasible (flow, green-time) pairs and costs are bounded. It is also shown that if the more special re-routeing model is combined with the more special green-time response model then every (flow, green-time) solution trajectory converges to a non-empty set of Wardrop equilibria consistent with the P0 control policy. Throughput is maximised in two senses. Given any constant feasible demand; this demand is (i) met as any routeing/green-time trajectory evolves (following either the general or the more special model) and also (ii) met at a Wardrop equilibrium which is consistent with the P0 green-time response. (This is guaranteed to exist, under natural conditions.) The paper then considers control models with explicit queues, and provides a statement of simple "pressure driven" responsive control policies, where cycle times are all fixed. In these policies stage pressures are given functions of flows, queues and green-times. Finally the paper considers modified Varaiya (2013a, b) and Le et al. (2015) pressure-driven responsive controls on a very simple one junction network. It is shown that (with each of these two modified policies) there is a steady demand within the capacity of the network for which there is no Wardrop equilibrium consistent with the policy. With each of these two modified policies on this simple network, as natural routeing/green-time trajectories evolve queues and delays are unbounded. It is shown that, in contrast, responsive P0 on this simple network does maximise throughput at a quasi-dynamic user equilibrium consistent with P0; queues and delays remain bounded in natural dynamical evolutions in this case. It is to be expected that this P0 result may be extended to allow for certain time-varying demands on a much wider variety of networks, including dynamic networks; to show that this is indeed the case is a challenge for the future.

Stability of transportation networks under adaptive routing policies

- Transportation Research Part B: Methodological---2015---Sebastien Boyer,Sebastien Blandin,Laura Wynter

Growing concerns regarding urban congestion, and the recent explosion of mobile devices able to provide real-time information to traffic users have motivated increasing reliance on real-time route guidance for the online management of traffic networks. However, while the theory of traffic equilibria is very well-known, fewer results exist on the stability of such equilibria, especially in the context of adaptive routing policy. In this work, we consider the problem of characterizing the stability properties of traffic equilibria in the context of online adaptive route choice induced by GPS-based decision making. We first extend the recent framework of "Markovian Traffic Equilibria" (MTE), in which users update their route choice at each intersection of the road network based on traffic conditions, to the case of non-equilibrium conditions, while preserving consistency with known existence and uniqueness results on MTE. We then exhibit sufficient conditions on the network topology and the latency functions for those MTEs to be stable in the sense of Lyapunov for a single destination problem. For various more restricted classes of network topologies motivated by the observed properties of travel patterns in the Singapore network, under certain assumptions we prove local exponential stability of the MTE, and derive analytical results on the sensitivity of the characteristic time of convergence to network and traffic parameters. The results proposed in this work are illustrated and validated on synthetic toy problems as well as on the Singapore road network with real demand and traffic data.

Stochastic approximations for the macroscopic fundamental diagram of urban networks

- Transportation Research Part B: Methodological---2015---Jorge A. Laval,Felipe Castrillón

This paper proposes a theory for estimating the Macroscopic Fundamental Diagram (MFD) on inhomogeneous corridors and networks using probabilistic methods. By exploiting a symmetry property of the stochastic MFD, whereby it exhibits identical probability distributions in free-flow and congestion, it is found that the network MFD depends mainly on two dimensionless parameters: the mean block length to green ratio and the mean red to green ratio. The theory is validated with an exact traffic simulation and with the empirical data from the city of Yokohama. It is also shown that the effect of buses can be approximated with the proposed theory by accounting for their effect in the red to green ratio parameter.

On the existence of stationary states in general road networks

- Transportation Research Part B: Methodological--2015---Wen-Long Jin

Our daily driving experience and empirical observations suggest that traffic patterns in a road network are relatively stationary during peak periods. In numerous transportation network studies, there has been an implicit conjecture that stationary states exist in a network when origin demands, route choice proportions, and destination supplies are constant. In this study, we first rigorously formulate the conjecture within the framework of a network kinematic wave theory with an invariant junction model. After defining stationary states, we derive a system of algebraic equations in 3-tuples of stationary link flow-rates, demands, and supplies. We then introduce a new definition of junction critical demand levels based on effective demands and supplies. With a map in critical demand levels, we show that its fixed points and, therefore, stationary states exist with the help of Brouwer's fixed point theorem. For two simple road networks, we show that the map is well-defined and can be used to solve stationary states with a brute-force method. Finally we summarize the study and present some future extensions and applications.

Beyond normality: A cross moment-stochastic user equilibrium model

- Transportation Research Part B: Methodological--2015---Selin Damla Ahipaşaoğlu,Rudabeh Meskarian,Thomas L. Magnanti,Karthik Natarajan

The Stochastic User Equilibrium (SUE) model predicts traffic equilibrium flow assuming that users choose their perceived maximum utility paths (or perceived shortest paths) while accounting for the effects of congestion that arise due to users sharing links. Inspired by recent work on distributionally robust optimization, specifically a Cross Moment (CMM) choice model, we develop a new SUE model that uses the mean and covariance information on path utilities but does not assume the particular form of the distribution. Robustness to distributional assumptions is obtained in this model by minimizing the worst-case expected cost over all distributions with fixed two moments. We show that under mild conditions, the CMM-SUE (Cross Moment-Stochastic User Equilibrium) exists and is unique. By combining a simple projected gradient ascent method to evaluate path choice probabilities with a gradient descent method to find flows, we show that the CMM-SUE is efficiently computable. CMM-SUE provides both modeling flexibility and computational advantages over approaches such as the well-known MNP-SUE (Multinomial Probit-Stochastic User Equilibrium) model that require distributional (normality) assumptions to model correlation effects from overlapping paths. In particular, it avoids the use of simulation methods employed in computations for the distribution-based MNP-SUE model. Preliminary computational results indicate that CMM-SUE provides a practical distributionally robust alternative to MNP-SUE.

Efficient transit network design and frequencies setting multi-objective optimization by alternating objective genetic algorithm

- Transportation Research Part B: Methodological--2015---Renato Oliveira Arbex,Claudio Barbieri da Cunha

The multi-objective transit network design and frequency setting problem (TNDFSP) involves finding a set of routes and their associated frequencies to operate in an urban area public transport system. The TNDFSP is a difficult combinatorial optimization problem, with a large search space and multiple constraints, leading to numerous infeasible solutions. We propose an Alternating Objective Genetic Algorithm (AOGA) to efficiently solve it, in which the objective to be searched is cyclically alternated along the generations. The two objectives are to minimize both passengers' and operators' costs. Transit users' costs are related to the total number of transfers, waiting and in-vehicle travel times, while operator’ s costs are related to the total required fleet to operate the set of routes. Our proposed GA also employs local search procedures to properly deal with infeasibility of newly generated individuals, as well as of those mutated. Extensive computational experiments results are reported using both Mandl’ s original benchmark set and instances with different demands and travel times as well, in order to determine Pareto Frontiers of optimal solutions, given that users’ and operators’ costs are conflicting objectives. The results evidence that the AOGA is very efficient, leading to improved solutions when compared to previously published results.

A real-time bus dispatching policy to minimize passenger wait on a high frequency route

- Transportation Research Part B: Methodological--2015---Simon J. Berrebi,Kari E. Watkins,Jorge A. Laval

One of the greatest problems facing transit agencies that operate high-frequency routes is maintaining stable headways and avoiding bus bunching. In this work, a real-time holding mechanism is proposed to dispatch buses on a loop-shaped route using real-time information. Holds are applied at one or several control points to minimize passenger waiting time while maintaining the highest possible frequency, i.e. using no buffer time. The bus dispatching problem is formulated as a stochastic decision process. The optimality equations are derived and the optimal holding policy is found by backward induction. A control method that requires much less information and that closely approximates the optimal dispatching policy is found. A simulation assuming stochastic operating conditions and unstable headway dynamics is performed to assess the expected average waiting time of passengers at stations. The proposed control strategy is found to provide lower passenger waiting time and better resiliency than methods used in practice and recommended in the literature.

Parking search equilibrium on a network

- Transportation Research Part B: Methodological--2015---Stephen D. Boyles,Shoupeng Tang,Avinash Unnikrishnan

This paper describes an equilibrium formulation for incorporating parking search into traffic network assignment models. The proposed model allows general network topologies and reflects uncertainty related to parking availability, including the possibility of cycling behavior as drivers search for parking. The equilibrium framework represents the mutual dependence between the probabilities of finding parking at different locations and the search processes employed by drivers to minimize total expected journey time (or cost). In this framework, network loading is represented by a system of nonlinear flow conservation networks, and feasibility and uniqueness issues are discussed. The equilibrium problem is formulated as a variational inequality and a convex combinations heuristic is proposed. Numerical results show that neglecting parking search can substantially underestimate network flows, and quantitatively demonstrate the relationship between parking duration effects and the cost of time spent walking relative to driving, and the expected driving and walking times.

Evaluation of a multimodal urban arterial: The passenger macroscopic fundamental diagram

- Transportation Research Part B: Methodological--2015---Nicolas Chiabaut

This paper aims to extend the concept of macroscopic fundamental diagram (MFD) to combine different transportation modes. Especially, we propose a unified relationship that accounts for cars and buses because the classical MFD is not sufficient to capture the traffic flow interactions of a multimodal traffic. The concept of passenger macroscopic fundamental diagram (p-MFD) is introduced. With this new relationship, the efficiency of the global transport system, i.e. behaviors of cars and buses, can be assessed. Intuitively, the p-MFD shape strongly depends on the mode ratio. Thus, user equilibrium and system optimum are studied and compared. Finally, this relationship is used to design bus system characteristics and to identify the optimal domains of applications for different transit strategies.

Rail-based public transport and urban spatial structure: The interplay between network design, congestion and urban form

- Transportation Research Part B: Methodological--2015---Martijn Dröes,Piet Rietveld

We examine the effect of spatial differences in access to a railway network on both urbanization and road congestion in a typical ‘transport corridor between cities’ setup. Using a spatial urban equilibrium model, we find that if the number of access nodes, i.e. stations, is limited, stations contribute to the degree of urbanization. The total effect on road congestion, however, is small. By contrast, if stations are omnipresent there is little effect on urban spatial structure, but a considerable decrease in congestion. This suggests there is a policy trade-off between congestion and urbanization which crucially depends on the type of railway network. We find similar results for a within-city metro network. The key methodological contribution is that, besides the dependence between mode choice and where to work/live, the model allows for differences in the degree of substitutability – local competition – between transport modes. We find that an increase in the substitutability between car travel and railway travel substantially decreases the congestion reduction benefits of a dense railway network.

Planning and operating a shared goods and passengers on-demand rapid transit system for sustainable city-logistics

- Transportation Research Part B: Methodological--2015---Ezzeddine Fatnassi,Jouhaina Chaouachi,Walid Klibi

This article investigates the potential of integrating a shared goods and passengers on-demand rapid transit system in urban areas. Although persons and goods movements have different objectives and constraints, mixing their travels on the same network is within current trends. So we investigate in this paper how they could share a rapid transit network and use the available transportation capacity within a city more efficiently in an interconnected way. Based on the common characteristics of personal rapid transit (PRT) and freight rapid transit (FRT), this paper proposes an emergent and efficient transportation solution in order to enhance the sustainability of city logistics. Next, the operational level is focused on to characterize the dynamic transportation problem and to propose two strategies to formulate it. This problem aims to respond to the number of transportation requests arriving on a periodic basis with adequate service level while minimizing the empty movements of a set of electric vehicles with limited battery capacity. An efficient solution approach based on the forward optimization of periodic transportation sub-problems is proposed and validated. The applicability of the PRT–FRT mode is demonstrated and computational results in comparison to other transportation option is also presented and discussed.

Trip pricing of one-way station-based carsharing networks with zone and time of day price variations

- Transportation Research Part B: Methodological--2015---Diana Jorge,Goran Molnar,Gonçalo Homem de Almeida Correia

One-way station-based carsharing systems provide short term car rentals in which users can take a car from the initial station and return it to any other station. They are more flexible than round-trip carsharing, where the vehicle can only be returned to the station where it was picked up, and can be used for daily commuting trips as well. This flexibility, however, comes at a cost of vehicle stock imbalance within the network. Several solutions and strategies have been suggested to counter this problem, one of which is variable trip pricing. By charging high prices for the trips that increase imbalance and lowering prices for trips that help improve the balance, it has been hypothesized, but never demonstrated, that the clients’ behavior could be used to balance the vehicle stocks and thus make carsharing systems more manageable and profitable. In this paper, we develop a mixed integer non-linear programming (MINLP) model, defined as the Trip Pricing Problem for One-Way Carsharing Systems (TPPOCS), which sets these prices in order to maximize profit. An iterated local search (ILS) metaheuristic is proposed for solving it. The method is applied to the theoretical case-study of a network of 75 stations distributed across the city of Lisbon (Portugal). Although the implemented metaheuristic is tuned for the Lisbon example, the generic nature of its operators makes the model applicable elsewhere. The results demonstrate that the trip pricing strategy can be used to increase profit through a more balanced system. If no price-based balancing strategies are applied, operating this service results in a daily deficit of €1161. When the trip pricing policy is applied, profits of 2068 €/day are possible. The optimal prices are on average 23% higher than the base price, and 18% less demand is served, but the enhanced performance leads to lower expenses with the fleet of vehicles and number of parking spaces.

Dynamic ridesharing: Is there a role for dedicated drivers?

- Transportation Research Part B: Methodological---2015---Alan Lee,Martin Savelsbergh

Growing congestion is a problem faced by cities around the world. Traditional solutions considered include new capital works to increase network capacity and expanding public transport offerings to make public transport more attractive. Dynamic ridesharing is a recent alternative in which people with similar travel plans are matched and travel together. Dynamic ridesharing requires no new network infrastructure and offers more convenience than public transport. The (long-term) success of ridesharing schemes, however, depends on their ability to attract a large number of users. We investigate the benefits, complexities, and costs of employing a small number of dedicated drivers to serve riders who would otherwise remain unmatched. An extensive computational study demonstrates the potential benefits of dedicated drivers and identifies environments in which dedicated drivers are most useful.

Effectiveness of variable speed limits considering commuters' long-term response

- Transportation Research Part B: Methodological---2015---Wei Liu,Yafeng Yin,Hai Yang

This paper examines the effectiveness of variable speed limits (VSLs) on improving traffic flow efficiency and reducing vehicular emissions in a stylized setting of morning commute where a fixed number of individuals commute from home to work through the freeway with a single recurrent bottleneck. The mechanism of interest is for a VSL system to prevent the bottleneck from being activated and thus avoid detrimental capacity drop that arises at the activated bottleneck. We firstly consider a VSL system installed along the freeway towards the bottleneck, which adjusts commuters' cruising speeds in a continuous fashion and essentially regulates the upstream flow into the bottleneck. By investigating the resulting departure-time equilibrium of commuters, we find the VSL system can eliminate the efficiency loss caused by capacity drop, and further bound its improvements on various performance measures. We then turn to a more practical VSL system, which adjusts commuters' cruising speeds in a discrete fashion. The conditions for such a system to improve various performance measures are established and its efficiencies are bounded. Based on empirical data, we conclude that the discrete VSL system can avoid or delay capacity drop associated with an active bottleneck and thus reduce queuing delay. It can help reduce the schedule delay cost and total emissions cost. However, it is unlikely for the system to reduce total travel time, individual travel cost and social cost in this particular setting. These results shed light on the effectiveness of VSL systems on realistic freeway networks.

Urban transportation emissions mitigation: Coupling high-resolution vehicular emissions and traffic models for traffic signal optimization

- Transportation Research Part B: Methodological---2015---Carolina Osorio,Kanchana Nanduri

This paper proposes a methodology that allows high-resolution traffic and emissions models, known as microscopic simulation models, to be efficiently used to address transportation optimization problems that account for complex environmental metrics. The methodology consists of a metamodel simulation-based optimization (SO) approach. The metamodel combines traffic and emissions information from high-resolution microscopic simulators with information from lower-resolution analytical macroscopic models. This paper formulates and uses an analytical and differentiable macroscopic approximation of the non-differentiable simulation-based microscopic emissions model. A differentiable macroscopic traffic model is also used.

A scalable non-myopic dynamic dial-a-ride and pricing problem

- Transportation Research Part B: Methodological--2015---Hamid R. Sayarshad,Joseph Y.J. Chow

Non-myopic dial-a-ride problem and other related dynamic vehicle routing problems often ignore the need for non-myopic pricing under the assumption of elastic demand, which leads to an overestimation of the benefits in level of service and resulting inefficiencies. To correct this problem, a new dynamic dial-a-ride policy is introduced, one that features non-myopic pricing based on optimal tolling of queues to fit with the multi-server queueing approximation method proposed by Hyttiä et al. (2012) for large-scale systems. By including social optimal pricing, the social welfare of the resulting system outperforms the marginal pricing assumed for previous approaches over a range of test instances. In the examples tested, improvements in social welfare of the non-myopic pricing over the myopic pricing were in the 20–31% range. For a given demand function, we can derive the optimal fleet size to maximize social welfare. Sensitivity tests to the optimal price confirm that it leads to an optimal social welfare while the marginal pricing policy does not. A comparison of single passenger taxis to shared-taxis shows that system cost may reduce at the expense of decreased social welfare, which agrees with the results of Jung et al. (2013).

Transportation network design for maximizing space–time accessibility

- Transportation Research Part B: Methodological--2015---Lu Tong,Xuesong Zhou,Harvey J. Miller

One of the goals of transportation system construction and management is to improve individuals’ accessibility or the ease of reaching desired activities, destinations and services. However, many transportation network design models instead focus on maximizing individuals’ mobility or the ease of movement within the network. By adapting a space–time prism analysis framework, this paper aims to address a new urban network design problem to maximize the system-wide transportation accessibility between major activity locations, subject to a given highway construction budget. By constructing a time-dependent space–time network, we formulate the problem as a linear integer programming model to maximize the number of accessible activity locations within travel time budget for road users. A Lagrangian relaxation solution framework effectively decomposes the original complex problem into classical subproblems such as knapsack and time-dependent least cost problems. Various examples and discussions are provided to consider the effectiveness of the proposed method in modeling accessibility-enhancement strategies such as congestion mitigation and land use policies.

Exploring trade-offs in frequency allocation in a transit network using bus route patterns: Methodology and application to large-scale urban systems

- Transportation Research Part B: Methodological--2015---İ. Ömer Verbas,Hani S. Mahmassani

Transit agencies seek to allocate their limited operational budget and fleet optimally to service routes in order to maximize user benefits. The Transit Network Frequency Setting Problem formulation developed in this study effectively captures the coupling between the routes and their prevailing patterns, which may have different subsets of stops visited at different times of the day. The number of riders is elastic to the prevailing number of bus trips at a given stop, which is the combination of different pattern dispatch frequencies. As a result, the study bridges the gap between the operator’s perspective where the decision unit is the pattern schedule, and the user’s perspective, which perceives frequencies at the route level. Two main formulations are introduced. The first one maximizes the number of riders and the total waiting time savings under budget, fleet, policy headway and bus loading constraints; the second minimizes the net cost under fleet, policy headway, bus loading, minimum ridership and minimum waiting time savings constraints. In both formulations, pattern headways are the decision variables. Spatial and temporal heterogeneity of ridership elasticity with respect to headway is captured. The formulations are applied to a large-scale test network for the Chicago area. The results show that a win–win solution is possible where both ridership and waiting time savings are increased, while the net cost is decreased.

A reliability model for facility location design under imperfect information

- Transportation Research Part B: Methodological---2015---Lifen Yun,Yong Qin,Hongqiang Fan,Changxu Ji,Xiaopeng Li,Limin Jia

This paper aims to propose a modeling framework for reliable facility location design under imperfect information, i.e., when customers do not know the real-time information of facility disruption states. We consider a realistic “trial-and-error” strategy for a customer to visit facilities without knowing their states until arriving at this facility; i.e., a customer keeps trying a number of pre-assigned facilities until she acquires the service or is forced to give up trying. The research problem is to determine the best facility location that minimizes the total system cost, including initial facility investment and expected long-term operational cost from transportation and loss of service, when facilities are subject to probabilistic disruptions and customers use the trial-and-error strategy. This problem is formulated into a compact integer program (IP), and we develop a Lagrangian relaxation algorithm to solve it. A set of case studies are conducted to test the performance of the proposed algorithm, and illustrate the applicability of the proposed model. The results reveal a number of interesting insights into the system design, including the significance of multi-level customer-facility assignments and the existence of a robust system design against variation of the loss-of-service penalty.

Optimization model for regional evacuation transportation system using macroscopic productivity function

- Transportation Research Part B: Methodological---2015---Zhao Zhang,Scott A. Parr,Hai Jiang,Brian Wolshon

The simulation of mass evacuation traffic processes, while enormously valuable in emergency planning and management, presents a number of challenges to transportation modelers and analysts. One area where evacuation modeling and analysis has lacked is in the ability to determine the specific evacuation travel demand and capacity and conditions under which a road network can most effectively carry the maximum outflow rate for an area under threat of catastrophic disasters. This is a difficult question to answer because evacuations are so complex and can include millions of people, traveling on tens of thousands of miles of roads, lasting several hours or even days in duration. Knowledge of how to reduce the likelihood of over-saturation would be useful, for example, to develop temporally and spatially phased evacuation plans that meter demand into the system for maximum overall benefit. In this paper an optimization model is proposed to maximize evacuation throughput traffic for regional networks. This model aims at optimizing network outflow and trip complete percentage at a macroscopic level by changing the distribution of evacuation traffic in the time horizon. The productivity function, pioneered by Geroliminis and Daganzo (2007, 2008) is used to assess network performance from a macroscopic point of view. Then, an optimization model with the objective of maximizing both total network productivity and outflow rate is proposed. Further, a simulation based study of the New Orleans metropolitan area is used to validate the effectiveness of the optimization model.

A mechanism design based approach to solving parking slot assignment in the information era

- Transportation Research Part B: Methodological---2015---Bo Zou,Nabin Kafle,Ouri Wolfson,Lin, Jie (Jane)

This paper proposes a mechanism design based approach for public parking slot assignment in an environment empowered by recent advances in parking sensing, infrastructure-to-vehicle, and vehicle-to-infrastructure communications. An important part of the parking slot assignment deals with eliciting truthful private information from drivers while maximizing social welfare. We consider both static and dynamic mechanisms and provide theoretic proofs that, by using coupled slot allocation and payment rules, drivers will be incentivized to participate in the assignment process and truthfully report their private information. The parking manager will benefit by generating non-negative revenue from each assigned driver. Our numerical analysis provides further insights into the implementation of the dynamic mechanisms.

Inferring the route-use patterns of metro passengers based only on travel-time data within a Bayesian framework using a reversible-jump Markov chain Monte Carlo (MCMC) simulation

- Transportation Research Part B: Methodological---2015---Minseo Lee,Keemin Sohn

The passenger share and the average travel time for multiple routes connecting an origin–destination pair on a metro network has been examined based on a known number of used routes. Determining how many routes were used based only on travel times from smart-card data is a difficult task, even though the automatic fare collection system can provide a massive amount of travel data. The present study proposes a robust approach to incorporate the number of used routes as an unknown parameter into a Bayesian framework based on a reversible-jump Markov chain Monte Carlo (MCMC) algorithm. Other route-use patterns such as the passenger share and the mean and variance of route travel times were also estimated. The performance of the present approach was compared with the existing method, which depends on the Bayesian information criterion (BIC). The present approach showed better performance in reproducing the observed number of routes used, and also provided greater flexibility in recognizing route-use patterns through the marginal posterior distribution of other unknown parameters.

Facility location design under continuous traffic equilibrium

- Transportation Research Part B: Methodological---2015---Yanfeng Ouyang,Zhaodong Wang,Hai Yang

This paper presents two modeling approaches for median-type facility location design under elastic customer demand and traffic equilibrium in a continuous space. The first approach, following the continuum approximation scheme, builds upon the special case of an infinite homogeneous plane where traffic equilibrium can be described by an ordinary differential equation. The solution to this homogeneous case, sometimes in a closed form, is then used to develop approximate solutions to more general cases (e.g., those in a heterogeneous space). This model provides a computationally efficient way to obtain managerial insights and near-optimal solutions, especially for large problem instances. We also develop a more traditional discrete location model in the form of a mixed-integer program, which builds directly upon a nonlinear partial differential equation description of customer traffic equilibrium. We develop a Lagrangian relaxation based solution approach with an embedded finite-element method subroutine, to separate and solve the location decisions as well as the traffic equilibrium. Numerical experiments are conducted to illustrate applicability of the proposed models and to compare performance of the two complementing modeling approaches.

An ordinary differential equation formulation of the bottleneck model with user heterogeneity

- Transportation Research Part B: Methodological---2015---Wen-Xiang Wu,Hai-Jun Huang

Considering heterogeneous values of time and schedule delay early, in this paper we develop an ordinary differential equation formulation of the bottleneck model without allowance of arriving late. We show that in no-toll equilibrium, the generalized travel cost increases with departure time as the ratio of value of schedule delay to value of time increases with these two values, and commuters with higher values would experience higher generalized costs. We then derive the first-best toll and analyses its efficiency and distributional impacts. We obtain the sufficient Pareto-improving condition for the first-best scheme without imposing specific functional forms on heterogeneity. It is a Pareto improvement when the gap between values of time and schedule delay early increases as the ratio of value of schedule delay early to value of time increases. The proposed approach is applied to deal with such user heterogeneity that both the values of time and schedule delay early follow uniform distributions. In this case, the Pareto-improving condition is not only sufficient but also necessary. The individual gain from tolling is strictly monotonically increasing with respect to values of time and schedule delay early. Outside this condition, the first-best toll scheme makes users with relatively higher values of time and schedule delay early better off and those with relatively lower values worse off. And, users with higher values of time and schedule delay early could gain more or lose less from tolling. In contrasts with previous literature, our approach is robust in the sense that it can deal with not only discrete but also continuous user heterogeneity.

Allowing for complementarity and rich substitution patterns in multiple discrete–continuous models

- Transportation Research Part B: Methodological---2015---Chandra R. Bhat,Marisol Castro,Abdul Rawoof Pinjari

Many consumer choice situations are characterized by the simultaneous demand for multiple alternatives that are imperfect substitutes for one another, along with a continuous quantity dimension for each chosen alternative. To model such multiple discrete–continuous choices, most multiple discrete–continuous models in the literature use an additively-separable utility function, with the assumption that the marginal utility of one good is independent of the consumption of another good. In this paper, we develop model formulations for multiple discrete–continuous choices that accommodate rich substitution structures and complementarity effects in the consumption patterns, and demonstrate an application of the model to transportation-related expenditures using data drawn from the 2002 Consumer Expenditure (CEX) Survey.

Development and field application of a multivariate statistical process control framework for health-monitoring of transportation infrastructure

- Transportation Research Part B: Methodological---2015---Yikai Chen,Pablo L. Durango-Cohen

We present a two-part multivariate statistical process control framework to support health-monitoring of transportation infrastructure. The first part consists of estimation of regression and ARIMA–GARCH models to explain, predict, and control for common-cause variation in the data, i.e., changes that can be attributed to usual operating conditions, including traffic loads, environmental effects, and damage when present throughout the data. The second part of the framework consists of using multivariate control charts to simultaneously analyze the standardized innovations of the aforementioned models in order to detect possible special-cause or extraordinary events, such as unique/infrequent traffic, weather, or the onset of damage. The proposed approach revolves around construction of T2 control charts as a framework to jointly monitor the evolution and contemporaneous correlation of a set of measurements. The approach provides significant practical/computational advantages over individual analysis of multiple structural properties, and addresses technical problems stemming from ignoring the relationships among them.

- Miska,Edward Chung

Solving simultaneous route guidance and traffic signal optimization problem using space-phase-time hypernetwork

- Transportation Research Part B: Methodological---2015---Pengfei Li,Pitu Mirchandani,Xuesong Zhou

This paper addresses the problem of simultaneous route guidance and traffic signal optimization problem (RGTSO) where each vehicle in a traffic network is guided on a path and the traffic signals servicing these vehicles are set to minimize their travel times. The network is modeled as a space-phase-time (SPT) hyper-network to explicitly represent the traffic signal control phases and time-dependent vehicle paths. A Lagrangian-relaxation-based optimization framework is proposed to decouple the RGTSO problem into two subproblems: the Route Guidance (RG) problem for multiple vehicles with given origins and destinations and the Traffic Signal Optimization (TSO) problem. In the RG subproblem, the route of each vehicle is provided subject to time-dependent link capacities imposed by the solution of the TSO problem, while the traffic signal timings are optimized according to the respective link travel demands aggregated from the vehicle trajectories. The dual prices of the RG subproblem indicate search directions for optimization of the traffic signal phase sequences and durations in the TSO subproblem. Both RG and TSO subproblems can be solved using a computationally efficient finite-horizon dynamic programming framework, enhanced by parallel computing techniques. Two numerical experiments demonstrated that the system optimum of the RGTSO problem can be quickly reached with relatively small duality gap for medium-size urban networks.

Probabilistic travel time progression and its application to automatic vehicle identification data

- Transportation Research Part B: Methodological---2015---Alfredo Nantes,Dong Ngoduy,Marc Miska,Edward Chung

Travel time has been identified as an important variable to evaluate the performance of a transportation system. Based on the travel time prediction, road users can make their optimal decision in choosing route and departure time. In order to utilise adequately the advanced data collection methods that provide real-time different types of information, this paper is aimed at a novel approach to the estimation of long roadway travel times, using Automatic Vehicle Identification (AVI) technology. Since the long roads contain a large number of scanners, the AVI sample size tends to reduce and, as such, computing the distribution for the total road travel time becomes difficult. In this work, we introduce a probabilistic framework that extends the deterministic travel time progression method to dependent random variables and enables the off-line estimation of road travel time distributions. In the proposed method, the accuracy of the estimation does not depend on the size of the sample over the entire corridor, but only on the amount of historical data that is available for each link. In practice, the system is also robust to small link samples and can be used to detect outliers within the AVI data.

Dynamic control of complex transit systems

- Transportation Research Part B: Methodological---2015---Juan Argote-Cabanero,Carlos F. Daganzo,Jacob W. Lynn

This paper proposes a dynamic control method to overcome bunching and improve the regularity of fixed-route transit systems. The method uses a combination of dynamic holding and en-route driver guidance to achieve its objectives. It applies to systems with a mix of headway-based and schedule-based lines but it is evaluated for scheduled systems as this is the more challenging application. Improved schedule adherence is the goal.

Complementarity models for traffic equilibrium with ridesharing

- Transportation Research Part B: Methodological---2015---Huayu Xu,Jong-Shi Pang,Fernando Ordóñez,Maged Dessouky

It is estimated that 76% of commuters are driving to work alone while each of them experiences a 38-h delay annually due to traffic congestion. Ridesharing is an efficient way to utilize the unused capacity and help with congestion reduction, and it has recently become more and more popular due to new communication technologies. Understanding the complex relations between ridesharing and traffic congestion is a critical step in the evaluation of a ridesharing enterprise or of the effectiveness of regulatory policies or incentives to promote ridesharing. The objective of this paper is to introduce a mathematical framework for the study of the ridesharing impacts on traffic congestion and to pave the way for the analysis of how people can be motivated to participate in ridesharing, and conversely, how congestion influences ridesharing activities. We accomplish this objective by developing a new traffic equilibrium model with ridesharing, and formulating the model as a mixed complementarity problem (MiCP). We provide conditions on the model parameters under which there exists one and only one solution to this model. The computational results show that when the congestion cost decreases or the ridesharing inconvenience cost increases, more travelers would become solo drivers and thus less people would participate in ridesharing. On the other hand, when the ridesharing price increases, more travelers would become ridesharing drivers.

Elastic demand dynamic network user equilibrium: Formulation, existence and computation

- Transportation Research Part B: Methodological---2015---Ke Han,Terry L. Friesz,W.Y. Szeto,Hongcheng Liu

This paper is concerned with dynamic user equilibrium with elastic travel demand (E-DUE) when the trip demand matrix is determined endogenously. We present an infinite-dimensional variational inequality (VI) formulation that is equivalent to the conditions defining a continuous-time E-DUE problem. An existence result for this VI is established by applying a fixed-point existence theorem (Browder, 1968) in an extended Hilbert space. We present three computational algorithms based on the aforementioned VI and its re-expression as a differential variational inequality (DVI): a projection method, a self-adaptive projection method, and a proximal point method. Rigorous convergence results are provided for these methods, which rely on increasingly relaxed notions of generalized monotonicity, namely mixed strongly-weakly monotonicity for the projection method; pseudomonotonicity for the self-adaptive projection method, and quasimonotonicity for the proximal point method. These three algorithms are tested and their solution quality, convergence, and computational efficiency are compared. Our convergence results, which transcend the transportation applications studied here, apply to a broad family of VIs and DVIs, and are the weakest reported to date.

Solving the step-tolled bottleneck model with general user heterogeneity

- Transportation Research Part B: Methodological---2015---Hongyu Chen,Yang Liu,Nie, Yu (Marco)

Two new numerical methods, a semi-analytical method and an exact method, are proposed in this paper for solving the step-tolled user equilibrium problem for the bottleneck model with general user heterogeneity. The semi-analytical method transforms the step-tolled user equilibrium problem into a static traffic assignment problem with side constraints, which is formulated and solved as a variational inequality problem (VIP). Existence and uniqueness results are obtained by examining the properties of the VIP. The exact method, on the other hand, locates the equilibrium solution by enumerating all possible combinations of user departure orders. To improve the computational efficiency of the exact method, a simple heuristic is developed to reduce the number of solutions to be enumerated. Examples of up to 1000 classes are tested. The results confirm that ignoring user heterogeneity may lead to sub-optimal design of step tolls. In all experiments, the semi-analytical method is found to be more efficient than the heuristic version of the exact method by an order of magnitude, albeit they consistently produce nearly identical equilibrium solutions.

Estimating exponential scheduling preferences

- Transportation Research Part B: Methodological---2015---Katrine Hjorth,Maria Börjesson,Leonid Engelson,Mogens Fosgerau

Different assumptions about travelers' scheduling preferences yield different measures of the cost of travel time variability. Only few forms of scheduling preferences provide non-trivial measures which are additive over links in transport networks where link travel times are arbitrarily distributed independent random variables: Assuming smooth preferences, this holds only for specifications with a constant marginal utility of time at the origin and an exponential or affine marginal utility of time at the destination. We apply a generalized version of this model to stated preference data of car drivers' route and mode choice under uncertain travel times. Our analysis exposes some important methodological issues related to complex non-linear scheduling models: One issue is identifying the point in time where the marginal utility of being at the destination becomes larger than the marginal utility of being at the origin. Another issue is that models with the exponential marginal utility formulation suffer from empirical identification problems. Though our results are not decisive, they partly support the constant-affine specification, in which the value of travel time variability is proportional to the variance of travel time.

An exact algorithm for the mean–standard deviation shortest path problem

- Transportation Research Part B: Methodological---2015---Alireza Khani,Stephen D. Boyles

This paper studies the reliable path problem in the form of minimizing the sum of mean and standard deviation of path travel time. For the case of independent link travel times, we show that the problem can be solved exactly by repeatedly solving a subproblem minimizing the sum of mean and variance of path travel time. The latter is an additive shortest path problem, and can be solved using a standard labeling algorithm. While these subproblems are similar in form to those obtained from Lagrangian relaxation, this formulation admits proof of finite convergence to the optimal solution. An iterative labeling algorithm is developed that solves the non-additive reliable path problem from a single origin to all destinations. Moreover, a labeling technique is employed to further reduce the computational time of the proposed algorithm by partially updating the network in each iteration. As an alternative, a bisection-type search algorithm is developed that solves the problem for the single-origin and single-destination case. Numerical tests are presented, indicating that the proposed algorithm outperform others recently proposed in the literature: unlike Lagrangian relaxation, two of the proposed algorithms find solutions exactly, and the computation time is an order of magnitude faster than outer approximation methods.

A branch-and-cut algorithm for a realistic dial-a-ride problem

- Transportation Research Part B: Methodological---2015---Mengyang Liu,Zhixing Luo,Andrew Lim

In this paper we study a realistic dial-a-ride problem which simultaneously considers multiple trips, heterogeneous vehicles, multiple request types, configurable vehicle capacity and manpower planning. All of these features originate from practical applications in recent years. To formulate the problem, we propose two mathematical models that use different methods to deal with requests associated with the depot. To further strengthen the models, we propose eight families of valid inequalities, and based on them, we propose a branch-and-cut algorithm to solve the problem. The branch-and-cut algorithm was extensively tested on a set of instances generated according to the data of a real world application. The computational results showed that seven families of inequalities can improve the lower bounds substantially and the branch-and-cut algorithm can solve instances with up to 22 requests within 4h.

Commuters' preferences for fast and reliable travel: A semi-parametric estimation approach

- Transportation Research Part B: Methodological---2015---Paul Koster,Hans R.A. Koster

We employ a semi-parametric estimation approach to analyse observed and unobserved heterogeneity in the value of savings in travel time and schedule delay. Our econometric approach allows for the estimation of unobserved and observed heterogeneity in preferences in a flexible way, meaning that we do not put any structure on how individual characteristics (such as income and age) relate to the value of savings in travel time and schedule delay. Using data from a stated choice experiment, we illustrate the estimation approach and find that there is substantial heterogeneity in the value of savings in travel time and schedule delay. For our data, we find that unobserved heterogeneity is more important than heterogeneity related to individual characteristics.

A modified Cell Transmission Model with realistic queue discharge features at signalized intersections

- Transportation Research Part B: Methodological---2015---Anupam Srivastava,Wen-Long Jin,Jean-Patrick Lebacque

Modeling realistic discharge flow-rate and headway features at signalized intersections is critical to the design of traffic signals, since they play a critical role in determining the startup lost times and intersection capacity. Traditional queue discharge models are either microscopic or stochastic, and macroscopic traffic flow models for signalized intersections are based on overly simplistic assumptions. They are incapable of modeling traffic dynamics at signalized intersections as well as capturing realistic queue discharge features.

A kinematic wave theory of capacity drop

- Transportation Research Part B: Methodological---2015---Wen-Long Jin,Qi-Jian Gan,Jean-Patrick Lebacque

Capacity drop at active bottlenecks is one of the most puzzling traffic phenomena, but a thorough understanding of its mechanism is critical for designing variable speed limit and ramp metering strategies. In this study, within the framework of the kinematic wave theory, we propose a simple model of capacity drop based on the observation that capacity drop occurs when an upstream queue forms at an active bottleneck. Different from existing models, the new model still uses continuous fundamental diagrams but employs an entropy condition defined by a discontinuous boundary flux function, which introduces a traffic state-dependent capacity constraint. For a lane-drop area, we demonstrate that the model is well-defined, and its Riemann problem can be uniquely solved. After deriving the flow-density relations upstream and downstream to a bottleneck location, we find that the model can replicate the following three characteristics of capacity drop: the maximum discharge flow-rate can be reached only when both upstream and downstream traffic conditions are uncongested, capacity drop occurs when the bottleneck is activated, and some steady traffic states cannot be observed at both locations. We show that the new model is bistable subject to perturbations in initial and boundary conditions. With empirical observations at a merging bottleneck we also verify the three characteristics of capacity drop predicted by the new model. Through this study, we establish that the new model is physically meaningful, conceptually simple, computationally efficient, and mathematically tractable. We finally discuss future extensions and potential applications of the new model.

Stochastic capacity expansion models for airport facilities

- Transportation Research Part B: Methodological---2015---Yanshuo Sun,Paul Schonfeld

It is important and also challenging to plan airport facilities to meet future traffic needs in a rapidly changing environment, which is characterized by various uncertainties. One key issue in airport facility development is that facility performance functions (delay levels as functions of capacity utilization rates) are nonlinear, which complicates the solution method design. Potential demand fluctuations in a deregulated aviation market add another dimension to the decision making process. To solve this problem, a deterministic total cost minimization model is proposed and then extended into stochastic programs, by including uncertainties in traffic forecasts. After the exploration of properties of the delay cost function, an Outer-Approximation (OA) technique which is superior to the existing discrete approximation is designed. After model enhancements, an efficient solution framework based on the OA technique is used to solve the model to its global optimality by interactively generating upper and lower bounds to the objective. Computational tests demonstrate the validity of developed models and efficiency of proposed algorithms. The total cost is reduced by 18.8% with the stochastic program in the numerical example.

A mixed integer programming model for optimizing multi-level operations process in railroad yards

- Transportation Research Part B: Methodological---2015---Tie Shi,Xuesong Zhou

A typical railroad hump yard contains multiple layers of complex operations. The railcars coming with inbound trains through the yard need to be humped into different classification tracks according to the destination, and then assembled to generate the desired outbound trains. During this complex procedure, the processing time of railcars and various resource constraints at different railroad yard facilities could significantly affect the overall performance of yard operations, individually and in combination. It is theoretically challenging to represent a large number of practical operation rules through tractable mathematical programming models. This paper first presents a time-expanded multi-layer network flow model to describe the connection between different layers of yard operations. A mixed integer programming model is developed to optimize the overall performance by jointly considering tightly interconnected facilities. We adopt a cumulative flow count representation to model the spatial capacity constraints in terms of the number of railcars in classification yards. A novel lot-sizing modeling framework and related valid inequality formulations are introduced to model the assembling jobs for outbound trains. We also develop an aggregated flow assignment model and earliest due date-based heuristic rules to determine the humping jobs sequence for reducing the search space. Numerical experiments are conducted to examine the solution quality and computational efficiency under different types of formulation strategies.

Compound Gamma representation for modeling travel time variability in a traffic network

- Transportation Research Part B: Methodological---2015---Jiwon Kim,Hani S. Mahmassani

This paper proposes a compound probability distribution approach for capturing both vehicle-to-vehicle and day-to-day variability in modeling travel time reliability in a network. Starting from the observation that standard deviation and mean of distance-normalized travel time in a network are highly positively correlated and their relationship is well characterized by a linear function, this study assumes multiplicative error structures to describe data with such characteristics and derives a compound distribution to model travel delay per unit distance as a surrogate for travel time. The proposed Gamma–Gamma model arises when (within-day) vehicle-to-vehicle travel delay per unit distance is distributed according to a Gamma distribution, with mean that itself fluctuates from day to day following another Gamma distribution. The study calibrates the model parameters and validates the underlying assumptions using both simulated and actual vehicle trajectory data. The Gamma–Gamma distribution shows good fits to travel delay observations when compared to the (simple) Gamma and Lognormal distributions. The main advantage of the Gamma–Gamma model is its ability to recognize different variability dimensions reflected in travel time data and clear physical meanings of its parameters in connection with vehicle-to-vehicle and day-to-day variability. Based on the linearity assumption for the relationship between mean and standard deviation, two shape parameters of the Gamma–Gamma model are linked to the coefficient of variation of travel delay in vehicle-to-vehicle and day-to-day distributions, respectively, and can be directly estimated from the slope of the associated mean-standard deviation plots. An extension of the basic model form was also introduced to address potential deviations from this linearity assumption. The extended Gamma–Gamma model can account for time-of-day variations in mean-standard deviation relationships—such as hysteresis patterns observed in mean and day-to-day variation in travel time—and incorporate such dynamics in travel time distribution modeling. In summary, the model provides a systematic way of quantifying, comparing, and assessing different types of variability, which is important in understanding travel time characteristics and evaluating various transportation measures that affect reliability.

Decomposition of general facility disruption correlations via augmentation of virtual supporting stations

- Transportation Research Part B: Methodological--2015---Siyang Xie,Xiaopeng Li,Yanfeng Ouyang

Infrastructure facilities may be subject to probabilistic disruptions that compromise individual facility functionality as well as overall system performance. Disruptions of distributed facilities often exhibit complex spatial correlations, and thus it is difficult to describe them with succinct mathematical models. This paper proposes a new methodological framework for analyzing and modeling facility disruptions with general correlations. This framework first proposes pairwise transformations that unify three probabilistic representations (i.e., based on conditional, marginal, and scenario probabilities) of generally correlated disruption profile among multiple distributed facilities. Then facilities with any of these disruption profile representations can be augmented into an equivalent network structure consisting of additional supporting stations that experience only independent failures. This decomposition scheme largely reduces the complexity associated with system evaluation and optimization. We prove analytical properties of the transformations and the decomposition scheme, and illustrate the proposed methodological framework using a set of numerical case studies and sensitivity analyses. Managerial insights are also drawn.

Trajectory data reconstruction and simulation-based validation against macroscopic traffic patterns

- Transportation Research Part B: Methodological--2015---Marcello Montanino,Vincenzo Punzo

This paper shows that the behavior of driver models, either individually or entangled in stochastic traffic simulation, is affected by the accuracy of empirical vehicle trajectories. To this aim, a “traffic-informed” methodology is proposed to restore physical and platoon integrity of trajectories in a finite time–space domain, and it is applied to one NGSIM I80 dataset. However, as the actual trajectories are unknown, it is not possible to verify directly whether the reconstructed trajectories are really “nearer” to the actual unknowns than the original measurements. Therefore, a simulation-based validation framework is proposed, that is also able to verify indirectly the efficacy of the reconstruction methodology. The framework exploits the main feature of NGSIM-like data that is the concurrent view of individual driving behaviors and emerging macroscopic traffic patterns. It allows showing that, at the scale of individual models, the accuracy of trajectories affects the distribution and the correlation structure of lane-changing model parameters (i.e. drivers heterogeneity), while it has very little impact on car-following calibration. At the scale of traffic simulation, when models interact in trace-driven simulation of the I80 scenario (multi-lane heterogeneous traffic), their ability to reproduce the observed macroscopic congested patterns is sensibly higher when model parameters from reconstructed trajectories are applied. These results are mainly due to lane changing, and are also the sought indirect validation of the proposed data reconstruction methodology.

An extended coordinate descent method for distributed anticipatory network traffic control

- Transportation Research Part B: Methodological--2015---Marco Rinaldi,Chris M.J. Tampère

Anticipatory optimal network control can be defined as the practice of determining the set of control actions that minimizes a network-wide objective function, so that the consequences of this action are taken in consideration not only locally, on the propagation of flows, but globally, taking into account the user’s routing behavior. Such an objective function is, in general, defined and optimized in a centralized setting, as knowledge regarding the whole network is needed in order to correctly compute it. This is a strong theoretical framework but, in practice, reaching a level of centralization sufficient to achieve said optimality is very challenging. Furthermore, even if centralization was possible, it would exhibit several shortcomings, with concerns such as computational speed (centralized optimization of a huge control set with a highly nonlinear objective function), reliability and communication overhead arising.

Implicit choice set generation in discrete choice models: Application to household auto ownership decisions

- Transportation Research Part B: Methodological--2015---Rajesh Paleti

Latent choice set models that account for probabilistic consideration of choice alternatives during decision making have long existed. The Manski model that assumes a two-stage representation of decision making has served as the standard workhorse model for discrete choice modeling with latent choice sets. However, estimation of the Manski model is not always feasible because evaluation of the likelihood function in the Manski model requires enumeration of all possible choice sets leading to explosion for moderate and large choice sets. In this study, we propose a new group of implicit choice set generation models that can approximate the Manski model while retaining linear complexity with respect to the choice set size. We examined the performance of the models proposed in this study using synthetic data. The simulation results indicate that the approximations proposed in this study perform considerably well in terms of replicating the Manski model parameters. We subsequently used these implicit choice set models to understand latent choice set considerations in household auto ownership decisions of resident population in the Southern California region. The empirical results confirm our hypothesis that certain segments of households may only consider a subset of auto ownership levels while making decisions regarding the number of cars to own. The results not only underscore the importance of using latent choice models for modeling household auto ownership decisions but also demonstrate the applicability of the approximations proposed in this study to estimate these latent choice set models.

Fine-grained OD estimation with automated zoning and sparsity regularisation

- Transportation Research Part B: Methodological--2015---Aditya Krishna Menon,Chen Cai,Weihong Wang,Tao Wen,Fang Chen

Given a road network, a fundamental object of interest is the matrix of origin destination (OD) flows. Estimation of this matrix involves at least three sub-problems: (i) determining a suitable set of traffic analysis zones, (ii) the formulation of an optimisation problem to determine the OD matrix, and (iii) a means of evaluating a candidate estimate of the OD matrix. This paper describes a means of addressing each of these concerns. We propose to automatically uncover a suitable set of traffic analysis zones based on observed link flows. We then employ regularisation to encourage the estimation of a sparse OD matrix. We finally propose to evaluate a candidate OD matrix based on its predictive power on held out link flows. Analysis of our approach on a real-world transport network reveals that it discovers automated zones that accurately capture regions of interest in the network, and a corresponding OD matrix that accurately predicts observed link flows.

Stochastic optimization approach for the car placement problem in ridesharing systems

- Transportation Research Part B: Methodological---2015---Joe Naoum-Sawaya,Randy Cogill,Bissan Ghaddar,Shravan Sajja,Robert Shorten,Nicole Taheri,Pierpaolo Tommasi,Rudi Verago,Fabian Wirth

With the increasing fuel prices and the pressure towards greener modes of transportation, ridesharing has emerged as an alternative to private car ownership and public transportation. In this paper, we focus on a common destination ridesharing system which is of interest in large organizations such as companies and government offices. Particularly, such organizations are looking at using company owned vehicles to offer a ridesharing service by which employees carpool to work thus leading to several benefits that include decreasing pressure on on-campus parking spaces, lowering localized on-campus congestion, in addition to offering a greener transportation mode while lowering transportation costs for employees. Based on discussions with our industry partners, optimizing the distribution of limited number of company vehicles while insuring robustness against unlikely vehicle unavailability is of critical importance. Thus in this paper, we present a stochastic mixed integer programming model to optimize the allocation of shared vehicles to employees while taking into account the unforeseen event of vehicle unavailability which would require some participants to take own vehicles or rerouting of existing vehicles. Since solving the proposed model to optimality is computationally challenging for problems of large sizes, we also propose a heuristic that is capable of finding good quality solutions in limited computational time. The proposed model and heuristic are tested on several instances of varying sizes showing the computational performance. Finally, a test case based on the city of Rome, Italy is presented and insights related to vehicle distribution and travel time savings are discussed.

A simple nonparametric car-following model driven by field data

- Transportation Research Part B: Methodological---2015---Zhengbing He,Liang Zheng,Wei Guan

Car-following models are always of great interest of traffic engineers and researchers. In the age of mass data, this paper proposes a nonparametric car-following model driven by field data. Different from most of the existing car-following models, neither driver’s behaviour parameters nor fundamental diagrams are assumed in the data-driven model. The model is proposed based on the simple k-nearest neighbour, which outputs the average of the most similar cases, i.e., the most likely driving behaviour under the current circumstance. The inputs and outputs are selected, and the determination of the only parameter k is introduced. Three simulation scenarios are conducted to test the model. The first scenario is to simulate platoons following real leaders, where traffic waves with constant speed and the detailed trajectories are observed to be consistent with the empirical data. Driver’s rubbernecking behaviour and driving errors are simulated in the second and third scenarios, respectively. The time–space diagrams of the simulated trajectories are presented and explicitly analysed. It is demonstrated that the model is able to well replicate periodic traffic oscillations from the precursor stage to the decay stage. Without making any assumption, the fundamental diagrams for the simulated scenario coincide with the empirical fundamental diagrams. These all validate that the model can well reproduce the traffic characteristics contained by the field data. The nonparametric car-following model exhibits traffic dynamics in a simple and parsimonious manner.

Path-differentiated pricing in congestion mitigation

- Transportation Research Part B: Methodological---2015---Mahmood Zangui,Hedayat Z. Aashtiani,Siriphong Lawphongpanich,Yafeng Yin

Instead of charging tolls on individual links, this paper considers doing the same on paths. Path and link tolls are “valid” if they encourage motorists to use routes that collectively lead to a target distribution, e.g., one that minimizes travel delay. Because the numbers of valid link and path tolls are typically infinite, an objective in pricing tolls is to find a set of valid tolls that yields the least revenue to lessen the financial burden on motorists.

Specification of the cross-nested logit model with sampling of alternatives for route choice models

- Transportation Research Part B: Methodological---2015---Xinjun Lai,Michel Bierlaire

We present an operational estimation procedure for the estimation of route choice multivariate extreme value (MEV) models based on sampling of alternatives. The procedure builds on the state-of-the-art literature, and in particular on recent methodological developments proposed by Flötteröd and Bierlaire (2013) and Guevara and Ben-Akiva (2013b). Case studies on both synthetic data and a real network demonstrate that the new method is valid and practical.

A day-to-day dynamical model for the evolution of path flows under disequilibrium of traffic networks with fixed demand

- Transportation Research Part B: Methodological---2015---Amit Kumar,Srinivas Peeta

Transportation networks are often subjected to perturbed conditions leading to traffic disequilibrium. Under such conditions, the traffic evolution is typically modeled as a dynamical system that captures the aggregated effect of paths-shifts by drivers over time. This paper proposes a day-to-day (DTD) dynamical model that bridges two important gaps in the literature. First, existing DTD models generally consider current path flows and costs, but do not factor the sensitivity of path costs to flow. The proposed DTD model simultaneously captures all three factors in modeling the flow shift by drivers. As a driver can potentially perceive the sensitivity of path costs with the congestion level based on past experience, incorporating this factor can enhance real-world consistency. In addition, it smoothens the time trajectory of path flows, a desirable property for practice where the iterative solution procedure is typically terminated at an arbitrary point due to computational time constraints. Second, the study provides a criterion to classify paths for an origin–destination pair into two subsets under traffic disequilibrium: expensive paths and attractive paths. This facilitates flow shifts from the set of expensive paths to the set of attractive paths, enabling a higher degree of freedom in modeling flow shift compared to that of shifting flows only to the shortest path, which is behaviorally restrictive. In addition, consistent with the real-world driver behavior, it also helps to preclude flow shifts among expensive paths. Improved behavioral consistency can lead to more meaningful path/link time-dependent flow profiles for developing effective dynamic traffic management strategies for practice. The proposed DTD model is formulated as the dynamical system by drawing insights from micro-economic theory. The stability of the model and existence of its stationary point are theoretically proven. Results from computational experiments validate its modeling properties and illustrate its benefits relative to existing DTD dynamical models.

Driver perception uncertainty in perceived relative speed and reaction time in car following – A quantum optical flow perspective

- Transportation Research Part B: Methodological---2015---Jiuh-Biing Sheu,Hsi-Jen Wu

Driver perception uncertainty characterized in perceived relatnd reaction time plays a key role in influencing car-following behavior; and however, is rarely investigated in related literature. Grounded on quantum optical flow theory, we propose a dynamic and stochastic driver perception model to investigate the relationship between the uncertainty of perceived relative speed and that of reaction time during car following. Specifically, the proposed model hypothesizes that driver perceived speed and reaction time are time-varying and uncertain, and correlate in a trade-off relationship mimicking the form of Heisenberg Uncertainty Principle. To test the assertion that a trade-off relationship of uncertainty in perceived relative speed and reaction time exists in car following, this study conducts qualitative analysis followed by a two-stage experiment rooted in quantum optical flow theory using data collected from a driver simulator. Analytical results further elucidate car-following phenomena under driver-perception uncertainty, potentially facilitating the development of new traffic flow theories.

Study on mean-standard deviation shortest path problem in stochastic and time-dependent networks: A stochastic dominance based approach

- Transportation Research Part B: Methodological---2015---Xing Wu

This paper studies a mean-standard deviation shortest path model, also called travel time budget (TTB) model. A route’s TTB is defined as this route’s mean travel time plus a travel time margin, which is the route travel time’s standard deviation multiplied with a factor. The TTB model violates the Bellman’s Principle of Optimality (BPO), making it difficult to solve it in any large stochastic and time-dependent network. Moreover, it is found that if path travel time distributions are skewed, the conventional TTB model cannot reflect travelers’ heterogeneous risk-taking behavior in route choice. This paper proposes to use the upper or lower semi-standard deviation to replace the standard deviation in the conventional TTB model (the new models are called derived TTB models), because these derived TTB models can well capture such heterogeneous risk-taking behavior when the path travel time distributions are skewed. More importantly, this paper shows that the optimal solutions of these two derived TTB models must be non-dominated paths under some specific stochastic dominance (SD) rules. These finding opens the door to solve these derived TTB models efficiently in large stochastic and time-dependent networks. Numerical examples are presented to illustrate these findings.

The impact on port competition of the integration of port and inland transport services

- Transportation Research Part B: Methodological---2015---Óscar Álvarez-SanJaime,Pedro Cantos-Sánchez,Rafael Moner-Colonques,José Sempere-Monerris,Óscar Álvarez San-Jaime

The performance of the transport chain is important for the efficiency and competitiveness of an economy. In the context of port competition, there has been an increasing cooperation between firms involved in the intermodal transport chain including seaport services. This paper examines the economic incentives and welfare implications to the integration of port activities with inland transport services under inter-ports competition. Although ports find it advantageous to engage in such integration process it may be detrimental to welfare, since shippers’ aggregate surplus decreases – noting that farther away users benefit at the expense of those closer to the ports. Several scenarios not leading to such welfare decrease are identified: asymmetries in port capacities, government regulation and efficiency gains. These latter results provide support to policies that favor integration processes of transport services.

Link travel time inference using entry/exit information of trips on a network

- Transportation Research Part B: Methodological---2015---Kai Yin,Wen Wang,Xiubin Bruce Wang,Teresa M. Adams

This paper studies link travel time estimation using entry/exit time stamps of trips on a steady-state transportation network. We propose two inference methods based on the likelihood principle, assuming each link associates with a random travel time. The first method considers independent and Gaussian distributed link travel times, using the additive property that trip time has a closed-form distribution as the summation of link travel times. We particularly analyze the mean estimates when the variances of trip time estimates are known with a high degree of precision and examine the uniqueness of solutions. Two cases are discussed in detail: one with known paths of all trips and the other with unknown paths of some trips. We apply the Gaussian mixture model and the Expectation–Maximization (EM) algorithm to deal with the latter. The second method splits trip time proportionally among links traversed to deal with more general link travel time distributions such as log-normal. This approach builds upon an expected log-likelihood function which naturally leads to an iterative procedure analogous to the EM algorithm for solutions. Simulation tests on a simple nine-link network and on the Sioux Falls network respectively indicate that the two methods both perform well. The second method (i.e., trip splitting approximation) generally runs faster but with larger errors of estimated standard deviations of link travel times.

Efficient intermodal transportation auctions for B2B e-commerce logistics with transaction costs

- Transportation Research Part B: Methodological---2015---Su Xiu Xu,Meng Cheng,George Q. Huang

We propose efficient intermodal transportation auctions for the B2B e-commerce logistics problem (ELP). This paper is among the first to consider transaction costs into auctions. In the ELP, the shipper is a B2B e-commerce platform by which a number of online orders between goods sellers and buyers are generated, and 3PLs (third-party logistics providers) can fulfill these online orders. The shipper bears transaction costs while goods sellers or buyers eventually pay intermodal services. We extend both Vickrey–Clarke–Groves (VCG) auction and primal–dual Vickrey (PDV) auction to the ELP where total logistics chain cost is minimized. The VCG-like auction realizes incentive compatibility, allocative efficiency, individual rationality, and budget balance for general valuations; while the PDV-like auction need presume the condition of seller-submodularity, which implies that the effect of each 3PL is decreasing when coalition increases. Computational results show that incorporating transaction costs leads to considerable cost saving for the shipper, shipper’s group (that consists of the shipper herself, good sellers and buyers), and the logistics chain, as well as higher profitability for the group of 3PLs. As the variance of transaction costs increases, incorporating transaction costs leads to higher cost saving for the entities that matter to the shipper (i.e., herself, her group, and the logistics chain), and higher profitability for the group of 3PLs, regardless of valuation distribution type. Finally, we investigate the impact of self-interested shipper and the impact of the gap between intermodal service costs and transaction costs.

On some experimental features of car-following behavior and how to model them

- Transportation Research Part B: Methodological---2015---Rui Jiang,Mao-Bin Hu,H.M. Zhang,Zi-You Gao,Bin Jia,Qing-Song Wu

We have carried out car-following experiments with a 25-car-platoon on an open road section to study the relation between a car’s speed and its spacing under various traffic conditions, in the hope to resolve a controversy surrounding this fundamental relation of vehicular traffic. In this paper we extend our previous analysis of these experiments, and report new experimental findings. In particular, we reveal that the platoon length (hence the average spacing within a platoon) might be significantly different even if the average velocity of the platoon is essentially the same. The findings further demonstrate that the traffic states span a 2D region in the speed-spacing (or density) plane. The common practice of using a single speed-spacing curve to model vehicular traffic ignores the variability and imprecision of human driving and is therefore inadequate. We have proposed a car-following model based on a mechanism that in certain ranges of speed and spacing, drivers are insensitive to the changes in spacing when the velocity differences between cars are small. It was shown that the model can reproduce the experimental results well.

Some insights into a sequential resource allocation mechanism for en route air traffic management

- Transportation Research Part B: Methodological---2015---Amy Kim,Mark Hansen

This paper presents a game theoretic model of a sequential capacity allocation process in a congestible transportation system. In this particular application, we investigate the governing principles at work in how airlines will time their requests for en route resources under capacity shortfalls and uncertain conditions, when flights are not able to take their preferred route at their preferred departure time slot due to the shortfalls. We examine a sequential "First Submitted First Assigned" (FSFA) capacity allocation process within an en route air traffic flow management (ATFM) program such as the Collaborative Trajectory Options Program (CTOP), which is a Federal Aviation Administration initiative that aims to manage en route capacity constraints brought on by inclement weather and capacity/demand imbalances. In the FSFA process, flights are assigned the best available routes and slots available at the time flight operators submit their preference requests during the planning period, in a sequential manner. Because flight operators compete with one another for resources, in such an allocation process they would be expected to make their requests as early as possible. However, because weather and traffic conditions – and therefore, the values of resources – can change significantly, flight operators may prefer to request resources later in the process rather than earlier. We use a game theoretic setup to understand how flight operators might tradeoff these conflicts and choose an optimal time to submit their preferences for their flights, as submission times are competitive responses by flight operators looking to maximize their benefits. We first develop a loss function that captures the expected utility of submitting preferences under uncertainty about operating conditions. Then, a conceptual model of the FSFA process is constructed using a simultaneous incomplete information game, where flight operators compete for the "prizes" of having submitted their inputs before others. A numerical study is performed in which it is demonstrated that preference submission times are heavily influenced by the general uncertainty surrounding weather and operational conditions of the ATFM program, and each flight operator's internal ability to handle this uncertainty. A key finding is that, in many of the scenarios presented, an optimal strategy for a flight operator is to submit their preferences at the very beginning of the planning period. If air traffic managers could expect to receive more submissions at the beginning of the planning period, they could more easily coordinate the ATFM program with other ATFM programs taking place or scheduled to take place, and they would have more opportunity to call another FSFA allocation route before the ATFM program begins, should conditions change enough to warrant this. Outputs of the model may provide some general insights to flight operators in planning submission strategies within competitive allocation processes such as FSFA. Also, this work may have a broader application to other sequential resource allocation strategies within congestible and controlled transportation systems.

Formulation, existence, and computation of boundedly rational dynamic user equilibrium with fixed or endogenous user tolerance

- Transportation Research Part B: Methodological---2015---Ke Han,W.Y. Szeto,Terry L. Friesz

This paper analyzes dynamic user equilibrium (DUE) that incorporates the notion of boundedly rational (BR) user behavior in the selection of departure times and routes. Intrinsically, the boundedly rational dynamic user equilibrium (BR-DUE) model we present assumes that travelers do not always seek the least costly route-and-departure-time choice. Rather, their perception of travel cost is affected by an indifference band describing travelers' tolerance of the difference between their experienced travel costs and the minimum travel cost. An extension of the BR-DUE problem is the so-called variable tolerance dynamic user equilibrium (VT-BR-DUE) wherein endogenously determined tolerances may depend not only on paths, but also on the established path departure rates.

A new generalized heterogeneous data model (GHDM) to jointly model mixed types of dependent variables

- Transportation Research Part B: Methodological---2015---Chandra R. Bhat

This paper formulates a generalized heterogeneous data model (GHDM) that jointly handles mixed types of dependent variables—including multiple nominal outcomes, multiple ordinal variables, and multiple count variables, as well as multiple continuous variables—by representing the covariance relationships among them through a reduced number of latent factors. Sufficiency conditions for identification of the GHDM parameters are presented. The maximum approximate composite marginal likelihood (MACML) method is proposed to estimate this jointly mixed model system. This estimation method provides computational time advantages since the dimensionality of integration in the likelihood function is independent of the number of latent factors. The study undertakes a simulation experiment within the virtual context of integrating residential location choice and travel behavior to evaluate the ability of the MACML approach to recover parameters. The simulation results show that the MACML approach effectively recovers underlying parameters, and also that ignoring the multi-dimensional nature of the relationship among mixed types of dependent variables can lead not only to inconsistent parameter estimation, but also have important implications for policy analysis.

A generalized queuing model and its solution properties

- Transportation Research Part B: Methodological--2015---Jia Li,H.M. Zhang

Modeling queuing behavior is central to the analysis of transportation and other service systems. To date, several queuing models been developed, but analytical insights on their global properties are hard to obtain. This is because in most cases, queuing dynamics are formulated as differential or difference equations, with possible discontinuities in their solutions, making most conventional analytical tools inadequate. As a result, simulations are often used to study these models, and if not properly treated, negative flows could arise from the simulation near certain discontinuities. In this paper, we propose a continuous-time queuing model that captures generalized queuing dynamics, where bottleneck discharging capacity and demand can vary simultaneously. We provide insights on the global properties of this model, upon deriving its closed-form variational solutions. Rather than resorting to the usual Hamilton–Jacobi theory, our derivations are built on an intrinsic periodicity property of the general queuing dynamics combined with measure-theoretic analysis. This treatment allows us to obtain results with more complex boundary conditions and make further extensions. We demonstrate its applications and show its solution properties in queuing simulation and performance bounding. In particular, we provide graphical, iterative and linearized solution schemes, which are all devoid of the well-known negative flow issue associated with numerical solutions to the point queue model.

The recoverable robust facility location problem

- Transportation Research Part B: Methodological--2015---Eduardo Álvarez-Miranda,Elena Fernández,Ivana Ljubić

This work deals with a facility location problem in which location and allocation (transportation) policy is defined in two stages such that a first-stage solution should be robust against the possible realizations (scenarios) of the input data that can only be revealed in a second stage. This solution should be robust enough so that it can be recovered promptly and at low cost in the second stage. In contrast to some related modeling approaches from the literature, this new recoverable robust model is more general in terms of the considered data uncertainty; it can address situations in which uncertainty may be present in any of the following four categories: provider-side uncertainty, receiver-side uncertainty, uncertainty in-between, and uncertainty with respect to the cost parameters.

Coordinated online in-vehicle routing balancing user optimality and system optimality through information perturbation

- Transportation Research Part B: Methodological--2015---Lili Du,Lanshan Han,Shuwei Chen

The inconsistence between system optimality and user optimality represents one of the key difficulties on network traffic congestion control. The advanced connected vehicle systems, enabling smart vehicles to possess/exchange real-time information and conduct portable computation, provide new opportunities to address this challenge. Motivated by this view, this study proposes a coordinated online in-vehicle routing mechanism with intentional information provision perturbation (CRM-IP), which seeks to shape individual vehicles online routing decisions so that user optimality and system optimality are balanced, by exploiting bounded rationality of the users. The proposed CRM-IP is modeled as a pure strategy atomic routing game, and implemented by a sequentially updating distributed algorithm. The mathematical analysis is conducted to quantify the absolute gain of system optimality corresponding to the loss of user optimality resulting from a given level of the information perturbation in the worst case so that the efficiency of the information perturbation can be evaluated. Furthermore, numerical experiments conducted based on City of Sioux Falls network investigate the average effects of the CRM-IP on system optimality and user optimality under various network traffic conditions, comparing to the CRM developed by Du et al. (in press). The results indicate that the improvement of system optimality and the reduction of individual vehicles' travel time from the CRM is more significant when the network traffic is under an mild congestion state, such as under the levels of service (LOS's) C, D, and E, rather than under extremely sparse or congested states, such as under LOS's A and B, or F. Moreover, higher level of information perturbation benefits system optimality more, but the marginal effect decreases after the perturbation reaching certain level, such as $\lambda = 0.1$ in this case study. In addition, a portion of vehicles may sacrifice user optimality due to the information perturbation, but the extent of the sacrifice is not significant, even though it increases with the information perturbation level. Hence, a small information perturbation is recommended to achieve an efficient network traffic control through the CRM-IP. Overall, this study proposes the CRM-IP as an efficient routing mechanism, which has a great potential to guide the routing decisions of individual vehicles so that their collective behavior improve network performance in both system optimality and user optimality.

A set-covering model for a bidirectional multi-shift full truckload vehicle routing problem

- Transportation Research Part B: Methodological---2015---Ruibin Bai,Ning Xue,Jianjun Chen,Gethin Wyn Roberts

This paper introduces a bidirectional multi-shift full truckload transportation problem with operation dependent service times. The problem is different from the previous container transport problems and the existing approaches for container transport problems and vehicle routing pickup and delivery are either not suitable or inefficient. In this paper, a set covering model is developed for the problem based on a novel route representation and a container-flow mapping. It was demonstrated that the model can be applied to solve real-life, medium sized instances of the container transport problem at a large international port. A lower bound of the problem is also obtained by relaxing the time window constraints to the nearest shifts and transforming the problem into a service network design problem. Implications and managerial insights of the results by the lower bound results are also provided.

Traffic user equilibrium and proportionality

- Transportation Research Part B: Methodological---2015---Marlies Borchers,Paul Breeuwsma,Walter Kern,Jaap Slootbeek,Georg Still,Wouter Tibben

We discuss the problem of proportionality and uniqueness for route flows in the classical traffic user equilibrium model. It is well-known that under appropriate assumptions the user equilibrium (f,x) is unique in the link flow x but typically not in the route flow f. We consider the concept of proportionality in detail and re-discuss the well-known relation between the so-called bypass proportionality and entropy maximization. We exhibit special proportionality conditions which uniquely determine the route flow f. The results are illustrated with some simple example networks.

A comprehensive dwelling unit choice model accommodating psychological constructs within a search strategy for consideration set formation

- Transportation Research Part B: Methodological---2015---Chandra R. Bhat

This study adopts a dwelling unit level of analysis and considers a probabilistic choice set generation approach for residential choice modeling. In doing so, we accommodate the fact that housing choices involve both characteristics of the dwelling unit and its location, while also mimicking the search process that underlies housing decisions. In particular, we model a complete range of dwelling unit choices that include tenure type (rent or own), housing type (single family detached, single family attached, or apartment complex), number of bedrooms, number of bathrooms, number of storeys (one or multiple), square footage of the house, lot size, housing costs, density of residential neighborhood, and commute distance. Bhat's (2015) generalized heterogeneous data model (GHDM) system is used to accommodate the different types of dependent outcomes associated with housing choices, while capturing jointness caused by unobserved factors. The proposed analytic framework is applied to study housing choices using data derived from the 2009 American Housing Survey (AHS), sponsored by the Department of Housing and Urban Development (HUD) and conducted by the U.S. Census Bureau. The results confirm the jointness in housing choices, and indicate the superiority of a choice set formation model relative to a model that assumes the availability of all dwelling unit alternatives in the choice set.

Reformulating the Hoogendoorn–Bovy predictive dynamic user-optimal model in continuum space with anisotropic condition

- Transportation Research Part B: Methodological---2015---Jie Du,S.C. Wong,Chi-Wang Shu,Mengping Zhang

Hoogendoorn and Bovy (2004) developed an approach for a pedestrian user-optimal dynamic assignment in continuous time and space. Although their model was proposed for pedestrian traffic, it can also be applied to urban cities. The model is very general, and consists of a conservation law (CL) and a Hamilton–Jacobi–Bellman (HJB) equation that contains a minimum value problem. However, only an isotropic application example was given in their paper. We claim that the HJB equation is difficult to compute numerically in an anisotropic case. To overcome this, we reformulate their model for a dense urban city that is arbitrary in shape and has multiple central business districts (CBDs). In our model, the minimum value problem is only used in the CL portion, and the HJB equation reduces to a Hamilton–Jacobi (HJ) equation for easier computation. The dynamic path equilibrium of our model is proven in a different way from theirs, and a numerical algorithm is also provided to solve the model. Finally, we show two numerical examples under the anisotropic case and compare the results with those of the isotropic case.

Infrastructure deployment under uncertainties and competition: The biofuel industry case

- Transportation Research Part B: Methodological---2015---Xin Wang,Michael K. Lim,Yanfeng Ouyang

Technological paradigm shifts often come with a newly emerging industry that seeks a viable infrastructure deployment plan to compete against established competitors. Such phenomenon has been repeatedly seen in the field of transportation systems, such as those related to the booming bioenergy production, among others. We develop a game-theoretic modeling framework using a continuum approximation scheme to address the impacts of competition on the optimal infrastructure deployment. Furthermore, we extend the model to incorporate uncertainties in supply/demand and the risk of facility disruptions. Analytical properties of the optimal infrastructure system are obtained, based on which fast numerical solution algorithms are developed. Several hypothetical problem instances are used to illustrate the effectiveness of the proposed algorithms and to quantify the impacts of various system parameters. A large-scale biofuel industry case study for the U.S. Midwest is conducted to obtain additional managerial insights.

A tractable two-stage robust winner determination model for truckload service procurement via combinatorial auctions

- Transportation Research Part B: Methodological---2015---Bo Zhang,Tao Yao,Terry L. Friesz,Yuqi Sun

A combinatorial auction is one of the adopted mechanisms for truckload (TL) service procurement. In such an auction, the shipper faces a well-known winner determination problem (WDP): the shipper, as the auctioneer, is given bids submitted by a group of carriers. In most literature, WDP is modeled as a deterministic mixed-integer program (MIP) and is solved by standard MIP algorithms. However, in practice, the exact shipping demand is unavailable until after the auction. This shipment volume uncertainty has a significant impact on the solution to WDP. Therefore, a deterministic winner determination model with an estimate of shipment volume may not provide solutions that attain low procurement costs. This paper proposes a new tractable two-stage robust optimization (RO) approach to solve WDP for TL service procurement under shipment volume uncertainty. Assuming that only historical data is available, we propose a data-driven approach based on the central limit theorem (CLT) to construct polyhedral uncertainty sets. In particular, we consider two random cases: independent shipment volume and correlated shipment volume. A two-stage RO model with integer first-stage decision variables and continuous recourse variables is then formulated. We develop a reformulation solution method and use numerical tests to demonstrate that it is much more computationally efficient than the widely adopted Benders' type constraint generation algorithm. We demonstrate by numerical tests that real-world sized instances of TL service procurement problems can be solved by our proposed robust method. Moreover, we compare our robust approach with benchmark and show that it is more tractable and robust to uncertainty.

From behavioral psychology to acceleration modeling: Calibration, validation, and exploration of drivers' cognitive and safety parameters in a risk-taking environment

- Transportation Research Part B: Methodological---2015---Samer H. Hamdar,Hani S. Mahmassani,Martin Treiber

We investigate a utility-based approach for driver car-following behavioral modeling while analyzing different aspects of the model characteristics especially in terms of capturing different fundamental diagram regions and safety proxy indices. The adopted model came from an elementary thought where drivers associate subjective utilities for accelerations (i.e. gain in travel times) and subjective dis-utilities for decelerations (i.e. loss in travel time) with a perceived probability of being involved in rear-end collision crashes. Following the testing of the model general structure, the authors translate the corresponding behavioral psychology theory – prospect theory – into an efficient microscopic traffic modeling with more elaborate stochastic characteristics considered in a risk-taking environment.

Empirical flow-density and speed-spacing relationships: Evidence of vehicle length dependency

- Transportation Research Part B: Methodological---2015---Benjamin Coifman

Traffic flow theory has come to a point where conventional, fixed time averaged data are limiting our insight into critical behavior both at the macroscopic and microscopic scales. This paper develops a methodology to measure relationships of density and vehicle spacing on freeways. These relationships are central to most traffic flow theories but have historically been difficult to measure empirically. The work leads to macroscopic flow-density and microscopic speed-spacing relationships in the congested regime derived entirely from dual loop detector data and then verified against the NGSIM data set. The methodology eliminates the need to seek out stationary conditions and yields clean relationships that do not depend on prior assumptions of the curve shape before fitting the data. Upon review of the clean empirical relationships a key finding of this work is the fact that many of the critical parameters of the macroscopic flow-density and microscopic speed-spacing relationships depend on vehicle length, e.g., upstream moving waves should travel through long vehicles faster than through short vehicles. Thus, the commonly used assumption of a homogeneous vehicle fleet likely obscures these important phenomena. More broadly, if waves travel faster or slower depending on the length of the vehicles through which the waves pass, then the way traffic is modeled should be updated to explicitly account for inhomogeneous vehicle lengths.

A two-stage robustness approach to evacuation planning with buses

- Transportation Research Part B: Methodological---2015---Marc Goerigk,Kaouthar Deghdak,T' Kindt, Vincent

We consider the problem of scheduling a bus fleet to evacuate persons from an endangered region. As most of the planning data is subject to uncertainty, we develop a two-stage bicriteria robust formulation, which considers both the evacuation time, and the vulnerability of the schedule to changing evacuation circumstances.

Analysis of real-time control strategies in a corridor with multiple bus services

- Transportation Research Part B: Methodological---2015---Daniel Hernández,Juan Carlos Muñoz,Ricardo Giesen,Felipe Delgado

Control strategies have been widely used in the literature to counteract the effects of bus bunching in passenger 's waiting times and its variability. These strategies have only been studied for the case of a single bus line in a corridor. However, in many real cases this assumption does not hold. Indeed, there are many transit corridors with multiple bus lines interacting, and this interaction affects the efficiency of the implemented control mechanism.

A joint bottom-up solution methodology for system-level pavement rehabilitation and reconstruction

- Transportation Research Part B: Methodological---2015---Jinwoo Lee,Samer Madanat

We present a methodology for the joint optimization of rehabilitation and reconstruction activities for heterogeneous pavement systems under multiple budget constraints. The proposed bottom-up approach adopts an augmented condition state to account for the history-dependent properties of pavement deterioration, and solves for steady-state policies for an infinite horizon. Genetic algorithms (GAs) are implemented in the system-level optimization based on segment-specific optimization results. The complexity of the proposed algorithm is polynomial in the size of the system and the policy-related parameters. We provide graphical presentations of the optimal solutions for various budget situations. As a case study, a subset of California' s highway system is analyzed. The case study results demonstrate the economic benefit of a combined rehabilitation and reconstruction budget compared to separate budgets.

A piecewise-constant congestion taxing policy for repeated routing games

- Transportation Research Part B: Methodological---2015---Farhad Farokhi,Karl H. Johansson

In this paper, we consider repeated routing games with piecewise-constant congestion taxing in which a central planner sets and announces the congestion taxes for fixed windows of time in advance. Specifically, congestion taxes are calculated using marginal congestion pricing based on the flow of the vehicles on each road prior to the beginning of the taxing window (and, hence, there is a time-varying delay in setting the congestion taxes). We motivate the piecewise-constant taxing policy by that users or drivers may dislike fast-changing prices and that they also prefer prior knowledge of the prices. We prove for this model that the multiplicative update rule and the discretized replicator dynamics converge to a socially optimal flow when using vanishing step sizes. Considering that the algorithm cannot adapt itself to a changing environment when using vanishing step sizes, we propose adopting constant step sizes in this case. Then, however, we can only prove the convergence of the dynamics to a neighborhood of the socially optimal flow (with the size of the neighbourhood being of the order of the selected step size). The results are illustrated on a nonlinear version of Pigou's famous routing game.

A time-dependent freight tour synthesis model

- Transportation Research Part B: Methodological--2015---Iván Sánchez-Díaz,José Holguín-Veras,Ban, Xuegang (Jeff)

This paper introduces a model of urban freight demand that seeks to estimate tour flows from secondary data sources e.g., traffic counts, to bypass the need for expensive surveys. The model discussed in this paper, referred as Freight Tour Synthesis (FTS), enhances current techniques by incorporating the time-dependent tour-based behavior of freight vehicles, and the decision maker's (e.g., metropolitan planning agency planner) preferences for different sources of information. The model, based on entropy maximization theory, estimates the most likely set of tour flows, given a set of freight trip generation estimates, a set of traffic counts per time interval, and total freight transportation cost in the network. The type of inputs used allows the assessment of changes in infrastructure, policy and land use. The ability of the model to replicate actual values is assessed using the Denver Region (CO) as a case study.

Applying variational theory to travel time estimation on urban arterials

- Transportation Research Part B: Methodological--2015---Etienne Hans,Nicolas Chiabaut,Ludovic Leclercq

The Variational Theory (VT) expresses the LWR model as a least cost path problem. Recent researches have shown that this problem can be simply applied on a graph with a minimal number of nodes and edges when the fundamental diagram is triangular (sufficient variational graph – SVG). Such a graph accounts for traffic signal settings on an urban arterial and leads to mean traffic states for the total arterial in free-flow or congested stationary conditions. The Macroscopic Fundamental Diagram (MFD) can then be directly estimated. In this paper, we extend this method to provide the complete distribution of deterministic travel times observed on an arterial. First, we will show how to obtain a tight estimation of the arterial capacity by properly identifying the most constraining part of the SVG. Then, we will show that a modified version of the SVG allows the exact calculation of the cumulative count curves at the entry and exit of an arterial. It is finally possible to derive the full travel time distributions for any dynamic conditions.

Real-time high-speed train rescheduling in case of a complete blockage

- Transportation Research Part B: Methodological--2015---Shuguang Zhan,Leo G. Kroon,Lucas P. Veelenturf,Joris C. Wagenaar

This paper focuses on real-time rescheduling of railway traffic on a high speed railway line in case of a complete blockage of the railway infrastructure. Due to the disruption, all tracks in a railway segment are out of order for a certain period of time. In the situation that we consider, trains that are blocked by the disruption do not return to their origin by taking over train services in the opposite direction, but wait inside the stations until the disruption is over. Thus the main decisions to be taken are the following: in which stations do trains have to wait, in which order do they have to leave when the disruption is over, and which trains have to be canceled? A Mixed Integer Programming model is formulated to minimize the total weighted train delay and the number of canceled trains, while adhering to headway and station capacity constraints. Most instances can be solved in a single optimization run, but for the most complex instances we propose a two-stage optimization approach to improve the computational efficiency. The model is tested on real-world instances of the Beijing–Shanghai high speed railway line. The results show that the model is promising for reducing the effect of a disruption on passenger service, especially in comparison with a heuristic method used in practice.

Port investments on coastal and marine disasters prevention: Economic modeling and implications

- Transportation Research Part B: Methodological---2015---Yi-bin Xiao,Xiaowen Fu,Adolf K.Y. Ng,Anming Zhang

Located along shorelines, seaports are highly vulnerable to coastal and marine natural disasters largely due to climate change. Damage caused by disasters can be prevented or alleviated if sufficient investments are made in a timely manner. However, despite a wide range of investment options and well-developed engineering expertise, port investment on disaster prevention remains a challenging task involving great complexities. This paper develops an integrated economic model for the analysis of disaster-prevention investments at a "landlord" port. It simultaneously considers the uncertainty of disaster occurrence and associated return of prevention investments, the information accumulation and related investment timing, and the benefit spillovers of investment among stakeholders. Our analysis shows that the timing of port investments depends on the probability of disasters. Immediate investment is optimal for disasters with very high probability, while investment should be postponed if such a probability is very low. Optimal timing for cases of intermediate probability cannot be determined analytically, as it is influenced by other factors such as discount rate, information accumulation and efficiency of investments. Positive spillovers between a port and its tenants lead to under-investment, which can be corrected by coordination between stakeholders. However, since there are risks of "overinvestment" (the marginal benefits of investments are zero ex post if there is no disaster), regulatory intervention is not always optimal when the regulator does not have a good understanding of disaster probability distribution. Therefore, scientific research would bring significant economic and strategic value to policy, planning and investment decisions.

Accounting for stochastic variables in discrete choice models

- Transportation Research Part B: Methodological---2015---Federico Díaz,Víctor Cantillo,Julian Arellana,Juan de Dios Ortúzar

The estimation of discrete choice models requires measuring the attributes describing the alternatives within each individual's choice set. Even though some attributes are intrinsically stochastic (e.g. travel times) or are subject to non-negligible measurement errors (e.g. waiting times), they are usually assumed fixed and deterministic. Indeed, even an accurate measurement can be biased as it might differ from the original (experienced) value perceived by the individual.

Robust weekly aircraft maintenance routing problem and the extension to the tail assignment problem

- Transportation Research Part B: Methodological---2015---Zhe Liang,Yuan Feng,Xiaoning Zhang,Tao Wu,Wanpracha Art Chaovalitwongse

In this paper, we study two closely related airline planning problems: the robust weekly aircraft maintenance routing problem (RWAMRP) and the tail assignment problem (TAP). In real life operations, the RWAMRP solution is used in tactical planning whereas the TAP solution is implemented in operational planning. The main objective of these two problems is to minimize the total expected propagated delay (EPD) of the aircraft routes. To formulate the RWAMRP, we propose a novel weekly line-of-flights (LOF) network model that can handle complex and nonlinear cost functions of EPD. Because the number of LOFs grows exponentially with the number of flights to be scheduled, we propose a two-stage column generation approach to efficiently solve large-scale real-life RWAMRPs. Because the EPD of an LOF is highly nonlinear and can be very time-consuming to accurately compute, we propose three lower bounds on the EPD to solve the pricing subproblem of the column generation. Our approach is tested on eight real-life test instances. The computational results show that the proposed approach provides very tight LP relaxation (within 0.6% of optimal solutions) and solves the test case with more than 6000 flights per week in less than three hours. We also investigate the solutions obtained by our approach over 500 simulated realizations. The simulation results demonstrate that, in all eight test instances, our solutions result in less EPDs than those obtained from traditional methods. We then extend our model and solution approach to solve realistically simulated TAP instances.

Estimating bike-share trips using station level data

- Transportation Research Part B: Methodological---2015---Cyrille Médard de Chardon,Geoffrey Caruso

Bicycle sharing systems (BSS) have increased in number rapidly since 2007. The potential benefits of BSS, mainly sustainability, health and equity, have encouraged their adoption through support and promotion by mayors in Europe and North America alike. In most cases municipal governments desire their BSS to be successful and, with few exceptions, state them as being so. New technological improvements have dramatically simplified the use and enforcement of bicycle return, resulting in the widespread adoption of BSS. Unfortunately little evaluation of the effectiveness of differently distributed and managed BSS has taken place. Comparing BSS systems quantitatively is challenging due to the limited data made available. The metrics of success presented by municipalities are often too general or incomparable to others making relative evaluations of BSS success arduous. This paper presents multiple methodologies allowing the estimation of the number of daily trips, the most significant measure of BSS usage, based on data that is commonly available, the number of bicycles available at a station over time. Results provide model coefficients as well as trip count estimates for select cities. Of four spatial and temporal aggregate models the day level aggregation is found to be most effective for estimation. In addition to trip estimation this work provides a rigorous formalization of station level data and the ability to distinguish spatio-temporal rebalancing quantities as well as new characteristics of BSS station use.

Statistical approach for activity-based model calibration based on plate scanning and traffic counts data

- Transportation Research Part B: Methodological---2015---Treerapot Siripirote,Agachai Sumalee,H.W. Ho,William H.K. Lam

Traditionally, activity-based models (ABM) are estimated from travel diary survey data. The estimated results can be biased due to low-sampling size and inaccurate travel diary data. For an accurate calibration of ABM parameters, a maximum-likelihood method that uses multiple sources of roadside observations (link counts and/or plate scanning data) is proposed. Plate scanning information (sensor path information) consists of sequences of times and partial paths that the scanned vehicles are observed over the preinstalled plate scanning locations. Statistical performances of the proposed method are evaluated on a test network using Monte Carlo technique for simulating the link flows and sensor path information. Multiday observations are simulated and derived from the true ABM parameters adopted in the choice models of activity pattern, time of the day, destination and mode. By assuming different number of plate scanning locations and identification rates, impacts of data quantity and data quality on ABM calibration are studied. The results illustrate the efficiency of the proposed model in using plate scanning information for ABM calibration and its potential for large and complex network applications.

Airline competition and market frequency: A comparison of the s-curve and schedule delay models

- Transportation Research Part B: Methodological---2015---Mark Hansen,Yi Liu

We compare two common ways of incorporating service frequency into models of airline competition. One is based on the so called s-curve, in which, all else equal, market shares are determined by frequency shares. The other is based on schedule delay—the time difference between when travelers wish to travel and when flights are available. We develop competition models that differ only with regard to which of the above approaches is used to capture the effect of frequency. The demand side of both models is an approximation of a nested logit model which yields endogenous travel demand by including not traveling in the choice set. We find symmetric competitive equilibrium for both models analytically, and compare their predictions concerning market frequency with empirical evidence. In contrast to the s-curve model, the schedule delay model depicts a more plausible relationship between market share and frequency share and accurately predicts observed patterns of supply side behavior. Moreover, the predictions from both models are largely the same if we employ numerical versions of the model that capture real-world aspects of competition. We also find that, for either model, the relationship between airline frequency and market traffic is the same whether frequency is determined by competitive equilibrium, social optimality, or social optimality with a break-even constraint.

Transit technology investment and selection under urban population volatility: A real option perspective

- Transportation Research Part B: Methodological---2015---Zhi-Chun Li,Qian-Wen Guo,William H.K. Lam,S.C. Wong

This paper addresses transit technology investment issues under urban population volatility using a real option approach. Two important problems are investigated: which transit technology should be selected and when should it be introduced. A real option model is proposed to incorporate explicitly the effects of transit technology investment on urban spatial structure in terms of households' residential location choices and housing market. The trigger population thresholds for investing in a transit technology project and for shifting from a transit technology to another are explored analytically. Comparative static analyses of the urban system and transit technology investment are also carried out. It was found that (i) transit technology investment can induce urban sprawl; (ii) ignoring the effects of transit technology investment on urban spatial equilibrium can lead to a late investment; and (iii) there is a significant difference in the trigger population thresholds for transit technology shift estimated by the net present value approach and the real option approach.

Introducing non-normality of latent psychological constructs in choice modeling with an application to bicyclist route choice

- Transportation Research Part B: Methodological---2015---Chandra R. Bhat,Subodh K. Dubey,Kai Nagel

In the current paper, we propose the use of a multivariate skew-normal (MSN) distribution function for the latent psychological constructs within the context of an integrated choice and latent variable (ICLV) model system. The multivariate skew-normal (MSN) distribution that we use is tractable, parsimonious in parameters that regulate the distribution and its skewness, and includes the normal distribution as a special interior point case (this allows for testing with the traditional ICLV model). Our procedure to accommodate non-normality in the psychological constructs exploits the latent factor structure of the ICLV model, and is a flexible, yet very efficient approach (through dimension-reduction) to accommodate a multivariate non-normal structure across all indicator and outcome variables in a multivariate system through the specification of a much lower-dimensional multivariate skew-normal distribution for the structural errors. Taste variations (i.e., heterogeneity in sensitivity to response variables) can also be introduced efficiently and in a non-normal fashion through interactions of explanatory variables with the latent variables. The resulting model we develop is suitable for estimation using Bhat's (2011) maximum approximate composite marginal likelihood

(MACML) inference approach. The proposed model is applied to model bicyclists' route choice behavior using a web-based survey of Texas bicyclists. The results reveal evidence for non-normality in the latent constructs. From a substantive point of view, the results suggest that the most unattractive features of a bicycle route are long travel times (for commuters), heavy motorized traffic volume, absence of a continuous bicycle facility, and high parking occupancy rates and long lengths of parking zones along the route.

Scheduling heterogeneous train traffic on double tracks with efficient dispatching rules

- Transportation Research Part B: Methodological--2015---Xiaoming Xu,Keping Li,Lixing Yang

To further improve the utilization rate of railway tracks and reduce train delays, this paper focuses on developing a high-efficiency train routing and timetabling approach for double-track railway corridors in condition that trains are allowable to travel on reverse direction tracks. We first design an improved switchable policy which is rooted in the approaches by Mu and Dessouky (2013), with the analysis of possible delays caused by different path choices. Then, three novel integrated train routing and timetabling approaches are proposed on the basis of a discrete event model and different dispatching rules, including no switchable policy (No-SP), Mu and Dessouky (2013)'s switchable policy (Original-SP) and improved switchable policy (Improved-SP). To demonstrate the performance of the proposed approaches, the heterogeneous trains on Beijing–Shanghai high speed railway are scheduled by aforementioned approaches. The case studies indicate that in comparison to No-SP and Original-SP approaches, respectively, the Improved-SP approach can reduce the total delay of trains up to 44.44% and 73.53% within a short computational time. Moreover, all of the performance criteria of the Improved-SP approach are usually better than those of other two approaches.

Data dependent input control for origin–destination demand estimation using observability analysis

- Transportation Research Part B: Methodological--2015---Yudi Yang,Yueyue Fan

In this paper, we address the observability issue of static O–D estimation based on link counts. Unlike most classic observability analyses that relied only on network topological relationships, our analysis incorporates the actual values of input parameters, thus including network operational relations as well. We first analyze possible mathematical properties of an O–D estimation problem with different data input. We then propose a modeling approach based on mixed-integer program for selecting model input that ensures observability and estimation quality. Through establishing a stronger connection between observability analysis and the corresponding estimation problem, the proposed method aims to improve estimation quality while reducing reliance on erroneous data.

Joint service capacity planning and dynamic container routing in shipping network with uncertain demands

- Transportation Research Part B: Methodological--2015---Jing-Xin Dong,Chung-Yee Lee,Dong-Ping Song

Service capacity planning is a key tactic decision in container shipping, which has a significant impact on daily operations of shipping company. On the other hand, operational decisions such as demand fulfilment and shipment routing will impact on service capacity requirements and utilisation, particularly in the presence of demand uncertainty. This article proposes a two stage stochastic programming model with recourse to deal with the problem of joint service capacity planning and dynamic container routing in liner shipping. The first stage of the model concerns how to determine the optimal service capacity, and the second focuses on the optimal routing of shipments in stochastic and dynamic environments under a given service capacity plan. Initially, SAA (Sample Average Approximation) is employed to solve the model. Noting the computational complexity of the problem, Progressive Hedging Algorithm (PHA) is employed to decompose the SAA model into a number of scenario-based models so that reasonably large scale problems can be solved. To handle larger scale problems, we develop a new solution procedure termed as APHA (Adapted Progressive Hedging Algorithm) that further decomposes the scenario-based model into job (customer order) based models with measurable error bounds. Numerical experiments are conducted to illustrate the effectiveness of the proposed APHA in solving the problems under consideration.

Point queue models: A unified approach

- Transportation Research Part B: Methodological---2015---Wen-Long Jin

In transportation and other types of facilities, various queues arise when the demands of service are higher than the supplies, and many point and fluid queue models have been proposed to study such queueing systems. However, there has been no unified approach to deriving such models, analyzing their relationships and properties, and extending them for networks. In this paper, we derive point queue models as limits of two link-based queueing model: the link transmission model and a link queue model. With two definitions for demand and supply of a point queue, we present four point queue models, four approximate models, and their discrete versions. We discuss the properties of these models, including equivalence, well-definedness, smoothness, and queue spillback, both analytically and with numerical examples. We then analytically solve Vickrey’s point queue model and stationary states in various models. We demonstrate that all existing point and fluid queue models in the literature are special cases of those derived from the link-based queueing models. Such a unified approach leads to systematic methods for studying the queueing process at a point facility and will also be helpful for studies on stochastic queues as well as networks of queues.

Mathematical programming formulations for transit network design

- Transportation Research Part B: Methodological---2015---Héctor Cancela,Antonio Mauttone,María E. Urquhart

In this work, we study the transit network design problem from the perspective of mathematical programming. More precisely, we consider the problem of defining the number and itinerary of bus routes and their frequencies, for a public transportation system. In this problem, the routes should be defined in terms of a given infrastructure of streets and stops and should cover a given origin–destination demand. The solution (routes and frequencies) should be convenient for the users and the operators. We review existing mathematical programming formulations and propose a new one, paying attention to the following aspects of public transportation systems, that are identified as key elements in order to have a realistic model: (a) the interest of the users, (b) the interest of the operators, (c) the behavior of the users, and (d) constraints regarding transfer, infrastructure and bus capacity. First, we discuss the formulations existing on the literature, in terms of the aspects mentioned above. Second, we propose a mixed integer linear programming (MILP) formulation, that incorporates the waiting time and the existence of multiple lines in the behavior of the users. We validate the proposed formulation using several cases, including a real one. Also, we compare the obtained results against results from the existing literature. In order to include transfer, infrastructure and bus capacity constraints, we propose an extension to the formulation and we discuss its impact in the structure of the model, based on concepts of bi-level mathematical programming. The mathematical formulations developed contribute towards a more realistic modeling effort, taking into account important aspects of the real system which were not included in previous proposals in the literature.

Planning, operation, and control of bus transport systems: A literature review

- Transportation Research Part B: Methodological---2015---O.J. Ibarra-Rojas,F. Delgado,R. Giesen,J.C. Muñoz

The efficiency of a transport system depends on several elements, such as available technology, governmental policies, the planning process, and control strategies. Indeed, the interaction between these elements is quite complex, leading to intractable decision making problems. The planning process and real-time control strategies have been widely studied in recent years, and there are several practical implementations with promising results. In this paper, we review the literature on Transit Network Planning problems and real-time control strategies suitable to bus transport systems. Our goal is to present a comprehensive review, emphasizing recent studies as well as works not addressed in previous reviews.

A general approach for controlling vehicle en-route diversions in dynamic vehicle routing problems

- Transportation Research Part B: Methodological---2015---Francesco Ferrucci,Stefan Bock

Previous research has shown that vehicle en-route diversion can improve the efficiency of dynamic vehicle routing processes. However, an uncontrolled utilization of en-route diversions may increase demands on drivers and cause distraction. This is likely to result in more accidents or reduced productivity which generates additional costs. Since the benefits to the solution quality make a prohibition of en-route diversions unattractive, we propose a general penalty cost based approach for controlling diversions. In contrast to known approaches that allow all diversions, the proposed approach also considers negative application-dependent consequences of diversions on drivers. The approach limits diversions to those which improve the solution quality above a customizable and application-dependent threshold that estimates their negative consequences. We evaluate the proposed general approach by applying it on an exemplary basis to recent deterministic and pro-active real-time routing approaches. Computational experiments show the impact of different penalty cost values on the resulting number of diversions as well as on the attained solution quality. Based on these results, we derive reasonable application-dependent penalty cost values for considering both the contradicting aims of quick request delivery and reducing diversions to a desired extent.

Impact of stop-and-go waves and lane changes on discharge rate in recovery flow

- Transportation Research Part B: Methodological---2015---Simon Oh,Hwasoo Yeo

In an effort to uncover traffic conditions that trigger discharge rate reductions near active bottlenecks, this paper analyzed individual vehicle trajectories at a microscopic level and documented the findings. Based on an investigation of traffic flow involving diverse traffic situations, a driver’s tendency to take a significant headway after passing stop-and-go waves was identified as one of the influencing factors for discharge rate reduction. Conversely, the pattern of lane changers caused a transient increase in the discharge rate until the situation was relaxed after completing the lane-changing event. Although we observed a high flow from the incoming lane changers, the events ultimately caused adverse impacts on the traffic such that the disturbances generated stop-and-go waves. Based on this observation, we regard upstream lane changes and stop-and-go waves as the responsible factors for the decreased capacity at downstream of active bottlenecks. This empirical investigation also supports the resignation effect, the regressive effect, and the asymmetric behavioral models in differentiating acceleration and deceleration behaviors.

The reliable hub-and-spoke design problem: Models and algorithms

- Transportation Research Part B: Methodological---2015---Yu An,Yu Zhang,Bo Zeng

Hub-and-spoke structure is widely adopted in industry, especially in transportation and telecommunications applications. Although hub-and-spoke paradigm demonstrates significant advantages in improving network connectivity with less number of routes and saving operating cost, the failure of hubs and reactive disruption management could lead to substantial recovery cost to the operators. Thus, we propose a set of reliable hub-and-spoke network design models, where the selection of backup hubs and alternative routes are taken into consideration to proactively handle hub disruptions. To solve these nonlinear mixed integer formulations for reliable network design problems, Lagrangian relaxation and Branch-and-Bound methods are developed to efficiently obtain optimal solutions. Numerical experiments are conducted with respect to real data to demonstrate algorithm performance and to show that the resulting hub-and-spoke networks are more resilient to hub unavailability.

Route choice and traffic signal control: A study of the stability and instability of a new dynamical model of route choice and traffic signal control

- Transportation Research Part B: Methodological---2015---Ronghui Liu,Mike Smith

This paper presents a novel idealised dynamical model of day to day traffic re-routeing (as traffic seeks cheaper routes) and proves a stability result for this dynamical model. (The dynamical model is based on swapping flow between paired alternative segments (these were introduced by Bar-Gera (2010)) rather than between routes.) It is shown that under certain conditions the dynamical system enters a given connected set of approximate equilibria in a finite number of days or steps. This proof allows for saturation flows which act as potentially active flow constraints. The dynamical system involving paired alternative segment swaps is then combined with a novel green-time-swapping rule; this rule swaps green-time toward more pressurised signal stages. It is shown that if (i) the delay formulae have a simple form and (ii) the "pressure" formula fits the special control policy P0 (see Smith, 1979a,b), then the combined flow-swapping/green-time-swapping dynamical model also enters a given connected set of approximate consistent equilibria in a finite number of steps. Computational results confirm, in a simple network, the positive P0 result and also show, on the other hand, that such good behaviour may not arise if the equi-saturation control policy is utilised. The dynamical models described here do not represent blocking back effects.

Stochastic user equilibrium with equilibrated choice sets: Part II – Solving the restricted SUE for the logit family

- Transportation Research Part B: Methodological---2015---Thomas Kjær Rasmussen,David Paul Watling,Carlo Giacomo Prato,Otto Anker Nielsen

We propose a new class of path-based solution algorithms to solve the Restricted Stochastic User Equilibrium (RSUE), as introduced in Watling et al. (2015). The class allows a flexible specification of how the choice sets are systematically grown by considering congestion effects and how the flows are allocated among routes. The specification allows adapting traditional path-based stochastic user equilibrium flow allocation methods (originally designed for pre-specified choice sets) to the generic solution algorithm. We also propose a cost transformation function and show that by using this we can, for certain Logit-type choice models, modify existing path-based Deterministic User Equilibrium solution methods to compute RSUE solutions. The transformation function also leads to a two-part relative gap measure for consistently monitoring convergence to a RSUE solution. Numerical tests are reported on two real-life cases, in which we explore convergence patterns and choice set composition and size, for alternative specifications of the RSUE model and solution algorithm.

Stochastic user equilibrium with equilibrated choice sets: Part I – Model formulations under alternative distributions and restrictions

- Transportation Research Part B: Methodological---2015---David Paul Watling,Thomas Kjær Rasmussen,Carlo Giacomo Prato,Otto Anker Nielsen

The aim of this paper is to remove the known limitations of Deterministic and Stochastic User Equilibrium (DUE and SUE), namely that only routes with the minimum cost are used in DUE, and that all permitted routes are used in SUE regardless of their costs. We achieve this by combining the advantages of the two principles, namely the definition of unused routes in DUE and of mis-perception in SUE, such that the resulting choice sets of used routes are equilibrated. Two model families are formulated to address this issue: the first is a general version of SUE permitting bounded and discrete error distributions; the second is a Restricted SUE model with an additional constraint that must be satisfied for unused paths. The overall advantage of these model families consists in their ability to combine the unused routes with the use of random utility models for used routes, without the need to pre-specify the choice set. We present model specifications within these families, show illustrative examples, evaluate their relative merits, and identify key directions for further research.

Continuous approximation models for mixed load school bus routing

- Transportation Research Part B: Methodological---2015---William A. Ellegood,James F. Campbell,Jeremy North

School bus routing is a complex and expensive transportation problem for many public school districts. Typical school bus routes serve a single school, but mixed load school bus routes carry students for more than one school at the same time. A mixed load policy reduces the number of stops and distance to pick up and drop off children, but it can increase travel distance by visiting multiple schools. This paper provides a general strategic analysis using continuous approximation models to assess the conditions under which mixed loading is likely to be beneficial. We also present a case study for a semi-rural Missouri school district to illustrate the application of the models in practice. Results show that mixed load routing is more beneficial for larger districts, when a large percentage of bus stops are shared by students of different schools, and when schools are closer together.

Leveraging social networks for efficient hurricane evacuation

- Transportation Research Part B: Methodological---2015---Manini Madireddy,Soundar Kumara,D.J. Medeiros,Venky N. Shankar

One of the important factors affecting evacuation performance is the departure time choices made by evacuees. Simultaneous departures of evacuees can lead to overloading of road networks causing congestion. We are especially interested in cases when evacuees subject to little or no risk of exposure evacuate along with evacuees subject to higher risk of threat (also known as shadow evacuation). One of the reasons for correlated evacuee departures is higher perceived risk of threat spread through social contacts. In this work, we study an evacuation scenario consisting of a high risk region and a surrounding low risk area. We propose a probabilistic evacuee departure time model incorporating both evacuee individual characteristics and the underlying evacuee social network. We find that the performance of an evacuation process can be improved by forcing a small subset of evacuees (inhibitors) in the low risk area to delay their departure. The performance of an evacuation is measured by both average travel time of the population and total evacuation time of the high risk evacuees. We derive closed form expressions for average travel time for ER random network. A detailed experimental analysis of various inhibitor selection strategies and their effectiveness on different social network topologies and risk distribution is performed. Results indicate that significant improvement in evacuation performance can be achieved in scenarios where evacuee social networks have short average path lengths and topologically influential evacuees do not belong to the high risk regions. Additionally, communities with stronger ties improve evacuation performance.

Continuum signalized junction model for dynamic traffic networks: Offset, spillback, and multiple signal phases

- Transportation Research Part B: Methodological---2015---Ke Han,Vikash V. Gayah

This paper extends the continuum signalized intersection model exhaustively studied in Han et al. (2014) to more accurately account for three realistic complications: signal offsets, queue spillbacks, and complex signal phasing schemes. The model extensions are derived theoretically based on signal cycle, green split, and offset, and are shown to approximate well traffic operations at signalized intersections treated using the traditional (and more realistic) on-and-off model. We propose a generalized continuum signal model, which explicitly handles complex vehicle spillback patterns on signalized networks with provable error estimates. Under mild conditions, the errors are small and bounded by fixed values that do not grow with time. Overall, this represents a significant improvement over the original continuum model, which had errors that grew quickly with time in the presence of any queue spillbacks and for which errors were not explicitly derived for different offset cases. Thus, the new model is able to more accurately approximate traffic dynamics in large networks with multiple signals under more realistic conditions. We also qualitatively describe how this new model can be applied to several realistic intersection configurations that might be encountered in typical urban networks. These include intersections with multiple entry and exit links, complex signal phasing, all-red times, and the presence of dedicated turning lanes. Numerical tests of the models show remarkable consistency with the on-and-off model, as expected from the theory, with the added benefit of significant computational savings and higher signal control resolution when using the continuum model.

Inference on mode preferences, vehicle purchases, and the energy paradox using a Bayesian structural choice model

- Transportation Research Part B: Methodological---2015---Ricardo Daziano

Discrete choice modeling is experiencing a reemergence of research interest in the inclusion of latent variables as explanatory variables of consumer behavior. There are several reasons that motivate the integration of latent attributes, including better-informed modeling of random consumer heterogeneity and treatment of endogeneity. However, current work still is at an early stage and multiple simplifying assumptions are usually imposed. For instance, most previous applications assume all of the following: independence of taste shocks and of latent attributes, exclusion restrictions, linearity of the effect of the latent attributes on the utility function, continuous manifest variables, and an a priori bound for the number of latent constructs. We derive and apply a structural choice model with a multinomial probit kernel and discrete effect indicators to analyze continuous latent segments of travel behavior, including inference on the energy paradox. Our estimator allows for interaction and simultaneity among the latent attributes, residual correlation, nonlinear effects on the utility function, flexible substitution patterns, and temporal correlation within responses of the same individual. Statistical properties of the Bayes estimator that we propose are exact and are not affected by the number of latent attributes.

Nonlinear multivariate time–space threshold vector error correction model for short term traffic state prediction

- Transportation Research Part B: Methodological---2015---Tao Ma,Zhou Zhou,Baher Abdulhai

We propose Time–Space Threshold Vector Error Correction (TS-TVEC) model for short term (hourly) traffic state prediction. The theory and method of cointegration with error correction mechanism is employed in the general design of the new statistical model TS-TVEC. An inherent connection between mathematical form of error correction model and traffic flow theory is revealed through the transformation of the well-known Fundamental Traffic Diagrams. A threshold regime switching framework is implemented to overcome any unknown structural changes in traffic time series. Spatial cross correlated information is incorporated with a piecewise linear vector error correction model. A Neural Network model is also constructed in parallel to comparatively test the effectiveness and robustness of the new statistical model. Our empirical study shows that the TS-TVEC model is an effective tool that is capable of modeling the complexity of stochastic traffic flow processes and potentially applicable to real time traffic state prediction.

The economic speed of an oceangoing vessel in a dynamic setting

- Transportation Research Part B: Methodological---2015---Evangelos F. Magirou,Harilaos N. Psaraftis,Theodore Bouritas

The optimal (economic) speed of oceangoing vessels has become of increased importance due to the combined effect of low freight rates and volatile bunker prices. We examine the problem for vessels operating in the spot market in a tramp mode. In the case of known freight rates between origin destination combinations, a dynamic programming formulation can be applied to determine both the optimal speed and the optimal voyage sequence. Analogous results are derived for random freight rates of known distributions. In the case of independent rates the economic speed depends on fuel price and the expected freight rate, but is independent of the revenue of the particular voyage. For freight rates that depend on a state of the market Markovian random variable, economic speed depends on the market state as well, with increased speed corresponding to good states of the market. The dynamic programming equations in our models differ from those of Markovian decision processes so we develop modifications of standard solution methods, and apply them to small examples.

A rolling horizon algorithm for auto-carrier transportation

- Transportation Research Part B: Methodological---2015---Jean-François Cordeau,Dell’Amico, Mauro,Simone Falavigna,Manuel Iori

This paper introduces a rolling horizon algorithm to plan the delivery of vehicles to automotive dealers by a heterogeneous fleet of auto-carriers. The problem consists in scheduling the deliveries over a multiple-day planning horizon during which requests for transportation arrive dynamically. In addition, the routing of the auto-carriers must take into account constraints related to the loading of the vehicles on the carriers. The objective is to minimize the sum of traveled distances, fixed costs for auto-carrier operation, service costs, and penalties for late deliveries. The problem is solved by a heuristic that first selects the vehicles to be delivered in the next few days and then optimizes the deliveries by an iterated local search procedure. A branch-and-bound search is used to check the feasibility of the loading. To handle the dynamic nature of the problem, the complete algorithm is applied repeatedly in a rolling horizon framework. Computational results on data from a major European logistics service provider show that the heuristic is fast and yields significant improvements compared to the sequential solution of independent daily problems.

Repeatability & reproducibility: Implications of using GPS data for freight activity chains

- Transportation Research Part B: Methodological---2015---Johan W. Joubert,Sumarie Meintjes

As transport modellers we are interested in capturing the behaviour of freight vehicles that includes the locations at which vehicles perform their activities, the duration of activities, how often these locations are visited, and the sequence in which they are visited. With disaggregated freight behaviour data being scarce, transport modellers have identified vehicle tracking and fleet management companies as ideal third party sources for GPS travel data. GPS data does not provide us with behavioural information, but allows us to infer and extract behavioural knowledge using a variety of processing techniques. Many researchers remain sceptical as specific human intervention, referred to as 'expert knowledge', is often required during the processing phase: each GPS data set has unique characteristics and requires unique processing techniques and validation to extract the necessary behavioural information. Although much of the GPS data processing is automated through algorithms, human scrutiny is required to decide what algorithmic parameters as considered 'best', or at least 'good'. In this paper we investigate the repeatability and reproducibility (R&R) of a method that entails variable human intervention in processing GPS data. More specifically, the judgement made by an observer with domain expertise on what clustering parameters applied to GPS data best identify the facilities where commercial vehicles perform their activities. By studying repeatability we want to answer the question 'if the same expert analyses the GPS data more than once, how similar are the outcomes?', and with reproducibility we want to answer the question 'if different experts analyse the same GPS data, how similar are their outcomes?' We follow two approaches to quantify the R&R and conclude in both cases that the measurement system is accurate. The use of GPS data and the associated expert judgements can hence be applied with confidence in freight transport models.

Cordon toll competition in a network of two cities: Formulation and sensitivity to traveller route and demand responses

- Transportation Research Part B: Methodological--2015---D.P. Watling,S.P. Shepherd,A. Koh

While there exists extensive literature on the first- and second-best tolling of congested transportation networks, much of it presumes the existence of a single agent responsible for toll-setting. The present paper extends the small but growing body of work studying the impact of several agents independently regulating tolls on different parts of a network. Specifically we consider the problem of a network consisting of two 'cities', each city independently regulated by a city 'authority' able to set a single cordon toll for entry to the city. It is supposed that each authority aims to maximise the social welfare of its own residents, anticipating the impact of its toll on travellers' route and demand decisions, while reacting to the toll level levied by the other authority. In addition, we model the possibility of the cities entering into a 'tax-exporting agreement', in which city A agrees to share with city B the toll revenues it collects from city B residents using city A's network. It is assumed that the sensitivity of travellers, in terms of their route and demand responses, is captured by an elastic demand, Stochastic User Equilibrium (SUE) model. Conditions for a Nash Equilibrium (NE) between cities are set out as an Equilibrium Problem with Equilibrium Constraints (EPEC). It is shown that weaker, 'local' solutions to the EPEC (which we term LNE for local NE) satisfy a single variational inequality, using the smooth implicit function of the SUE map. Standard variational algorithms may then be used to identify such LNE solutions, allowing NE solutions to be identified from this candidate set; we test the use of a Sequential Linear Complementarity Problem algorithm. Numerical results are reported in which we see that the sensitivity of travellers may affect many factors, including: the number of LNE solutions, the initial conditions for which algorithms might determine such solutions, the gap between LNE and a global regulator solution, and the incentive for cities to cooperate in terms of tax-exporting.

Train scheduling for minimizing passenger waiting time with time-dependent demand and skip-stop patterns: Nonlinear integer programming models with linear constraints

- Transportation Research Part B: Methodological--2015---Huimin Niu,Xuesong Zhou,Ruhu Gao

This paper focuses on how to minimize the total passenger waiting time at stations by computing and adjusting train timetables for a rail corridor with given time-varying origin-to-destination passenger demand matrices. Given predetermined train skip-stop patterns, a unified quadratic integer programming model with linear constraints is developed to jointly synchronize effective passenger loading time windows and train arrival and departure times at each station. A set of quadratic and quasi-quadratic objective functions are proposed to precisely formulate the total waiting time under both minute-dependent demand and hour-dependent demand volumes from different origin–destination pairs. We construct mathematically rigorous and algorithmically tractable nonlinear mixed integer programming models for both real-time scheduling and medium-term planning applications. The proposed models are implemented using general purpose high-level optimization solvers, and the model effectiveness is further examined through numerical experiments of real-world rail train timetabling test cases.

Systematic bias in transport model calibration arising from the variability of linear data projection

- Transportation Research Part B: Methodological---2015---Wai Wong,S.C. Wong

In transportation and traffic planning studies, accurate traffic data are required for reliable model calibration to accurately predict transportation system performance and ensure better traffic planning. However, it is impractical to gather data from an entire population for such estimations because the widely used loop detectors and other more advanced wireless sensors may be limited by various factors. Thus, making data inferences based on smaller populations is generally inevitable. Linear data projection is a commonly and intuitively adopted method for inferring population traffic characteristics. It projects a sample of observable traffic quantities such as traffic count based on a set of scaling factors. However, scaling factors are subject to different types of variability such as spatial variability. Models calibrated based on linearly projected data that do not account for variability may introduce a systematic bias into their parameters. Such a bias is surprisingly often ignored. This paper reveals the existence of a systematic bias in model calibration caused by variability in the linear data projection. A generalized multivariate polynomial model is applied to examine the effect of this variability on model parameters. Adjustment factors are derived and methods are proposed for detecting and removing the embedded systematic bias. A simulation is used to demonstrate the effectiveness of the proposed method. To illustrate the applicability of the method, case studies are conducted using real-world global positioning system data obtained from taxis. These data calibrate the Macroscopic Bureau of Public Road function for six 1×1km regions in Hong Kong.

A simple algorithm for the estimation of road traffic space mean speeds from data available to most management centres

- Transportation Research Part B: Methodological---2015---Margarita Martínez-Díaz,Ignacio Pérez

The control of the evolution of road traffic streams is highly related to productivity, safety, sustainability and, even, comfort. Although, nowadays, the findings from research efforts and the development of new technologies enable accurate traffic forecasts in almost any conditions, these calculations are usually limited by the data and the equipment available. Most traffic management centres depend on the data provided, at best, by double-loop detectors. These loops supply time means over different aggregation periods, which are indiscriminately used as the bases for subsequent estimations. Since space mean speeds are those needed in most applications (note the fundamental relationship between flow and density in traffic flow theory), most current practice begins with an error. This paper introduces a simple algorithm that the allows estimation of space mean speeds from the data provided by the loops without the need for any additional financial outlay, as long as the traffic in each time interval of aggregation is stationary and its speed distribution is log-normal. Specifically, it is focused on the calculation of the variance of the speeds with regard to the time mean, thus making possible to use the relationship between time mean speeds and space mean speeds defined by Rakha (2005). The results obtained with real data show that the algorithm behaves well if the calculation conditions help fulfil the initial hypotheses.

The primary difficulties arise with transient traffic and, in this case, other specific methodologies should be used. Data fusion seems promising in this regard. Nevertheless, it cannot be denied that the improvement provided by the algorithm turns out to be highly beneficial both when used alone in the case of stationarity or as a part of a fusion.

An anisotropic continuum model considering bi-directional information impact

- Transportation Research Part B: Methodological---2015---Liang Zheng,Peter J. Jin,Helai Huang

In traffic flow with naturalistic driving only, stimulus information pre-dominantly comes from the preceding vehicles with drivers occasionally responding to the following vehicles through the inspection of rear-view mirrors. Such one-sided information propagation may potentially be altered in future connected vehicle environment. This brings new motivations of modeling vehicle dynamics under bi-directional information propagation. In this study, stemming from microscopic bi-directional car-following models, a continuum traffic flow model is put forward that incorporates the bi-directional information impact macroscopically but can still preserve the anisotropic characteristics of traffic flow and avoid non-physical phenomenon such as wrong-way travels. We then analyze the properties of the continuum model and respectively illustrate the condition that guarantees the anisotropy, eradicates the negative travel speed, preserves the traveling waves and keeps the linear stability. Through a series of numerical experiments, it is concluded that (1) under the bi-directional looking context only when the backward weight ratio belongs to an appropriate range then the anisotropic property can be maintained; (2) forward-propagating traffic density waves and standing waves emerge with the increasing consideration ratio for backward information; (3) the more aggressive driving behaviors for the forward direction can delay the backward-propagating and speed up the forward-propagating of traffic density waves; (4) positive holding effect and negative pushing effect of backward looking can also be observed under different backward weight ratios; and (5) traffic flow stability varies with different proportion of backward traffic information contribution and such stability impact is sensitive to the initial traffic density condition. This proposed continuum model may contribute to future development of traffic control and coordination in future connected vehicle environment.

The split-demand one-commodity pickup-and-delivery travelling salesman problem

- Transportation Research Part B: Methodological---2015---Juan-José Salazar-González,Beatriz Santos-Hernández

This paper introduces a new vehicle routing problem transferring one commodity between customers with a capacitated vehicle that can visit a customer more than once, although a maximum number of visits must be respected. It generalizes the capacitated vehicle routing problem with split demands and some other variants recently addressed in the literature. We model the problem with a single commodity flow formulation and design a branch-and-cut approach to solve it. We make use of Benders Decomposition to project out the flow variables from the formulation. Inequalities to strengthen the linear programming relaxation are also presented and separated within the approach. Extensive computational results illustrate the performance of the approach on benchmark instances from the literature.

Optimal layout of transshipment facility locations on an infinite homogeneous plane

- Transportation Research Part B: Methodological---2015---Weijun Xie,Yanfeng Ouyang

This paper studies optimal spatial layout of transshipment facilities and the corresponding service regions on an infinite homogeneous plane R2 that minimize the total cost for facility set-up, outbound delivery and inbound replenishment transportation. The problem has strong implications in the context of freight logistics and transit system design. This paper first focuses on a Euclidean plane and shows that a tight upper bound can be achieved by a type of elongated cyclic hexagons, while a cost lower bound based on relaxation and idealization is also obtained. The gap between the analytical upper and lower bounds is within 0.3%. This paper then shows that a similar elongated non-cyclic hexagon shape, with proper orientation, is actually optimal for service regions on a rectilinear metric plane. Numerical experiments are conducted to verify the analytical findings and to draw further insights.

Distance-dependent congestion pricing for downtown zones

- Transportation Research Part B: Methodological---2015---Carlos F. Daganzo,Lewis J. Lehe

A growing literature exploits macroscopic theories of traffic to model congestion pricing policies in downtown zones. This study introduces trip length heterogeneity into this analysis and proposes a usage-based, time-varying congestion toll that alleviates congestion while prioritizing shorter trips. Unlike conventional trip-based tolls the scheme is intended to align the fees paid by drivers with the actual congestion damage they do, and to increase the toll’s benefits as a result.

A nested recursive logit model for route choice analysis

- Transportation Research Part B: Methodological---2015---Tien Mai,Mogens Fosgerau,Emma Frejinger

We propose a route choice model that relaxes the independence from irrelevant alternatives property of the logit model by allowing scale parameters to be link specific. Similar to the recursive logit (RL) model proposed by Fosgerau et al. (2013), the choice of path is modeled as a sequence of link choices and the model does not require any sampling of choice sets. Furthermore, the model can be consistently estimated and efficiently used for prediction.

Dynamics of heterogeneity in urban networks: aggregated traffic modeling and hierarchical control

- Transportation Research Part B: Methodological---2015---Mohsen Ramezani,Jack Haddad,Nikolas Geroliminis

Real traffic data and simulation analysis reveal that for some urban networks a well-defined Macroscopic Fundamental Diagram (MFD) exists, which provides a unimodal and low-scatter relationship between the network vehicle density and outflow. Recent studies demonstrate that link density heterogeneity plays a significant role in the shape and scatter level of MFD and can cause hysteresis loops that influence the network performance. Evidently, a more homogeneous network in terms of link density can result in higher network outflow, which implies a network performance improvement. In this article, we introduce two aggregated models, region- and subregion-based MFDs, to study the dynamics of heterogeneity and how they can affect the accuracy scatter and hysteresis of a multi-subregion MFD model. We also introduce a hierarchical perimeter flow control problem by integrating the MFD heterogeneous modeling. The perimeter flow controllers operate on the border between urban regions, and manipulate the percentages of flows that transfer between the regions such that the network delay is minimized and the distribution of congestion is more homogeneous. The first level of the hierarchical control problem can be solved by a model predictive control approach, where the prediction model is the aggregated parsimonious region-based MFD and the plant (reality) is formulated by the subregion-based MFDs, which is a more detailed model. At the lower level, a feedback controller of the hierarchical structure, tries to maximize the outflow of critical regions, by increasing their homogeneity. With inputs that can be observed with existing monitoring techniques and without the need for detailed traffic state information, the proposed framework succeeds to increase network flows and decrease the hysteresis loop of the MFD. Comparison with existing perimeter controllers without considering the more advanced heterogeneity modeling of MFD highlights the importance of such approach for traffic modeling and control.

A family of macroscopic node models

- Transportation Research Part B: Methodological---2015---Erik-Sander Smits,Michiel Bliemer,Adam J. Pel,Bart van Arem

The family of macroscopic node models which comply to a set of basic requirements is presented and analysed. Such models are required in macro-, mesoscopic traffic flow models, including dynamic network loading models for dynamic traffic assignment. Based on the behaviour of drivers approaching and passing through intersections, the model family is presented. The headway and the turn delay of vehicles are key variables. Having demand and supply as input creates a natural connection to macroscopic link models. Properties like the invariance principle and the conservation of turning fractions are satisfied. The inherent non-uniqueness is analysed by providing the complete set of feasible solutions. The node models proposed by Tampère et al. (2011), Flötteröd and Rohde (2011) and Gibb (2011) are members of the family. Furthermore, two new models are added to the family. Solution methods for all family members are presented, as well as a qualitative and quantitative comparison. Finally, an outlook for the future development of empirically verified models is given.

Optimization of bus stop placement for routes on uneven topography

- Transportation Research Part B: Methodological---2015---Ceder, Avishai (Avi),Matthew Butcher,Lingli Wang

The improvement and expansion of public transport is an increasingly important solution to the high congestion costs and worsening environmental impacts of the car dominated transport systems seen in many cities today. The intelligent design of stop locations is one way to improve the quality of PT and thereby improve its ridership. Stop placement is a relatively complex task as it involves a trade-off between two competing goals; accessibility and operation; however this trade-off can be made explicit using an appropriate mathematical model. Many such models have been developed in the literature, however none consider the effects of uneven topography. Topography is an important but often neglected factor in the design of public transportation systems, with the potential to have a significant impact on the accessibility, operation and planning of a transit service. In this work a mathematical modelling approach to bus stop placement is developed which includes considerations of uneven topography in three ways; (1) Its effect on walking speed; (2) Its impact on the attractiveness of an access path to a transit service; and (3) Its effect on acceleration rates at stops. Because of the complexity of the model developed, a heuristic evolutionary algorithm' is employed to approximate an optimal solution to the model. Finally, the model and solution method are applied to a case study in the Auckland CBD area in New Zealand.

Optimal housing supply in a bid-rent equilibrium framework

- Transportation Research Part B: Methodological---2015---Ka Fai Ng,Hong K. Lo

In this study, we examine how the spatial distribution of housing supply impacts people's residential choices and developers' profitability. By optimally providing housing supply in a region, developers attempt to maximize their profits; on the other hand, if residents were given a chance to decide on housing supply, what patterns of housing supply they would prefer in order to maximize their consumer surpluses. This paper studies the interplay between these two perspectives. A nested multinomial-logit choice structure that encapsulates the bid-rent process is used to capture residents' location and travel choices simultaneously, and the resultant rents at different locations. To investigate the optimal housing supply for these two stakeholders, we conduct sensitivity analyzes to explore the impact of different housing supply patterns on total rental profit and total consumer surplus. Specifically, analytical results are derived for a simple linear network with two residential locations and one destination under homogeneous and heterogeneous value(s) of time. The results of the sensitivity analyzes indicate that segregation of housing supplies at different locations for different income classes is, surprisingly, a "preferred" outcome by residents under consumer surplus maximization, whereas creating housing supply shortages at convenient locations is a natural outcome under housing profit maximization. These results provide insights on revealing the differences and tradeoffs in performance between these two different perspectives, and on where land use regulations may be needed to balance these two objectives.

Container vessel fleet deployment for liner shipping with stochastic dependencies in shipping demand

- Transportation Research Part B: Methodological---2015---ManWo Ng

The problem of optimal container vessels deployment is one of great significance for the liner shipping industry. Although the pioneering work on this problem dates back to the early 1990s, only until recently have researchers started to acknowledge and account for the significant amount of uncertainty present in shipping demand in real world container shipping. In this paper, new analytical results are presented to further relax the input requirements for this problem. Specifically, only the mean and variance of the maximum shipping demand are required to be known. An optional symmetry assumption is shown to further reduce the feasible region and deployment cost for typical confidence levels. Moreover, unlike previous work that tends to ignore stochastic dependencies between the shipping demands on the various routes (that are known to exist in the real world), our models account for such dependencies in the most general setting to date. A salient feature of our modeling approach is that the exact dependence structure does not need to be specified, something that is hard, if not simply impossible, to determine in practice. A numerical case study is provided to illustrate the proposed models.

Continuous formulations and analytical properties of the link transmission model

- Transportation Research Part B: Methodological---2015---Wen-Long Jin

The link transmission model (LTM) has great potential for simulating traffic flow in large-scale networks since it is much more efficient and accurate than the Cell Transmission Model (CTM). However, there lack general continuous formulations of LTM, and there has been no systematic study on its analytical properties such as stationary states and stability of network traffic flow. In this study we attempt to fill the gaps. First we apply the Hopf–Lax formula to derive Newell's simplified kinematic wave model with given boundary cumulative flows and the triangular fundamental diagram. We then apply the Hopf–Lax formula to define link demand and supply functions, as well as link queue and vacancy functions, and present two continuous formulations of LTM, by incorporating boundary demands and supplies as well as invariant macroscopic junction models. With continuous LTM, we define and solve the stationary states in a road network. We also apply LTM to directly derive a Poincaré map to analyze the stability of stationary states in a diverge-merge network. Finally we present an example to show that LTM is not well-defined with non-invariant junction models. We can see that Newell's model and continuous LTM complement each other and provide an alternative formulation of the network kinematic wave theory. This study paves the way for further extensions, analyses, and applications of LTM in the future.

Dynamic stride length adaptation according to utility and personal space

- Transportation Research Part B: Methodological---2015---Isabella von Sivers,Gerta Köster

Pedestrians adjust both speed and stride length when they navigate difficult situations such as tight corners or dense crowds. They try to avoid collisions and to preserve their personal space. State-of-the-art pedestrian motion models automatically reduce speed in dense crowds simply because there is no space where the pedestrians could go. The stride length and its correct adaptation, however, are rarely considered. This leads to artefacts that impact macroscopic observation parameters such as densities in front of bottlenecks and, through this, flow. Hence modelling stride adaptation is important to increase the predictive power of pedestrian models. To achieve this we reformulate the problem as an optimisation problem on a disk around the pedestrian. Each pedestrian seeks the position that is most attractive in a sense of balanced goals between the search for targets, the need for individual space and the need to keep a distance from obstacles. The need for space is modelled according to findings from psychology defining zones around a person that, when invaded, cause unease. The result is a fully automatic adjustment that allows calibration through meaningful social parameters and that gives visually natural results with an excellent fit to measured experimental data.

Would competition between air transport and high-speed rail benefit environment and social welfare?

- Transportation Research Part B: Methodological---2015---D' Alfonso, Tiziana,Changmin Jiang,Valentina Bracaglia

We develop a duopoly model to analyze the impact of air transport and high-speed rail (HSR) competition on the environment and social welfare. We show that the introduction of HSR may have a net negative effect on the environment, since it may result in additional demand, i.e., there is a trade-off between the substitution effect and the traffic generation effect. Furthermore, if environmental externalities are taken into account when assessing social welfare, the surplus measure may be higher when only air transport serves the market than when the two modes compete. When the airline and the HSR operator decide frequencies, the airline reduces the aircraft size in order to keep load factors high while offering lower frequency and carrying fewer passengers. In these circumstances, the introduction of HSR may be beneficial to the environment on a per seat basis only if the market size is large enough. When the HSR operator decides speed, it has incentive to keep it at the maximum level in order to reduce travel time. When the increase in the emissions of HSR due to the increase in the speed of the train is sufficiently high, the overall level of emissions grows after the introduction of HSR. Therefore, there can be a trade-off between the attractiveness of the service due to reduced travel time and the effects on the environment.

A Lagrangian heuristic framework for a real-life integrated planning problem of railway transportation resources

- Transportation Research Part B: Methodological---2015---Stéphane Dauzère-Pérès,David De Almeida,Olivier Guyon,Faten Benhizia

Train path (infrastructure), rolling stock and crew scheduling are three critical planning decisions in railway transportation. These resources are usually planned separately in a sequential process that typically starts from planning (1) train paths and goes further on to (2) rolling stock and (3) train drivers. Such a sequential approach helps to handle the complexity of the planning process and simplify the underlying mathematical models. However, it generates solutions with higher costs because the decisions taken at one step can drastically reduce the set of feasible solutions in the following steps. In this paper, we propose a Lagrangian heuristic framework to solve an integrated problem which globally and simultaneously considers the planning of two railway resources: Rolling stock units and train drivers. Based on a mixed integer linear programming formulation, this approach has two important characteristics in an industrial context: (i) It can tackle real-life integrated planning problems and (ii) the Lagrangian dual is solved by calling two proprietary software modules available at SNCF. Various relaxation schemes are analyzed. Moreover, coupling constraints are rewritten to improve the heuristic effectiveness. Numerical experiments on real-life instances illustrate the effectiveness of the Lagrangian heuristic, and the impact of various parameters is analyzed.

Compared to a sequential approach, it leads to cost reductions and generates good solutions in a reasonable CPU time.

Approximation methods for large-scale spatial queueing systems

- Transportation Research Part B: Methodological---2015---Burak Boyacı,Nikolas Geroliminis

Different than the conventional queueing systems, in spatial queueing systems (SQS) the service rate for each customer-server pairs differs and the server that intervenes for a specific customer is not known a priori, depending on the availability of servers at the moment a request was made. These features make the SQS computationally expensive (almost intractable for large scale) but at the same time more suitable for real-life problems with high reliability expectations. Emergency response and on-demand transportation systems are two similar systems that can be modeled with the SQS.

An intersection-movement-based stochastic dynamic user optimal route choice model for assessing network performance

- Transportation Research Part B: Methodological---2015---Jiancheng Long,W.Y. Szeto,Hai-Jun Huang,Ziyou Gao

Different from traditional methods, this paper formulates the logit-based stochastic dynamic user optimal (SDUO) route choice problem as a fixed point (FP) problem in terms of intersection movement choice probabilities, which contain travelers' route information so that the realistic effects of physical queues can be captured in the formulation when a physical-queue traffic flow model is adopted, and that route enumeration and column generation heuristics can be avoided in the solution procedure when efficient path sets are used. The choice probability can be either destination specific or origin–destination specific, resulting into two formulations. To capture the effect of physical queues in these FP formulations, the link transmission model is modified for the network loading and travel time determination. The self-regulated averaging method (SRAM) was adopted to solve the FP formulations. Numerical examples were developed to illustrate the properties of the problem and the effectiveness of the solution method. The proposed models were further used to evaluate the effect of information quality and road network improvement on the network performance in terms of total system travel time (TSTT) and the cost of total vehicle emissions (CTVE). Numerical results show that providing better information quality, enhancing link outflow capacity, or constructing a new road can lead to poor network performance.

Pricing of parking games with atomic players

- Transportation Research Part B: Methodological---2015---Fang He,Yafeng Yin,Zhibin Chen,Jing Zhou

This paper considers a parking competition game where a finite number of vehicles from different origins compete for the same number of parking spaces located at various places in a downtown area to minimize their own parking costs. If one vehicle reaches a desired vacant parking space before another vehicle, it will occupy the space and the other vehicle would have to search elsewhere. We first present a system of nonlinear equations to describe the equilibrium assignment of parking spaces to vehicles, and then discuss optimal pricing schemes that steer such parking competition to a system optimum assignment of parking spaces. These schemes are characterized by a union of polyhedrons. Given that the equilibrium state of parking competition is not unique, we further introduce a valid price vector to ensure that the parking competition outcome will always be system optimum. A sufficient condition is provided for the existence of such a valid price vector. Lastly, we seek for a robust price vector that yields the best worst-case outcome of the parking competition.

GHG-emission models for assessing the eco-friendliness of road and rail freight transports

- Transportation Research Part B: Methodological---2015---Thomas Kirschstein,Frank Meisel

Intermodal rail/road transportation is an instrument of green logistics, which may help reducing transport related greenhouse gas (GHG) emissions. In order to assess the environmental impact of road and rail transports, researchers have formulated very detailed microscopic models, which determine vehicle emissions precisely based on a vast number of parameters. They also developed macroscopic models, which estimate emissions more roughly from few parameters that are considered most influential. One of the goals of this paper is to develop mesoscopic models that combine the preciseness of micro-models while requiring only little more information than macro-models. We propose emission models designed for transport planning purposes which are simple to calibrate by transport managers. Despite their compactness, our models are able to reflect the influence of various traffic conditions on a transport's total emissions. Furthermore, contrasting most papers considering either the road or the rail mode, we provide models on a common basis for both modes of transportation. We validate our models using popular micro- and macroscopic models and we apply them to artificial and real world transport scenarios to identify under which circumstances intermodal transports actually effect lower emissions. We find that travel speed and country-specific energy emission factors influence the eco-friendliness of intermodal transports most severely. Hence, the particular route chosen for a transnational intermodal transport is an important but so far neglected option for eco-friendly transportation.

Bid price optimization for truckload carriers in simultaneous transportation procurement auctions

- Transportation Research Part B: Methodological--2015---Gültekin Kuyzu,Çağla Gül Akyol,Özlem Ergun,Martin Savelsbergh

We study simultaneous transportation procurement auctions from a truckload carrier's perspective. We formulate a stochastic bid price optimization model aimed at maximizing the carrier's expected profit. The model accounts for synergies among lanes and competing carriers' bid patterns. We develop an iterative coordinate search algorithm to find high-quality solutions. The benefits of employing the bid price optimization technology are demonstrated through computational experiments involving a simulated marketplace.

Method for investigating intradriver heterogeneity using vehicle trajectory data: A Dynamic Time Warping approach

- Transportation Research Part B: Methodological--2015---Jeffrey Taylor,Xuesong Zhou,Nagui M. Rouphail,Richard J. Porter

After first extending Newell's car-following model to incorporate time-dependent parameters, this paper describes the Dynamic Time Warping (DTW) algorithm and its application for calibrating this microscopic simulation model by synthesizing driver trajectory data. Using the unique capabilities of the DTW algorithm, this paper attempts to examine driver heterogeneity in car-following behavior, as well as the driver's heterogeneous situation-dependent behavior within a trip, based on the calibrated time-varying response times and critical jam spacing. The standard DTW algorithm is enhanced to address a number of estimation challenges in this specific application, and a numerical experiment is presented with vehicle trajectory data extracted from the Next Generation Simulation (NGSIM) project for demonstration purposes. The DTW algorithm is shown to be a reasonable method for processing large vehicle trajectory datasets, but requires significant data reduction to produce reasonable results when working with high resolution vehicle trajectory data. Additionally, singularities present an interesting match solution set to potentially help identify changing driver behavior; however, they must be avoided to reduce analysis complexity.

Analysis of fixed-time control

- Transportation Research Part B: Methodological--2015---Ajith Muralidharan,Ramtin Pedarsani,Pravin Varaiya

The paper presents an analysis of the traffic dynamics in a network of signalized intersections. The intersections are regulated by fixed-time (FT) controls, all with the same cycle length or period, T. The network is modeled as a queuing network. Vehicles arrive from outside the network at entry links in a deterministic periodic stream, also with period T. They take a fixed time to travel along each link, and at the end of the link they join a queue. There is a separate queue at each link for each movement or phase. Vehicles make turns at intersections in fixed proportions, and eventually leave the network, that is, a fraction r(i,j) of vehicles that leave queue i go to queue j and the fraction [1-Σjr(i,j)] leave the network. The storage capacity of the queues is infinite, so there is no spill back. The main contribution of the paper is to show that if the signal controls accommodate the demands then, starting in any initial condition, the network state converges to a unique periodic orbit. Thus, the effect of initial conditions disappears. More precisely, the state of the network at time t is the vector x(t) of all queue lengths, together with the position of vehicles traveling along the links. Suppose that the network is stable, that is, x(t) is bounded. Then

On the fundamental diagram for freeway traffic: A novel calibration approach for single-regime models

- Transportation Research Part B: Methodological---2015---Xiaobo Qu,Shuaian Wang,Jin Zhang

The speed-density or flow-density relationship has been considered as the foundation of traffic flow theory. Existing single-regime models calibrated by the least square method (LSM) could not fit the empirical data consistently well both in light-traffic/free-flow conditions and congested/jam conditions. In this paper, first, we point out that the inaccuracy of single-regime models is not caused solely by their functional forms, but also by the sample selection bias. Second, we apply a weighted least square method (WLSM) that addresses the sample selection bias problem. The calibration results for six well-known single-regime models using the WLSM fit the empirical data reasonably well both in light-traffic/free-flow conditions and congested/jam conditions. Third, we conduct a theoretical investigation that reveals the deficiency associated with the LSM is because the expected value of speed (or a function of it) is nonlinear with regard to the density (or a function of it).

Optimization of mid-block pedestrian crossing network with discrete demands

- Transportation Research Part B: Methodological---2015---Chunhui Yu,Wanjing Ma,Hong K. Lo,Xiaoguang Yang

In many cases, pedestrian crossing demands are distributed discretely along an arterial segment. Demand origins, destinations and crosswalks comprise a pedestrian crossing network. An integrated model for optimizing the quantity, locations and signal settings of mid-block crosswalks simultaneously is proposed to best trade-off the operational performances between pedestrians and vehicles. Pedestrian behavior of choosing crosswalks is captured under a discrete demand distribution. Detour distance and delay at signalized crosswalks are formulated as a measure of pedestrian crossing cost. Maximum bandwidths are modeled in analytical expressions as a measure of vehicular cost. To solve the proposed model, the Non-dominated Sorting Genetic Algorithm II (NSGA II) based algorithm is designed and employed to obtain the Pareto frontier efficiently. From the numerical study, it is found that there exists an optimal number of mid-block crosswalks. Excess available crosswalks may make no contributions to improvement in pedestrian cost when the constraint of the minimum interval between crosswalks and vehicular cost are taken into account. Two-stage crosswalks are more favorable than one-stage ones for the benefits of both pedestrian and vehicles. The study results show promising properties of the proposed method to assist transportation engineers in properly designing mid-block crosswalks along a road segment.

A comparison of price-cap and light-handed airport regulation with demand uncertainty

- Transportation Research Part B: Methodological---2015---Hangjun Yang,Xiaowen Fu

This study analytically compares the performance of ex ante price-cap airport regulation vs. ex post light-handed airport regulation in the presence of demand uncertainty. Our modeling results suggest that light-handed regulation is a promising method which may lead to higher welfare than price-cap regulation. However, neither regulation strictly dominates the other in terms of welfare, airport charge or service quality. The relative performance of alternative regulations depends on many market factors and the specification of penalty under light-handed regulation. Our analytical results also suggest that if service quality matters and if an airport is allowed to invest in a higher quality, average cost pricing may not be optimal due to possible sub-optimal choices of quality, and the overall performance of alternative regulatory regimes should be assessed with a comprehensive welfare analysis. Our investigation confirms that light-handed regulation is worth preserving subject to monitoring and continuous improvements.

A tailored branch-and-price approach for a joint tramp ship routing and bunkering problem

- Transportation Research Part B: Methodological---2015---Qiang Meng,Shuaian Wang,Chung-Yee Lee

This paper deals with a practical tramp ship routing problem while taking into account different bunker prices at different ports, which is called the joint tramp ship routing and bunkering (JSRB) problem. Given a set of cargoes to be transported and a set of ports with different bunker prices, the proposed problem determines how to route ships to carry the cargoes and the amount of bunker to purchase at each port, in order to maximize the total profit. After building an integer linear programming model for the JSRB problem, we propose a tailored branch-and-price (B&P) solution approach. The B&P approach incorporates an efficient method for obtaining the optimal bunkering policy and a novel dominance rule for detecting inefficient routing options. The B&P approach is tested with randomly generated large-scale instances derived from real-world planning problems. All of the instances can be solved efficiently. Moreover, the proposed approach for the JSRB problem outperforms the conventional sequential planning approach and can incorporate the prediction of future cargo demand to avoid making myopic decisions.

Global optimization method for network design problem with stochastic user equilibrium

- Transportation Research Part B: Methodological---2015---Haoxiang Liu,David Z.W. Wang

In this paper, we consider the continuous road network design problem with stochastic user equilibrium constraint that aims to optimize the network performance via road capacity expansion. The network flow pattern is subject to stochastic user equilibrium, specifically, the logit route choice model. The resulting formulation, a nonlinear nonconvex programming problem, is firstly transformed into a nonlinear program with only logarithmic functions as nonlinear terms, for which a tight linear programming relaxation is derived by using an outer-approximation technique. The linear programming relaxation is then embedded within a global optimization solution algorithm based on range reduction technique, and the proposed approach is proved to converge to a global optimum.

Profit-based maritime container assignment models for liner shipping networks

- Transportation Research Part B: Methodological---2015---Shuaian Wang,Zhiyuan Liu,Michael G.H. Bell

We propose the problem of profit-based container assignment (P-CA), in which the container shipment demand is dependent on the freight rate, similar to the “elastic demand” in the literature on urban transportation networks. The problem involves determining the optimal freight rates, the number of containers to transport and how to transport the containers in a liner shipping network to maximize the total profit. We first consider a tactical-level P-CA with known demand functions that are estimated based on historical data and formulate it as a nonlinear optimization model. The tactical-level P-CA can be used for evaluating and improving the container liner shipping network. We then address the operational-level P-CA with unknown demand functions, which aims to design a mechanism that adjusts the freight rates to maximize the profit. A theoretically convergent trial-and-error approach, and a practical trial-and-error approach, are developed. A numerical example is reported to illustrate the application of the models and approaches.

A trial-and-error congestion pricing scheme for networks with elastic demand and link capacity constraints

- Transportation Research Part B: Methodological----2015---Bojian Zhou,Michiel Bliemer,Hai Yang,Jie He

This paper proposes a combination of trial-and-error congestion pricing schemes that have been studied in the literature. It not only considers the minimization of the total system cost but also addresses the capacity constraints. A two-level iteration method is proposed for solving the hybrid problem, in which the approximate subgradient projection method is used for the outer level iteration phase, and the partial linearization method is used for the inner level iteration phase. We prove the convergence of the two-level iteration method, under the condition that the subproblem for the inner level iteration is only solved approximately, which makes the method efficient and practical. A numerical example is presented to illustrate the application of the two-level iteration method to the trial-and-error congestion pricing scheme.

Strategic considerations behind the network–regional airline tie ups – A theoretical and empirical study

- Transportation Research Part B: Methodological---2015---David Gillen,Hamed Hasheminia,Changmin Jiang

The paper examines the strategic vertical relationship between network and regional airlines. We develop a model to illustrate how network airlines can use the contractual relationship with regional airlines as an efficient tool to simultaneously drive out inefficient network airlines and also accommodate other cost efficient network airlines in any specific market. The model is tested on U.S. data using simultaneous and sequential choice models. We find that market size, cost differences between network airlines, as well as cost differences between network and regional airlines, are the chief determinants of the network airlines' decisions on whether or not to serve a market with their own fleet, as well as how many regional airlines to contract with.

A case study on the coordination of last trains for the Beijing subway network

- Transportation Research Part B: Methodological---2015---Liujiang Kang,Jianjun Wu,Huijun Sun,Xiaoning Zhu,Ziyou Gao

Passengers may make several transfers between different lines to reach their destinations in urban railway transit networks. Coordination of last trains in feeding lines and connecting lines at transfer stations is especially important because it is the last chance for many travellers to transfer. In this paper, a mathematical method is used to reveal the relationships between passenger transfer connection time (PTCT) and passenger transfer waiting time (PTWT). A last-train network transfer model (LNTM) is established to maximize passenger transfer connection headways (PTCH), which reflect last-train connections and transfer waiting time. Additionally, a genetic algorithm (GA) is developed based upon this LNTM model and used to test a numerical example to verify its effectiveness. Finally, the Beijing subway network is taken as a case study. The results of the numerical example show that the model improves five connections and reduces to zero the number of cases when a feeder train arrives within one headway's time after the connecting train departed.

Segment-based alteration for container liner shipping network design

- Transportation Research Part B: Methodological---2015---Shuaian Wang,Zhiyuan Liu,Qiang Meng

Container liner shipping companies only partially alter their shipping networks to cope with the changing demand, rather than entirely redesign and change the network. In view of the practice, this paper proposes an optimal container liner shipping network alteration problem based on an interesting idea of segment, which is a sequence of legs from a head port to a tail port that are visited by the same type of ship more than once in the existing shipping network. In segment-based network alteration, the segments are intact and each port is visited by the same type of ship and from the same previous ports. As a result, the designed network needs minimum modification before implementation. A mixed-integer linear programming model with a polynomial number of variables is developed for the proposed segmented-based liner shipping network alternation problem. The developed model is applied to an Asia–Europe–Oceania liner shipping network with a total of 46 ports and 11 ship routes. Results demonstrate that the problem could be solved efficiently and the optimized network reduces the total cost of the initial network considerably.

Compromising system and user interests in shelter location and evacuation planning

- Transportation Research Part B: Methodological---2015---Vedat Bayram,Barbaros Ç. Tansel,Hande Yaman

Traffic management during an evacuation and the decision of where to locate the shelters are of critical importance to the performance of an evacuation plan. From the evacuation management authority's point of view, the desirable goal is to minimize the total evacuation time by computing a system optimum (SO). However, evacuees may not be willing to take long routes enforced on them by a SO solution; but they may consent to taking routes with lengths not longer than the shortest path to the nearest shelter site by more than a tolerable factor. We develop a model that optimally locates shelters and assigns evacuees to the nearest shelter sites by assigning them to shortest paths, shortest and nearest with a given degree of tolerance, so that the total evacuation time is minimized. As the travel time on a road segment is often modeled as a nonlinear function of the flow on the segment, the resulting model is a nonlinear mixed integer programming model. We develop a solution method that can handle practical size problems using second order cone programming techniques. Using our model, we investigate the importance of the number and locations of shelter sites and the trade-off between efficiency and fairness.

Discomfort in mass transit and its implication for scheduling and pricing

- Transportation Research Part B: Methodological---2015---André de Palma,Moez Kilani,Stef Proost

This paper discusses the formulation of crowding in public transport and its implications for pricing, seating capacity and optimal scheduling. An analytical model is used to describe the user equilibrium and the optimal equilibrium for different stylized conditions. For the one OD pair case with identical desired arrival time, we derive the optimal dynamic pricing and optimal share of seats. For the uniformly distributed desired arrival times case, we derive the optimal time table and the optimal pricing. Next we generalize the results to the case of a small network with several stations, stochastic choice and allocation of seats.

Real-time congestion pricing strategies for toll facilities

- Transportation Research Part B: Methodological---2015---Jorge A. Laval,Hyun W. Cho,Juan C. Muñoz,Yafeng Yin

This paper analyzes the dynamic traffic assignment problem on a two-alternative network with one alternative subject to a dynamic pricing that responds to real-time arrivals in a system optimal way. Analytical expressions for the assignment, revenue and total delay in each alternative are derived as a function of the pricing strategy. It is found that minimum total system delay can be achieved with many different pricing strategies. This gives flexibility to operators to allocate congestion to either alternative according to their specific objective while maintaining the same minimum total system delay. Given a specific objective, the optimal pricing strategy can be determined by finding a single parameter value in the case of HOT lanes. Maximum revenue is achieved by keeping the toll facility at capacity with no queues for as long as possible. Guidelines for implementation are discussed.

Regenerator Location Problem and survivable extensions: A hub covering location perspective

- Transportation Research Part B: Methodological---2015---Barış Yıldız,Oya Ekin Karaşan

In a telecommunications network the reach of an optical signal is the maximum distance it can traverse before its quality degrades. Regenerators are devices to extend the optical reach. The regenerator placement problem seeks to place the minimum number of regenerators in an optical network so as to facilitate the communication of a signal between any node pair. In this study, the Regenerator Location Problem is revisited from the hub location perspective directing our focus to applications arising in transportation settings. Two new dimensions involving the challenges of survivability are introduced to the problem. Under partial survivability, our designs hedge against failures in the regeneration equipment only, whereas under full survivability failures on any of the network nodes are accounted for by the utilization of extra regeneration equipment. All three variations of the problem are studied in a unifying framework involving the introduction of individual flow-based compact formulations as well as cut formulations and the implementation of branch and cut algorithms based on the cut formulations. Extensive computational experiments are conducted in order to evaluate the performance of the proposed solution methodologies and to gain insights from realistic instances.

A semi-analytical approach for solving the bottleneck model with general user heterogeneity

- Transportation Research Part B: Methodological---2015---Yang Liu,Nie, Yu (Marco),Jonathan Hall

This paper proposes a novel semi-analytical approach for solving the dynamic user equilibrium (DUE) of a bottleneck model with general heterogeneous users. The proposed approach makes use of the analytical solutions from the bottleneck analysis to create an equivalent assignment problem that admits closed-form commute cost functions. The equivalent problem is a static and asymmetric traffic assignment problem, which can be formulated as a variational inequality problem (VIP). This approach provides a new tool to analyze the properties of the bottleneck model with general heterogeneity, and to design efficient solution methods. In particular, the existence and uniqueness of the DUE solution can be established using the P-property of the Jacobian matrix. Our numerical experiments show that a simple decomposition algorithm is able to quickly solve the equivalent VIP to high precision. The proposed VIP formation is also extended to address simultaneous departure time and route choice in a single O–D origin-destination network with multiple parallel routes.

Train design and routing optimization for evaluating criticality of freight railroad infrastructures

- Transportation Research Part B: Methodological---2015---Abdullah A. Khaled,Mingzhou Jin,David B. Clarke,Mohammad A. Hoque

Freight transportation by railroads is an integral part of the U.S. economy. Identifying critical rail infrastructures can help stakeholders prioritize protection initiatives or add necessary redundancy to maximize rail network resiliency. The criticality of an infrastructure element, link or yard, is based on the increased cost (delay) incurred when that element is disrupted. An event of disruption can cause heavy congestion so that the capacity at links and yards should be considered when freight is re-routed. This paper proposes an optimization model for making-up and routing of trains in a disruptive situation to minimize the system-wide total cost, including classification time at yards and travel time along links. Train design optimization seeks to determine the optimal number of trains, their routes, and associated blocks, subject to various capacity and operational constraints at rail links and yards. An iterative heuristic algorithm is proposed to attack the computational burden for real-world networks. The solution algorithm considers the impact of volume on travel time in a congested or near-congested network. The proposed heuristics provide quality solutions with high speed, demonstrated by numerical experiments for small instances. A case study is conducted for the network of a major U.S. Class-I railroad based on publicly available data. The paper provides maps showing the criticality of infrastructure in the study area from the viewpoint of strategic planning.

Determining optimal frequency and vehicle capacity for public transit routes: A generalized newsvendor model

- Transportation Research Part B: Methodological---2015---Avi Herbon,Yuval Hadas

The level of service on public transit routes is very much affected by the frequency and vehicle capacity. The combined values of these variables contribute to the costs associated with route operations as well as the costs associated with passenger comfort, such as waiting and overcrowding. The new approach to the problem that we introduce combines both passenger and operator costs within a generalized newsvendor model. From the passenger perspective, waiting and overcrowding costs are used; from the operator’s perspective, the costs are related to vehicle size, empty seats, and lost sales. Maximal passenger average waiting time as well as maximal vehicle capacity are considered as constraints that are imposed by the regulator to assure a minimal public transit service level or in order to comply with other regulatory considerations. The advantages of the newsvendor model are that (a) costs are treated as shortages (overcrowding) and surpluses (empty seats); (b) the model presents simultaneous optimal results for both frequency and vehicle size; (c) an efficient and fast algorithm is developed; and (d) the model assumes stochastic demand, and is not restricted to a specific distribution. We demonstrate the usefulness of the model through a case study and sensitivity analysis.

Optimizing intersections

- Transportation Research Part B: Methodological---2015---Ruth Evers,Stef Proost

In this paper we optimize the regulation of an intersection of two routes connecting one origin–destination pair and study the effects of priority rules, traffic lights and tolls. We show that when the intersection is regulated by a priority rule the optimal policy is generally to block one of the two routes. When the intersection is regulated by traffic lights, it can only be optimal to leave both routes open when both routes are subject to congestion or if a toll is levied.

Probe vehicle data sampled by time or space: Consistent travel time allocation and estimation

- Transportation Research Part B: Methodological---2015---Erik Jenelius,Haris N. Koutsopoulos

A characteristic of low frequency probe vehicle data is that vehicles traverse multiple network components (e.g., links) between consecutive position samplings, creating challenges for (i) the allocation of the measured travel time to the traversed components, and (ii) the consistent estimation of component travel time distribution parameters. This paper shows that the solution to these problems depends on whether sampling is based on time (e.g., one report every minute) or space (e.g., one every 500m). For the special case of segments with uniform space-mean speeds, explicit formulae are derived under both sampling principles for the likelihood of the measurements and the allocation of travel time. It is shown that time-based sampling is biased towards measurements where a disproportionally long time is spent on the last segment. Numerical experiments show that an incorrect likelihood formulation can lead to significantly biased parameter estimates depending on the shapes of the travel time distributions. The analysis reveals that the sampling protocol needs to be considered in travel time estimation using probe vehicle data.

Microscopic driving theory with oscillatory congested states: Model and empirical verification

- Transportation Research Part B: Methodological---2015---Junfang Tian,Martin Treiber,Shoufeng Ma,Bin Jia,Wenyi Zhang

The essential distinction between the Fundamental Diagram Approach (FDA) and Kerner's three-phase theory (KTPT) is the existence of a unique gap–speed (or flow–density) relationship in the former class. In order to verify this relationship, empirical data are analyzed with the following findings: (1) linear relationship between the actual space gap and speed can be identified when the speed difference between vehicles approximates zero; (2) vehicles accelerate or decelerate around the desired space gap most of the time. To explain these phenomena, we propose that, in congested traffic flow, the space gap between two vehicles will oscillate around the desired space gap in the deterministic limit. This assumption is formulated in terms of a cellular automaton. In contrast to FDA and KTPT, the new model does not have any congested steady-state solution. Simulations under periodic and open boundary conditions reproduce the empirical findings of KTPT. Calibrating and validating the model to detector data produces results that are better than that of previous studies.

The load-dependent vehicle routing problem and its pick-up and delivery extension

- Transportation Research Part B: Methodological---2015---Emmanouil E. Zachariadis,Christos D. Tarantilis,Chris T. Kiranoudis

The present paper examines a Vehicle Routing Problem (VRP) of major practical importance which is referred to as the Load-Dependent VRP (LDVRP). LDVRP is applicable for transportation activities where the weight of the transported cargo accounts for a significant part of the vehicle gross weight. Contrary to the basic VRP which calls for the minimization of the distance travelled, the LDVRP objective is aimed at minimizing the total product of the distance travelled and the gross weight carried along this distance. Thus, it is capable of producing sensible routing plans which take into account the variation of the cargo weight along the vehicle trips. The LDVRP objective is closely related to the total energy requirements of the vehicle fleet, making it a credible alternative when the environmental aspects of transportation activities are examined and optimized. A novel LDVRP extension which considers simultaneous pick-up and delivery service is introduced, formulated and solved for the first time. To deal with large-scale instances of the examined problems, we propose a local-search algorithm. Towards an efficient implementation, the local-search algorithm employs a computational scheme which calculates the complex weighted-distance objective changes in constant time. Solution results are presented for both problems on a variety of well-known test cases demonstrating the effectiveness of the proposed solution approach. The structure of the obtained LDVRP and VRP solutions is compared in pursuit of interesting conclusions on the relative suitability of the two routing models, when the decision maker must deal with the weighted distance objective. In addition, results of a branch-and-cut procedure for small-scale instances of the LDVRP with simultaneous pick-ups and deliveries are reported. Finally, extensive computational experiments have been performed to explore the managerial implications of three key problem characteristics, namely the deviation of customer demands, the cargo to tare weight ratio, as well as the size of the available vehicle fleet.

The kinematic wave model with finite decelerations: A social force car-following model approximation

- Transportation Research Part B: Methodological---2015---Rafael Delpiano,Jorge Laval,Juan Enrique Coeymans,Juan Carlos Herrera

This paper derives a five-parameter social force car-following model that converges to the kinematic wave model with triangular fundamental diagram. Analytical solutions for vehicle trajectories are found for the lead-vehicle problem, which exhibit clockwise and counter-clockwise hysteresis depending on the model' s parameters and the lead vehicle trajectory. When coupled with a stochastic vehicle dynamics module, the model is able to reproduce periods and amplitudes of stop-and-go waves, as reported in the field. The model' s stability conditions are analysed and its trajectories are compared to real data.

Bidirectional pedestrian fundamental diagram

- Transportation Research Part B: Methodological---2015---Gunnar Flötteröd,Gregor Lämmel

This article presents a new model of stationary bidirectional pedestrian flow. Starting out from microscopic first principles, a bidirectional fundamental diagram (FD) is derived that defines direction-specific flow rates as functions of direction-specific densities. The FD yields non-negative and bounded flows and guarantees that the instantaneous density changes that would result from these flows stay bounded between zero and jam density. In its minimal configuration, it uses just as many parameters as a unidirectional triangular FD: maximum walking speed, jam density, a collision avoidance parameter (from which the backward wave speed can be derived). A one-on-one mapping between the parameters guiding uni- and bidirectional pedestrian flows is proposed and both conceptually and empirically justified. Generalizations of the FD that maintain its desirable properties turn out to be straightforward by making its parameters density-dependent. The FD performs very well in comparisons against simulated and real data.

Entropy weighted average method for the determination of a single representative path flow solution for the static user equilibrium traffic assignment problem

- Transportation Research Part B: Methodological---2015---Amit Kumar,Srinivas Peeta

The formulation of the static user equilibrium traffic assignment problem (UETAP) under some simplifying assumptions has a unique solution in terms of link flows but not in terms of path flows. Large variations are possible in the path flows obtained using different UETAP solution algorithms. Many transportation planning and management applications entail the need for path flows. This raises the issue of generating a meaningful path flow solution in practice. Past studies have sought to determine a single path flow solution using the maximum entropy concept. This study proposes an alternate approach to determine a single path flow solution that represents the entropy weighted average of the UETAP path flow solution space. It has the minimum expected Euclidean distance from all other path flow solution vectors of the UETAP. The mathematical model of the proposed entropy weighted average method is derived and its solution stability is proved. The model is easy to interpret and generalizes the proportionality condition of Bar-Gera and Boyce (1999). Results of numerical experiments using networks of different sizes suggest that the path flow solutions for the UETAP using the proposed method are about identical to those obtained using the maximum entropy approach. The entropy weighted average method requires low computational effort and is easier to implement, and can therefore serve as a potential alternative to the maximum entropy approach in practice.

A 3-step math heuristic for the static repositioning problem in bike-sharing systems

- Transportation Research Part B: Methodological---2015---Iris A. Forma,Tal Raviv,Michal Tzur

Over the last few years, bike-sharing systems have emerged as a new mode of transportation in a large number of big cities worldwide. This new type of mobility mode is still developing, and many challenges associated with its operation are not well addressed yet. One such major challenge of bike-sharing systems is the need to respond to fluctuating demands for bicycles and for vacant lockers at each station, which directly influences the service level provided to its users. This is done using dedicated repositioning vehicles (light trucks) that are routed through the stations, loading and unloading bicycles to/from them. Performing this operation during the night when the demand in the system is negligible is referred to as the static repositioning problem. In this paper, we propose a 3-step mathematical programming based heuristic for the static repositioning problem. In the first step, stations are clustered according to geographic as well as inventory (of bicycles) considerations. In the second step the repositioning vehicles are routed through the clusters while tentative inventory decisions are made for each individual station. Finally, the original repositioning problem is solved with the restriction that traversal of the repositioning vehicles is allowed only between stations that belong to consecutive clusters according to the routes determined in the previous step, or between stations of the same cluster. In the first step the clusters are formed using a specialized saving heuristic. The last two steps are formulated as Mixed Integer Linear Programs and solved by a commercial solver. The method was tested on instances of up to 200 stations and three repositioning vehicles, and was shown to outperform a previous method suggested in the literature for the same problem.

Link-based day-to-day network traffic dynamics and equilibria

- Transportation Research Part B: Methodological---2015---Ren-Yong Guo,Hai Yang,Hai-Jun Huang,Zhijia Tan

A general dynamical system model with link-based variables is formulated to characterize the processes of achieving equilibria from a non-equilibrium state in traffic networks. Several desirable properties of the dynamical system model are established, including the equivalence between its stationary state and user equilibrium, the invariance of its evolutionary trajectories, and the uniqueness and stability of its stationary points. Moreover, it is shown that not only a link-based version of two existing day-to-day traffic dynamics models but also two existing link-based dynamical system models of traffic flow are the special cases of the proposed model. The stabilities of stationary states of these special cases are also analyzed and discussed. In addition, an extension is made to the case with elastic demand. The study is helpful for better understanding the day-to-day adjustment mechanism of traffic flows in networks.

Fare evasion in proof-of-payment transit systems: Deriving the optimum inspection level

- Transportation Research Part B: Methodological---2014---Benedetto Barabino,Sara Salis,Bruno Useli

In proof-of-payment systems, fare evasion represents a crucial topic for public transport companies (PTCs) due to lost fare revenues, damaged corporate image, and increased levels of violence on public transport, which might also have negative economic repercussions on PTCs. Therefore, there is a need to establish the level of inspection (i.e. the number of inspectors) to tackle fare dodgers as a possible option. By building on previous models, this paper develops a formal economic framework to derive the optimum inspection level in a long time window, based on system-wide profit maximization when fare evasion exists. The framework takes into account: (i) the refined segmentation of passengers and potential fare evaders, (ii) the variability of perceived inspection level by passengers, and (iii) the fact that an inspector cannot fine every passenger caught evading. Its implementation is illustrated by using three years of real data from an Italian PTC. Based on 27,514 stop-level inspections and 10,586 on-board personal interviews, the results show that the optimum inspection level is 3.8%. Put differently, it is sufficient to check 38 passengers out of every 1000 to maximize profit in the presence of fare evasion. This outcome is very useful, because it improves the one obtained in previous formulations. Indeed, profit maximization is achieved with a lower number of inspectors, thus reducing inspection costs, which are relevant determinants in proficient PTCs. Finally, the framework is flexible and may be applied to public transport modes other than buses as long as proof-of-payment systems are in use.

Understanding relative efficiency among airports: A general dynamic model for distinguishing technical and allocative efficiency

- Transportation Research Part B: Methodological---2014---A. George Assaf,David Gillen,Mike Tsionas

The paper introduces a new dynamic frontier model that is used to analyze the impact of both ownership and regulation on airport technical and allocative efficiencies. We differentiate between the short and long-term effects. Based on a large sample of international airports, we find in the short-run the majority of the improvements are from reducing technical inefficiency, which come for the most part from adjusting output, something that can be accomplished in the short-term. There are relatively small changes, in the short run, resulting from improving allocative efficiency. We find that adding economic regulation leads to a decrease in technical efficiency in the short-run. Quite different conclusions hold for the long-term; there are improvements available from reducing allocative inefficiency and comparable benefits are available from cutting technical inefficiency. In the long-run we find that technical and allocative inefficiency decreases by moving away from government owned to fully privatized airports and moving away from rigid regulation.

An integrated approach for timetabling and vehicle scheduling problems to analyze the trade-off between level of service and operating costs of transit networks

- Transportation Research Part B: Methodological---2014---Omar J. Ibarra-Rojas,Ricardo Giesen,Yasmin A. Rios-Solis

In transit systems there is a critical trade-off between the level of service and operating costs. At the planning level, for a given network design, this trade-off is captured by the timetabling (TT) and vehicle scheduling (VS) problems. In the TT problem we try to maximize the number of passengers benefited by well timed transfers, while in the VS problem we seek to minimize the operating costs, which are related to the fleet size. This paper presents two integer linear programming models for the TT and VS problems, and combines them in a bi-objective integrated model. We propose and implement an -constraint method to jointly solve this TT and VS bi-objective problem. This allows to analyze the trade-off between these two criteria in terms of Pareto fronts. Numerical experiments show that our proposed approach can solve scenarios with up to 50 bus lines.

Travel time resilience of roadway networks under disaster

- Transportation Research Part B: Methodological---2014---Reza Faturechi,Elise Miller-Hooks

A bi-level, three-stage Stochastic Mathematical Program with Equilibrium Constraints (SMPEC) is proposed for quantifying and optimizing travel time resilience in roadway networks under non-recurring natural or human-induced disaster events. At the upper-level, a sequence of optimal preparedness and response decisions is taken over pre-event mitigation and preparedness and post-event response stages of the disaster management life cycle. Assuming semi-adaptive user behavior exists shortly after the disaster and after the implementation of immediate response actions, the lower-level problem is formulated as a Partial User Equilibrium, where only affected users are likely to rethink their routing decisions. An exact Progressive Hedging Algorithm is presented for solution of a single-level equivalent, linear approximation of the SMPEC. A recently proposed technique from the literature that uses Schur’s decomposition with SOS1 variables in creating a linear equivalent to complementarity constraints is employed. Similarly, recent advances in piecewise linearization are exploited in addressing non-separable link travel time functions. The formulation and solution methodology are demonstrated on an illustrative example.

Assessing partial observability in network sensor location problems

- Transportation Research Part B: Methodological--2014---Francesco Viti,Marco Rinaldi,Francesco Corman,Chris M.J. Tampère

The quality of information on a network is crucial for different transportation planning and management applications. Problems focusing on where to strategically extract this information can be broadly subdivided into observability problems, which rely on the topological properties of the network, and flow-estimation problems, where (prior) information on observed flows is needed to identify optimal sensor locations.

Price of anarchy for non-atomic congestion games with stochastic demands

- Transportation Research Part B: Methodological--2014---Chenlan Wang,Xuan Vinh Doan,Bo Chen

We generalize the notions of user equilibrium, system optimum and price of anarchy to non-atomic congestion games with stochastic demands. In this generalized model, we extend the two bounding methods from Roughgarden and Tardos (2004) and Correa et al. (2008) to bound the price of anarchy, and compare the upper bounds we have obtained. Our results show that the price of anarchy depends not only on the class of cost functions but also demand distributions and, to some extent, the network topology. The upper bounds are tight in some special cases, including the case of deterministic demands.

A variational formulation for higher order macroscopic traffic flow models: Numerical investigation

- Transportation Research Part B: Methodological--2014---Guillaume Costeseque,Jean-Patrick Lebacque

This paper deals with numerical methods providing semi-analytic solutions to a wide class of macroscopic traffic flow models for piecewise affine initial and boundary conditions. In a very recent paper, a variational principle has been proved for models of the Generic Second Order Modeling (GSOM) family, yielding an adequate framework for effective numerical methods. Any model of the GSOM family can be recast into its Lagrangian form as a Hamilton–Jacobi equation (HJ) for which the solution is interpreted as the position of vehicles. This solution can be computed thanks to Lax–Hopf like formulas and a generalization of the inf-morphism property. The efficiency of this computational method is illustrated through a numerical example and finally a discussion about future developments is provided.

Single-line rail rapid transit timetabling under dynamic passenger demand

- Transportation Research Part B: Methodological--2014---Eva Barrena,David Canca,Leandro C. Coelho,Gilbert Laporte

Railway planning is a complex activity which is usually decomposed into several stages, traditionally network design, line design, timetabling, rolling stock, and staffing. In this paper, we study the design and optimization of train timetables for a rail rapid transit (RRT) line adapted to a dynamic demand environment, which focuses on creating convenient timetables for passengers. The objective is to minimize the average passenger waiting time at the stations, thus focusing on passenger welfare. We first propose two mathematical programming formulations which generalize the non-periodic train timetabling problem on a single line under a dynamic demand pattern. We then analyze the properties of the problem before introducing a fast adaptive large neighborhood search (ALNS) metaheuristic in order to solve large instances of the problem within short computation times. The algorithm yields timetables that may not be regular or periodic, but are adjusted to a dynamic demand behavior. Through extensive computational experiments on artificial and real-world based instances, we demonstrate the computational superiority of our ALNS compared with a truncated branch-and-cut algorithm. The average reduction in passenger waiting times is 26%, while the computational time of our metaheuristic is less than 1% of that required by the alternative CPLEX-based algorithm. Out of 120 open instances, we obtain 84 new best known solutions and we reach the optimum on 10 out of 14 instances with known optimal solutions.

A simple procedure for the calculation of the covariances of any Generalized Extreme Value model

- Transportation Research Part B: Methodological---2014---Vittorio Marzano

This paper illustrates a simple procedure for calculating the covariances underlying any Generalized Extreme Value (GEV) model, based on an appropriate generalization of a result already established in the literature for the Cross-Nested Logit model (i.e. a particular GEV model). Specifically, the paper proves that the covariances in any GEV model are always expressed by a one-dimensional integral, whose integrand function is available in closed form as a function of the generating function of the GEV model. This integral may be simulated very easily with a parsimonious computational burden. Two practical examples are also presented. The first is an application to the CNL model, so as to check the consistency of the proposed method with the results already established in the literature. The second deals with the calculation of the covariances of the Network GEV (NGEV) model: notably, the NGEV is the most general type of GEV model available so far, and its covariances have not yet been calculated. On this basis, insights on the domain of the covariances reproduced by the NGEV model are also presented.

Benders Decomposition for Discrete–Continuous Linear Bilevel Problems with application to traffic network design

- Transportation Research Part B: Methodological---2014---Pirmin Fontaine,Stefan Minner

We propose a new fast solution method for linear Bilevel Problems with binary leader and continuous follower variables under the partial cooperation assumption. We reformulate the Bilevel Problem into a single-level problem by using the Karush–Kuhn–Tucker conditions. This non-linear model can be linearized because of the special structure achieved by the binary leader decision variables and subsequently solved by a Benders Decomposition Algorithm to global optimality. We illustrate the capability of the approach on the Discrete Network Design Problem which adds arcs to an existing road network at the leader stage and anticipates the traffic equilibrium for the follower stage. Because of the non-linear objective functions of this problem, we use a linearization method for increasing, convex and non-linear functions based on continuous variables. Numerical tests show that this algorithm can solve even large instances of Bilevel Problems.

On uniqueness and proportionality in multi-class equilibrium assignment

- Transportation Research Part B: Methodological---2014---Michael Florian,Calin D. Morosan

Over the past few years, much attention has been paid to computing flows for multi-class network equilibrium models that exhibit uniqueness of the class flows and proportionality (Bar-Gera et al., 2012). Several new algorithms have been developed such as bush based methods of Bar-Gera (2002), Dial (2006), and Gentile (2012) that are able to obtain very fine solutions of network equilibrium models. These solutions can be post processed (Bar-Gera, 2006) in order to ensure proportionality and class uniqueness of the flows. Recently developed, the TAPAS, algorithm (Bar Gera, 2010) is able to produce solutions that have proportionality embedded, without requiring post processing. It was generally accepted that these methods for solving UE traffic assignment are the only way to obtain unique path and class link flows. The purpose of this paper is to show that the linear approximation method and some of its variants satisfy these conditions as well. In addition, some analytical results regarding the relation between steps of the linear approximation algorithm and the path flows entropy are presented.

Approximating dynamic equilibrium conditions with macroscopic fundamental diagrams

- Transportation Research Part B: Methodological---2014---Mehmet Yildirimoglu,Nikolas Geroliminis

Real-time coordinated traffic management strategies that benefit from parsimonious models with aggregated network dynamics, provide a new generation of smart hierarchical strategies to improve network capacity and performance. However, this raises the question of route choice behavior in case of heterogeneous urban networks, where different parts of the city are subject to different types of control. Traffic equilibrium phenomena have not been thoroughly investigated in these models. Approximate traffic equilibrium conditions can be integrated within the parsimonious traffic models to develop regional routing strategies, while detailed route choice strategies can be incorporated at a later stage in a hierarchical framework. In this study, we develop an aggregated and approximate dynamic traffic assignment (DTA) procedure to be incorporated in the macroscopic fundamental diagram (MFD) dynamics, and establish dynamic stochastic user equilibrium (DSUE) conditions. The methodology consists of two main components; stochastic network loading and a fixed-point solution method. Loading procedure is designed to handle stochastic components in the model such as trip length uncertainty, variation of speeds across the links, perception error of travelers. The results taken from this procedure are averaged through the well-known method of successive averages (MSA) to reach fixed-point solution for the system. Real-time route guidance strategies can be revisited towards a “system of systems” approach.

Game-theoretical models for competition analysis in a new emerging liner container shipping market

- Transportation Research Part B: Methodological---2014---Hua Wang,Qiang Meng,Xiaoning Zhang

This paper develops three game-theoretical models to analyze shipping competition between two carriers in a new emerging liner container shipping market. The behavior of each carrier is characterized by an optimization model with the objective to maximize his payoff by setting optimal freight rate and shipping deployment (a combination of service frequency and ship capacity setting). The market share for each carrier is determined by the Logit-based discrete choice model. Three competitive game strategic interactions are further investigated, namely, Nash game, Stackelberg game and deterrence by taking account of the economies of scale of the ship capacity settings. Three corresponding competition models with discrete pure strategy are formulated as the variables in shipment deployment are indivisible and the pricing adjustment is step-wise in practice. A -approximate equilibrium and related numerical solution algorithm are proposed to analyze the effect of Nash equilibrium. Finally, the developed models are numerically evaluated by a case study. The case study shows that, with increasing container demand in the market, expanding ship capacity setting is preferable due to its low marginal cost. Furthermore, Stackelberg equilibrium is a prevailing strategy in most market situations since it makes players attain more benefits from the accommodating market. Moreover, the deterrence effects largely depend on the deterrence objective. An aggressive deterrence strategy may make potential monopolist suffer large benefit loss and an easing strategy has little deterrence effect.

A parsimonious model for the formation of oscillations in car-following models

- Transportation Research Part B: Methodological---2014---Jorge A. Laval,Christopher S. Toth,Yi Zhou

This paper shows that the formation and propagation of traffic oscillations in the absence of lane changes can be explained by the stochastic nature of drivers’ acceleration processes. By adding a white noise to drivers’ desired acceleration in free-flow, oscillations are produced that accord well with observation. This theory suggests that driver error is a function of roadway geometry, that it determines the average speed at the bottleneck, as well as oscillation period and amplitude. The model has been implemented with a single additional parameter compared to the kinematic wave model with bounded accelerations.

The fleet size and mix pollution-routing problem

- Transportation Research Part B: Methodological---2014---Çağrı Koç,Tolga Bektaş,Ola Jabali,Gilbert Laporte

This paper introduces the fleet size and mix pollution-routing problem which extends the pollution-routing problem by considering a heterogeneous vehicle fleet. The main objective is to minimize the sum of vehicle fixed costs and routing cost, where the latter can be defined with respect to the cost of fuel and CO2 emissions, and driver cost. Solving this problem poses several methodological challenges. To this end, we have developed a powerful metaheuristic which was successfully applied to a large pool of realistic benchmark instances. Several analyses were conducted to shed light on the trade-offs between various performance indicators, including capacity utilization, fuel and emissions and costs pertaining to vehicle acquisition, fuel consumption and drivers. The analyses also quantify the benefits of using a heterogeneous fleet over a homogeneous one.

On the impacts of locally adaptive signal control on urban network stability and the Macroscopic Fundamental Diagram

- Transportation Research Part B: Methodological---2014---Vikash V. Gayah,Gao, Xueyu (Shirley),Andrew S. Nagle

Urban traffic networks are inherently unstable when congested. This instability causes a natural tendency towards spatially inhomogeneous vehicle distributions and less consistent and reproducible relationships between urban traffic variables. It is important to find ways to mitigate this unstable behavior since well-defined relationships between average network flow and density – the MFD – are useful to aid network design and control.

Energy minimization in dynamic train scheduling and control for metro rail operations

- Transportation Research Part B: Methodological---2014---Xiang Li,Hong K. Lo

Since the passenger demands change frequently in daily metro rail operations, the headway, cycle time, timetable and speed profile for trains should be adjusted correspondingly to satisfy the passenger demands while minimizing energy consumption. In order to solve this problem, we propose a dynamic train scheduling and control framework. First, we forecast the passenger demand, and determine the headway and cycle time for the next cycle. Then we optimize the reference timetable and speed profile for trains at the next cycle subject to the headway and cycle time constraints. Finally, the automatic train control system is used to operate trains with real-life conditions based on the reference timetable and speed profile. In this paper, we focus on the optimization of the timetable and speed profile. Generally speaking, the former distributes the cycle time to different stations and inter-stations under the headway constraint, and the latter controls the trains’ speeds at inter-stations to reduce the consumption on tractive energy and increase the storage on regenerative energy. In order to achieve a global optimality on energy saving, we formulate an integrated energy-efficient timetable and speed profile optimization model, which is transformed to a convex optimization problem by using the linear approximation method. We use the Kuhn–Tucker conditions to solve the optimal solution and present some numerical experiments based on the actual operation data of Beijing Metro Yizhuang Line of China, which shows that the integrated approach can reduce the net energy consumption around 11% than the practical timetable. Furthermore, with given passenger demand sequence at off-peak hours, the dynamic scheduling and integrated optimization approach with adaptive cycle time can reduce the net energy consumption around 7% than the static scheduling and integrated optimization approach with fixed cycle time.

Online routing and battery reservations for electric vehicles with swappable batteries

- Transportation Research Part B: Methodological---2014---Jonathan D. Adler,Pitu B. Mirchandani

Electric vehicles are becoming a more popular form of transportation, however their limited range has proven problematic. Battery-exchange stations allow the vehicles to swap batteries during their trip, but if a vehicle arrives at a station without a full battery available it may have to wait an extended period of time to get one. The vehicles can be routed so that they avoid stations without available batteries or to keep batteries available for other vehicles that need them in the future. The batteries can also be reserved during the routing process so that each vehicle is ensured the battery it plans to use is available. This paper provides a method of online routing of electric vehicles and making battery reservations that minimizes the average delay of the all vehicles by occasionally detouring them to the benefit of future ones. The system is modeled as a Markov chance-decision process and the optimal policy is approximated using the approximate dynamic programming technique of temporal differencing with linear models. The solution algorithm provides a quick way for vehicles to be routed using onboard vehicle software connected to a central computer. Computational results for the algorithm are provided using data on the Arizona highway network.

The shared-taxi problem: Formulation and solution methods

- Transportation Research Part B: Methodological---2014---Hadi Hosni,Joe Naoum-Sawaya,Hassan Artail

With the rising fuel costs, ride sharing is becoming a common mode of transportation. Sharing taxis which has been prominent in several developing countries is also becoming common in several cities around the world. Sharing taxis presents several advantages as it minimizes vacant seats in cars thus reducing costs on taxi operators which results in significantly lower taxi fares for passengers. Besides the economical advantages, taxi sharing is highly important for reducing congestion on the roads and for minimizing the impact of transportation on the environment. In this paper, we formulate the problem of assigning passengers to taxis and computing the optimal routes of taxis as a mixed integer program. To solve the proposed model, we present a Lagrangian decomposition approach which exploits the structure of the problem leading to smaller problems that are solved separately. Furthermore, we propose two heuristics that are used to obtain good quality feasible solutions. The Lagrangian approach along with the heuristics are implemented and compared to solving the full problem using CPLEX. The computational results indicate the efficiency of the methodology in providing tighter bounds than CPLEX in shorter computational time.

Stop-and-go traffic analysis: Theoretical properties, environmental impacts and oscillation mitigation

- Transportation Research Part B: Methodological---2014---Xiaopeng Li,Jianxun Cui,Shi An,Mohsen Parsafard

This study aims (i) to analyze theoretical properties of a recently proposed describing-function (DF) based approach (Li and Ouyang, 2011; Li et al., 2012) for traffic oscillation quantification, (ii) to adapt it for estimating fuel consumption and emission from traffic oscillation and (iii) to explore vehicle control strategies of smoothing traffic with advanced technologies. The DF approach was developed to predict traffic oscillation propagation across a platoon of vehicles following each other by a nonlinear car-following law with only the leading vehicle’s input. We first simplify the DF approach and prove a set of properties (e.g., existence and uniqueness of its solution) that assure its prediction is always consistent with observed traffic oscillation patterns. Then we integrate the DF approach with existing estimation models of fuel consumption and emission to analytically predict environmental impacts (i.e., unit-distance fuel consumption and emission) from traffic oscillation. The prediction results by the DF approach are validated with both computer simulation and field measurements. Further, we explore how to utilize advantageous features of emerging sensing, communication and control technologies, such as fast response and information sharing, to smooth traffic oscillation and reduce its environmental impacts. We extend the studied car-following law to incorporate these features and apply the DF approach to demonstrate how these features can help dampen the growth of oscillation and environmental impact measurements. For information sharing, we convert the corresponding extended car-following law into a new fixed point problem and propose a simple bisecting based algorithm to efficiently solve it. Numerical experiments show that these new car-following control strategies can effectively suppress development of oscillation amplitude and consequently mitigate fuel consumption and emission.

Variable speed limit control for steady and oscillatory queues at fixed freeway bottlenecks

- Transportation Research Part B: Methodological---2014---Danjue Chen,Soyoung Ahn,Andreas Hegyi

New variable speed limit (VSL) schemes are developed based on the Kinematic Wave theory to increase freeway bottleneck discharge rates under two scenarios: (i) steady queue and (ii) oscillatory queue. The key principle is to impose VSL control some distance upstream of a bottleneck to starve the inflow to the bottleneck and dissipate the queue. Once the queue near the bottleneck vanishes, another less restrictive VSL is imposed upstream to (i) resolve the heavy queue generated by the first VSL and (ii) regulate the inflow to the bottleneck to sustain the stable maximum bottleneck discharge rate and prevent traffic breakdown. Several strategies are developed for each scenario ranging from the simplest strategy that maximizes the delay saving to more sophisticated strategies for upstream queue management. An analysis of the model parameters suggests that a wide range of the first speed limit (to clear the queue around the bottleneck) can be imposed to realize significant delay savings.

A three level location-inventory problem with correlated demand

- Transportation Research Part B: Methodological---2014---Mehrdad Shahabi,Avinash Unnikrishnan,Ehsan Jafari-Shirazi,Stephen D. Boyles

This paper considers a three level location-inventory problem where demand across the retailers is assumed to be correlated. We first present a reformulation scheme by which the initial formulation is transformed into a mixed integer conic quadratic program. In addition, we propose a solution approach based on an outer approximation strategy and show the algorithmic advantage of such framework for this class of programs. The results from numerical experiments show that the proposed solution procedure clearly outperforms state-of-the-art commercial solvers. In addition, we show that neglecting the effect of correlation can lead to substantially sub-optimal solutions.

Real time traffic states estimation on arterials based on trajectory data

- Transportation Research Part B: Methodological---2014---Gabriel Hiribarren,Juan Carlos Herrera

New technologies able to register vehicle trajectories, such as GPS (Global Position Systems)-enabled cell phones, have opened a new way of collecting traffic data. However, good methods that convert these data into useful information are needed to leverage these data. In this study a new method to estimate traffic states on arterials based on trajectory data is presented and assessed. The method is based on the Lighthill–Whitham–Richards (LWR) theory. By using this theory, traffic dynamics on arterials can be better captured by extracting more information from the same piece of data. Trajectory data used consist of the trajectory of the latest equipped vehicle that crossed the segment under study. Preliminary analysis based on micro-simulation suggests that this method yields good traffic state estimates both at congested and uncongested situations, even for very low penetration rates (1%). The method is also able to forecast queue length at intersections and travel times along a road section.

An analysis of logit and weibit route choices in stochastic assignment paradox

- Transportation Research Part B: Methodological---2014---Jia Yao,Anthony Chen

Paradox in the transportation literature is about improving an existing link or adding a new link can actually increase network-wide travel costs or travel costs of each traveler. In this paper, we investigate the stochastic assignment paradox using the multinomial weibit (MNW) model, a new route choice model developed by Castillo et al. (2008), and compare it to the counter-intuitive results of the multinomial logit (MNL) model when an inferior travel alternative is marginally improved. Using a simple two-link network, we derive the conditions for paradoxical phenomenon to occur for both route choice models, and graphically compare and contrast the paradoxical regions. The results show the stochastic assignment paradox depends on how the cost difference is being considered in the route choice model (i.e., absolute cost difference in the MNL model and relative cost difference in the MNW model) to some extent. Hence, the stochastic paradox analysis is extended to a hybrid model that considers both MNW and MNL models (i.e., both relative cost difference and absolute cost difference). The paradox area of the hybrid model is shown to be a combination of the paradox areas of the two models. In addition, the stochastic assignment paradox conditions derived for a simple two-link network are generalized to three cases: (a) one O–D pair with multiple links on a route, (b) multiple O–D pairs, and (c) adding a new link. Analytical solutions, graphical illustrations, and numerical results are provided to demonstrate the stochastic paradox under different conditions. Future research directions are also discussed in the paper.

Singularities in kinematic wave theory: Solution properties, extended methods and duality revisited

- Transportation Research Part B: Methodological---2014---Carlos F. Daganzo

According to Euler–Lagrange duality principle of kinematic wave (KW) theory any well-posed initial value traffic flow problem can be solved with the same methods either on the time–space (Euler) plane or the time vs vehicle number (Lagrange) plane. To achieve this symmetry the model parameters and the boundary data need to be expressed in a form appropriate for each plane. It turns out, however, that when boundary data that are bounded in one plane are transformed for the other, singular points with infinite density sometimes arise. Duality theory indicates that solutions to these problems must exist and be unique. Therefore, these solutions should be characterized.

A macroscopic loading model for time-varying pedestrian flows in public walking areas

- Transportation Research Part B: Methodological---2014---Flurin S. Hänseler,Michel Bierlaire,Bilal Farooq,Thomas Mühlematter

A macroscopic loading model applicable to time-dependent and congested pedestrian flows in public walking areas is proposed. Building on the continuum theory of pedestrian flows and the cell transmission model for car traffic, an isotropic framework is developed that can describe the simultaneous and potentially conflicting propagation of multiple pedestrian groups. The model is formulated at the aggregate level and thus computationally cheap, which is advantageous for studying large-scale problems. A detailed analysis of several basic flow patterns including counter- and cross flows, as well as two generic scenarios involving a corner- and a bottleneck flow is carried out. Various behavioral patterns ranging from disciplined queueing to impatient jostling can be realistically reproduced. Following a systematic model calibration, two case studies involving a Swiss railway station and a Dutch bottleneck flow experiment are presented. A comparison with the social force model and pedestrian tracking data shows a good performance of the proposed model with respect to predictions of travel time and density.

Optimal joint distance and time toll for cordon-based congestion pricing

- Transportation Research Part B: Methodological---2014---Zhiyuan Liu,Shuaian Wang,Qiang Meng

This paper addresses the optimal toll design problem for the cordon-based congestion pricing scheme, where both a time-toll and a nonlinear distance-toll (i.e., joint distance and time toll) are levied for each network user's trip in a pricing cordon. The users' route choice behaviour is assumed to follow the Logit-based stochastic user equilibrium (SUE). We first propose a link-based convex programming model for the Logit-based SUE problem with a joint distance and time toll pattern. A mathematical program with equilibrium constraints (MPEC) is developed to formulate the optimal joint distance and time toll design problem. The developed MPEC model is equivalently transformed into a semi-infinite programming (SIP) model. A global optimization method named Incremental Constraint Method (ICM) is designed for solving the SIP model. Finally, two numerical examples are used to assess the proposed methodology.

Block time reliability and scheduled block time setting

- Transportation Research Part B: Methodological---2014---Lu Hao,Mark Hansen

While in ground transportation the concept of reliability has been extensively studied, there is little literature in air transportation. Scheduled block time (SBT) setting is a crucial part in airlines' scheduling. Interviews with an airline and relevant work in ground transportation have shown that SBT and the historical block time distribution, reflecting block time reliability, have a close relationship. This paper investigates how the change in actual block time distribution will affect SBT and system performance. Firstly this relationship is studied with empirical data and multiple regression models. The distribution of the historical block time for a flight is depicted by the difference between every 10th percentiles. We found that gate delay plays a minor role in setting SBT and that SBTs have decreasing sensitivity to historical flight times toward the right tail of the distribution. To specifically link SBT setting with the flight's on-time performance, a SBT adjustment model is further developed. Poor on-time performance leads to increased SBT in the next year. With the behavior model results showing that both the median block time and the "inner right tail" of the distribution affect SBT setting, an impact study is conducted to validate these impacts with historical data. The impact of historical block time distribution on SBT is validated with real data in year 2006–2008 and 2009–2011. Furthermore, by studying the flight performance difference based on different changes in SBT, we conclude that ignoring the impact on SBT changes when considering potential benefits of improved block time distribution could lead to inaccurate results.

Post-disaster evacuation and temporary resettlement considering panic and panic spread

- Transportation Research Part B: Methodological---2014---Zhi-Hua Hu,Jiuh-Biing Sheu,Ling Xiao

After a disaster, a huge number of homeless victims should be evacuated to temporary resettlement sites. However, because the number of temporary shelters is insufficient, as are shelter building capabilities, victims must be evacuated and resettled in batches. The perceived psychological penalty to victims may increase due to heightened panic when waiting for evacuation and resettlement, whereas psychological interventions can decrease the magnitude of this panic. Based on the susceptible–infective-removal model, panic spread among homeless victims and other disaster-affected people is modeled, while considering the effects of psychological interventions on panic spread. A function is derived to compute the increase in the number of victims to be evacuated due to panic spread. A novel mixed-integer linear program is constructed for multistep evacuation and temporary resettlement under minimization of panic-induced psychological penalty cost, psychological intervention cost, and costs associated with transportation and building shelters. The model is solved by aggregating objectives into a single objective by assigning weights to these objectives. With Wenchuan County as the test case, the epicenter of the 2008 Sichuan earthquake, the influence and the sensitivity of parameters, tradeoff among costs, and the effects of various functions of panic strength on psychological penalty and monetary costs are assessed using six experimental scenarios. Analytical results reveal the complexity and managerial insights gained by applying the proposed method to post-disaster evacuation and temporary resettlement.

Adding a new station and a road link to a road–rail network in the presence of modal competition

- Transportation Research Part B: Methodological---2014---Federico Perea,Juan A. Mesa,Gilbert Laporte

In this paper we study the problem of locating a new station on an existing rail corridor and a new junction on an existing road network, and connecting them with a new road segment under a budget constraint. We consider three objective functions and the corresponding optimization problems, which are modeled by means of mixed integer non-linear programs. For small instances, the models can be solved directly by a standard solver. For large instances, an enumerative algorithm based on a discretization of the problem is proposed. Computational experiments show that the latter approach yields high quality solutions within short computing times.

Cost scaling based successive approximation algorithm for the traffic assignment problem

- Transportation Research Part B: Methodological---2014---Hong Zheng,Srinivas Peeta

This paper presents a cost scaling based successive approximation algorithm, called ε-BA (ε-optimal bush algorithm), to solve the user equilibrium traffic assignment problem by successively refining ε-optimal flows. As ε reduces to zero, the user equilibrium solution is reached. The proposed method is a variant of bush-based algorithms, and also a variant of the min-mean cycle algorithm to solve the min-cost flow by successive approximation. In ε-BA, the restricted master problem, implying traffic equilibration restricted on a bush, is solved to ε-optimality by cost scaling before bush reconstruction. We show that ε-BA can reduce the number of flow operations substantially in contrast to Dial’s Algorithm B, as the former operates flows on a set of deliberately selected cycles whose mean values are sufficiently small. Further, the bushes can be constructed effectively even if the restricted master problem is not solved to a high level of convergence, by leveraging the ε-optimality condition. As a result, the algorithm can solve a highly precise solution with faster convergence on large-scale networks compared to our implementation of Dial’s Algorithm B.

A joint count-continuous model of travel behavior with selection based on a multinomial probit residential density choice model

- Transportation Research Part B: Methodological---2014---Chandra R. Bhat,Sebastian Astroza,Raghuprasad Sidharthan,Mohammad Jobair Bin Alam,Waleed H. Khushefati

This paper formulates a multidimensional choice model system that is capable of handling multiple nominal variables, multiple count dependent variables, and multiple continuous dependent variables. The system takes the form of a treatment-outcome selection system with multiple treatments and multiple outcome variables. The Maximum Approximate Composite Marginal Likelihood (MACML) approach is proposed in estimation, and a simulation experiment is undertaken to evaluate the ability of the MACML method to recover the model parameters in such integrated systems. These experiments show that our estimation approach recovers the underlying parameters very well and is efficient from an econometric perspective. The parametric model system proposed in the paper is applied to an analysis of household-level decisions on residential location, motorized vehicle ownership, the number of daily motorized tours, the number of daily non-motorized tours, and the average distance for the motorized tours. The empirical analysis uses the NHTS 2009 data from the San Francisco Bay area. Model estimation results show that the choice dimensions considered in this paper are inter-related, both through direct observed structural relationships and through correlations across unobserved factors (error terms) affecting multiple choice dimensions. The significant presence of self-selection effects (endogeneity) suggests that modeling the various choice processes in an independent sequence of models is not reflective of the true relationships that exist across these choice dimensions, as also reinforced through the computation of treatment effects in the paper.

Estimation of mean and covariance of peak hour origin–destination demands from day-to-day traffic counts

- Transportation Research Part B: Methodological---2014---Hu Shao,William H.K. Lam,Agachai Sumalee,Anthony Chen,Martin L. Hazelton

This paper proposes a generalized model to estimate the peak hour origin–destination (OD) traffic demand variation from day-to-day hourly traffic counts throughout the whole year. Different from the conventional OD estimation methods, the proposed modeling approach aims to estimate not only the mean but also the variation (in terms of covariance matrix) of the OD demands during the same peak hour periods due to day-to-day fluctuation over the whole year. For this purpose, this paper fully considers the first- and second-order statistical properties of the day-to-day hourly traffic count data so as to capture the stochastic characteristics of the OD demands. The proposed model is formulated as a bi-level optimization problem. In the upper-level problem, a weighted least squares method is used to estimate the mean and covariance matrix of the OD demands. In the lower-level problem, a reliability-based traffic assignment model is adopted to take account of travelers' risk-taking path choice behaviors under OD demand variation. A heuristic iterative estimation-assignment algorithm is proposed for solving the bi-level optimization problem. Numerical examples are presented to illustrate the applications of the proposed model for assessment of network performance over the whole year.

Integration of conventional and flexible bus services with timed transfers

- Transportation Research Part B: Methodological---2014---Kim, Myungseob (Edward),Paul Schonfeld

Conventional bus services, which have fixed routes and fixed service schedules, and flexible bus services, which provide doorstep services, have different advantages and disadvantages, with conventional services being generally preferable at high demand densities and flexible services being preferable at low densities. By efficiently integrating conventional and flexible services and thus matching service type to various regions, the total cost of transit services may be significantly reduced, especially in regions with substantial demand variations over time and space. Additionally, transit passengers must often transfer among routes because it is prohibitively expensive to provide direct routes for among all origin–destination pairs in large networks. Coordinating vehicle arrivals at transfer terminals can greatly reduce the transfer times of passengers. In this paper, probabilistic optimization models, which are proposed to deal with stochastic variability in travel times and wait times, are formulated for integrating and coordinating bus transit services for one terminal and multiple local regions. Solutions for decision variables, which include the selected service type for particular regions, the vehicle size, the number of zones, headways, fleet, and slack times, are found here with analytic optimization or numerical methods. The proposed models generate either common headway or integer-ratio headway solutions for timed transfer coordination based on the given demand. A genetic algorithm is proposed as a solution method and tested with numerical examples.

Continuous-time dynamic system optimum for single-destination traffic networks with queue spillbacks

- Transportation Research Part B: Methodological---2014---Rui Ma,Ban, Xuegang (Jeff),Jong-Shi Pang

Dynamic system optimum (DSO) is a special case of the general dynamic traffic assignment (DTA). It predicts the optimal traffic states of a network under time-dependent traffic conditions from the perspective of the entire system. An optimal control framework is proposed in this paper for the continuous-time DSO problem for single-destination traffic networks. Departure time choice is part of this DSO model. Double-queue model is applied to capture the impact of downstream congestion and possible queue spillbacks. Feasibility conditions and model properties are discussed. A constructive procedure to compute a free-flow DSO solution is also proposed. A discretization method is described to the continuous-time systems and numerical results on two test networks are shown.

On the impacts of bus stops near signalized intersections: Models of car and bus delays

- Transportation Research Part B: Methodological---2014---Weihua Gu,Vikash V. Gayah,Michael J. Cassidy,Nathalie Saade

Models are formulated to predict the added vehicle and person delays that can occur when a bus stop is located a short distance upstream or downstream of a signalized intersection. Included in the set of models are those that predict the expected delays that cars collectively incur when a bus blocks one of multiple lanes while loading and unloading passengers at the stop. Others in this set predict the expected added delays incurred by the bus due to car queues. Each model is consistent with the kinematic wave theory of highway traffic, as is confirmed through a battery of tests. And each accounts for the randomness in both, bus arrival times at a stop, and the durations that buses dwell there to serve passengers. Though the models are analytical in form, solutions come through iteration. Hence model applications are performed with the aid of a computer.

Joint optimization of pavement design, resurfacing and maintenance strategies with history-dependent deterioration models

- Transportation Research Part B: Methodological---2014---Jinwoo Lee,Samer Madanat

The subject of this paper is the joint optimization of pavement design, maintenance and resurfacing (M&R) strategies. This problem is solved for continuous pavement state, continuous time, infinite planning horizon and non-Markovian (history-dependent) pavement deterioration model. This paper presents a mathematical formulation of the joint optimization problem to minimize the total discounted lifecycle costs, using a combination of analytical and numerical tools. The lifecycle costs include both user costs and agency (construction, resurfacing and maintenance) costs. This paper shows that resurfacing schedule converges to a steady state after a few resurfacing cycles. The research results should be of use to developing countries in the process of expanding their highway networks facing multiple constraints.

Pre-trip information and route-choice decisions with stochastic travel conditions: Experiment

- Transportation Research Part B: Methodological---2014---Amnon Rapoport,Eyran J. Gisches,Terry Daniel,Charles Lindsey

This paper studies the effects of pre-trip information on route-choice decisions when travel conditions on two alternative congestible routes vary unpredictably. It presents and discusses an experiment designed to test a model recently proposed in a companion paper by Lindsey et al. (2013). That model predicts that if free-flow costs on the two routes are unequal, travel cost functions are convex, and capacities are positively and perfectly correlated, then in equilibrium, paradoxically, total expected travel costs increase with the provision of pre-trip information about travel conditions on each route. By contrast, when capacities vary independently, total expected travel costs are predicted to decrease with pre-trip information. We reformulate the model for finite populations, and then test and find support for its predictions in an experiment where under different capacity scenarios, and with and without pre-trip information, subjects are asked to choose routes with payoff contingent on their performance.

Revisiting the empirical fundamental relationship

- Transportation Research Part B: Methodological---2014---Benjamin Coifman

This paper develops a new methodology for deriving an empirical fundamental relationship from vehicle detector data. The new methodology seeks to address several sources of noise present in conventional measures of the traffic state that arise from the data aggregation process, e.g., averaging across all vehicles over a fixed time period. In the new methodology vehicles are no longer taken successively in the order in which they arrived and there is no requirement to seek out stationary traffic conditions; rather, the traffic state is measured over the headway for each individual vehicle passage and the vehicles are grouped by similar lengths and speeds before aggregation. Care is also taken to exclude measurements that might be corrupted by detector errors. The result is a homogeneous set of vehicles and speeds in each bin. While conventional fixed time averages may have fewer than 10 vehicles in a sample, the new binning process ensures a large number of vehicles in each bin before aggregation. We calculate the median flow and median occupancy for each combined length and speed bin. Then we connect these median points across all of the speed bins for a given vehicle length to derive the empirical fundamental relationship for that length. This use of the median is also important; unlike conventional aggregation techniques that find the average, the median is far less sensitive to outliers arising from uncommon driver behavior or occasional detector errors.

Cycle-by-cycle intersection queue length distribution estimation using sample travel times

- Transportation Research Part B: Methodological---2014---Peng Hao,Ban, Xuegang (Jeff),Dong Guo,Qiang Ji

We propose Bayesian Network based methods for estimating the cycle by cycle queue length distribution of a signalized intersection. Queue length here is defined as the number of vehicles in a cycle which have experienced significant delays. The data input to the methods are sample travel times from mobile traffic sensors collected between an upstream location and a downstream location of the intersection. The proposed methods first classify traffic conditions and sample scenarios to seven cases. BN models are then developed for each case. The methods are tested using data from NGSIM, a field experiment, and microscopic traffic simulation. The results are satisfactory compared with two specific queue length estimation methods previously developed in the literature.

A probabilistic stationary speed–density relation based on Newell’s simplified car-following model

- Transportation Research Part B: Methodological---2014---Saif Eddin Jabari,Jianfeng Zheng,Henry X. Liu

Probabilistic models describing macroscopic traffic flow have proven useful both in practice and in theory. In theoretical investigations of wide-scatter in flow–density data, the statistical features of flow density relations have played a central role. In real-time estimation and traffic forecasting applications, probabilistic extensions of macroscopic relations are widely used. However, how to obtain such relations, in a manner that results in physically reasonable behavior has not been addressed. This paper presents the derivation of probabilistic macroscopic traffic flow relations from Newell’s simplified car-following model. The probabilistic nature of the model allows for investigating the impact of driver heterogeneity on macroscopic relations of traffic flow. The physical features of the model are verified analytically and shown to produce behavior which is consistent with well-established traffic flow principles. An empirical investigation is carried out using trajectory data from the New Generation SIMulation (NGSIM) program and the model's ability to reproduce real-world traffic data is validated.

A Generalized Random Regret Minimization model

- Transportation Research Part B: Methodological---2014---Caspar Chorus

This paper presents, discusses and tests a Generalized Random Regret Minimization (G-RRM) model. The G-RRM model is created by recasting a fixed constant in the attribute-specific regret functions of the conventional RRM model, into an attribute-specific regret-weight. Given that regret-weights of different attributes can take on different values, the G-RRM model allows for additional flexibility when compared to the conventional RRM model, as it allows the researcher to capture choice behavior that equals that implied by, respectively, the canonical linear-in-parameters Random Utility Maximization (RUM) model, the conventional Random Regret Minimization (RRM) model, and hybrid RUM–RRM specifications. Furthermore, for particular values of the attribute-specific regret-weights, models are obtained where regret minimization (i.e., reference dependency and asymmetry of preferences) is present for the attribute, but in a less pronounced way than in a conventional RRM model. When regret-weights are written as binary logit functions, the G-RRM model can be estimated on choice data using conventional software packages. As an empirical proof of concept, the G-RRM model is estimated on a stated route choice dataset as well as on synthetic data, and its outcomes are compared with RUM, RRM, hybrid RUM–RRM and latent class counterparts.

Non-planar hole-generated networks and link flow observability based on link counters

- Transportation Research Part B: Methodological---2014---Enrique Castillo,Aida Calviño,Hong K. Lo,José María Menéndez,Zacarías Grande

The concepts of hole, cycle added link and non-planar hole-generated network are introduced for the first time and used to determine (a) the immediate solution of the node conservation equations in terms of hole and cycle added vectors, and (b) the paths as linear combinations of hole vectors. Two equivalent formulas to obtain the number of links to be observed for complete link observability in non-planar hole-generated networks are given in terms of the numbers of links, nodes, holes, cycle added links and centroid node types. These formulas are applicable without any limitation in the number of centroids and possible link connections. Some simple methods are given to obtain first the maximum number of linearly independent (l.i.) paths and next a minimum set of links to be counted in order to get observability of all link flows. It is demonstrated that the number of l.i. paths in a non-planar hole-generated network coincides with the number of holes and cycle added links in the network and that any path can be obtained by linear combinations of the vectors associated with the hole and cycle added links. The methods are illustrated by their application to several networks.

Bottleneck model revisited: An activity-based perspective

- Transportation Research Part B: Methodological---2014---Zhi-Chun Li,William H.K. Lam,S.C. Wong

The timing of commuting trips made during morning and evening peaks has typically been investigated using Vickrey's bottleneck model. However, in the conventional trip-based approach, the decisions that commuters make during the day about their activity schedules and time use are not explicitly considered. This study extends the bottleneck model to address the scheduling problem of commuters' morning home-to-work and evening work-to-home journeys by using an activity-based approach. A day-long activity-travel scheduling model is proposed for the simultaneous determination of departure times for morning and evening commutes, together with allocations of time during the day among travel and activities undertaken at home or at the workplace. The proposed model maximizes the total net utility of the home-based tour, which is the difference between the benefits derived from participating in activities and the disutility incurred by travel between activity locations. The properties of the model solution are analytically explored and compared with the conventional bottleneck model for a special case with constant marginal-activity utility. For the case with linear marginal-activity utility, we develop a heuristic procedure to seek the equilibrium scheduling solution. We also explore the effects of marginal-work utility (or the employees' average wage level) and of flexible work-hour schemes on the scheduling problem in relation to the morning and evening commuting tours.

Post-disaster relief–service centralized logistics distribution with survivor resilience maximization

- Transportation Research Part B: Methodological---2014---Jiuh-Biing Sheu

This work proposes a post-disaster demand-oriented emergency logistics operational model that aims at disaster relief–service distribution to maximize survivor resilience. Rooted in survival psychology and cognition theories, this work proposes a conceptual model which hypothesizes post-disaster survivor perception–attitude–resilience relationships. This is followed by conducting a normative analysis which includes establishing survivor-specific disaggregate attitudinal functions and a post-disaster relief–service distribution optimization model, based on the proposed conceptual model and hypotheses. Using structural equation modeling we conduct an empirical study which verifies that the proposed survivor perception–attitude–resilience conceptual model is valid, supporting the results of the normative analyses. Furthermore, a numerical study of a real earthquake disaster is conducted. Numerical results demonstrate the applicability of the proposed method and its potential advantages in evaluating the performance of an emergency logistics system from the perspective of not only the suppliers but also the demanders.

Robust perimeter control design for an urban region

- Transportation Research Part B: Methodological---2014---Jack Haddad,Arie Shraiber

Recent works have introduced perimeter feedback-control strategies for a homogenous urban region and multiple urban regions with the help of the Macroscopic Fundamental Diagram (MFD) representation, that relates average flow and density (or accumulation) across the network. The perimeter controller is located on the region border, and manipulates the transfer flows across the border, while aiming at regulating around (nearby) the critical densities or accumulations, whereby the system throughput is maximized. While the desired state in the one urban region system is known in advance (given the MFD shape), for the system with multiple urban regions the desired accumulation points are not well known. Moreover, in some traffic scenarios the controller cannot regulate around the critical accumulations for both systems, e.g. because of high demand. In this paper, a robust perimeter controller for an urban region is designed. The controller aims at satisfying the control specifications and having a good performance for the whole accumulation set, uncongested and congested accumulations, and not necessary for a value range nearby the critical accumulation set-point. Moreover, unlike previous works, the robust controller is also designed to handle uncertainty in the MFD and the control constraints within the design level in a systematic way, where the constraints are explicitly integrated utilizing the so-called describing function. Comparison results show that the performances of the robust controller are significantly better than a "standard" feedback controller, for different traffic scenarios.

Continuum approximation approach to bus network design under spatially heterogeneous demand

- Transportation Research Part B: Methodological---2014---Yanfeng Ouyang,Seyed Mohammad Nourbakhsh,Michael J. Cassidy

A methodological framework is formulated so that continuum approximation techniques can be used to design bus networks for cities where travel demand varies gradually over space. The bus-route configurations that result consist of (i) a main, possibly city-wide grid with relatively large physical spacings between its parallel routes and the stops along those routes; together with (ii) one or more local grids with more closely-spaced routes and stops that serve neighborhoods of higher demand densities. The so-called power-of-two concept is borrowed from the field of inventory control, and is enforced so that local grids can be inserted seamlessly within the main one.

A competing Markov model for cracking prediction on civil structures

- Transportation Research Part B: Methodological---2014---K. Kobayashi,K. Kaito,N. Lethanh

Cracks on the surface of civil structures (e.g. pavement sections, concrete structures) progress in several formations and under different deterioration mechanisms. In monitoring practice, it is often that cracking type with its worst damage level is selected as a representative condition state, while other cracking types and their damage levels are neglected in records, remaining as hidden information. Therefore, the practice in monitoring has a potential to conceal with a bias selection process, which possibly result in not optimal intervention strategies. In overcoming these problems, our paper presents a non-homogeneous Markov hazard model, with competing hazard rates. Cracking condition states are classified in three types (longitudinal crack, horizontal crack, and alligator crack), with three respective damage levels. The dynamic selection of cracking condition states are undergone a competing process of cracking types and damage levels. We apply a numerical solution using Bayesian estimation and Markov Chain Monte Carlo method to solve the problem of high-order integration of complete likelihood function. An empirical study on a data-set of Japanese pavement system is presented to demonstrate the applicability and contribution of the model.

Quasi-dynamic traffic assignment with residual point queues incorporating a first order node model

- Transportation Research Part B: Methodological---2014---Michiel Bliemer,Mark P.H. Raadsen,Erik-Sander Smits,Bojian Zhou,Michael G.H. Bell

Static traffic assignment models are still widely applied for strategic transport planning purposes in spite of the fact that such models produce implausible traffic flows that exceed link capacities and predict incorrect congestion locations. There have been numerous attempts to constrain link flows to capacity. Capacity constrained models with residual queues are often referred to as quasi-dynamic traffic assignment models. After reviewing the literature, we come to the conclusion that an important piece of the puzzle has been missing so far, namely the inclusion of a first order node model. In this paper we propose a novel path-based static traffic assignment model for finding a stochastic user equilibrium in general transportation networks. This model includes a first order (steady-state) node model that yields more realistic turn capacities, which are then used to determine consistent capacity constrained traffic flows, residual point (vertical) queues (upstream bottleneck links), and path travel times consistent with queuing theory. The route choice part of the model is specified as a variational inequality problem, while the network loading part is formulated as a fixed point problem. Both problems are solved using existing techniques to find a solution. We illustrate the model using hypothetical examples, and also demonstrate feasibility on large-scale networks.

Deadlock analysis, prevention and train optimal travel mechanism in single-track railway system

- Transportation Research Part B: Methodological---2014---Feng Li,Jiuh-Biing Sheu,Zi-You Gao

In this paper, train scheduling problem (TSCP) is discussed for the case of single-track railway corridor, in which variable sensitivity on train delay are discussed in detailed for different types of trains. The mathematical model is a complicated nonlinear mixed-integer programming. The object of the model reflects sensitivity of trains with different types or travelling mileages on delay. A heuristic method based on the global conflicts distribution prediction (CDP) is presented. In the CDP, two critical problems restricting the development of simulation method, i.e., train deadlock and near-optimal travel strategy of train, are effectively solved. Numerical experiments show that the CDP can obtain a solution close enough to the optimal solution within a very short computational time. Variable cost weight with trapezoid-shape structure is investigated. Compared with constant weight, the schedule plan has more rational structure when variable cost weight is adopted.

Distributed coordinated in-vehicle online routing using mixed-strategy congestion game

- Transportation Research Part B: Methodological--2014---Lili Du,Lanshan Han,Xiang-Yang Li

This study proposes a coordinated online in-vehicle routing mechanism for smart vehicles with real-time information exchange and portable computation capabilities. The proposed coordinated routing mechanism incorporates a discrete choice model to account for drivers' behavior, and is implemented by a simultaneously-updating distributed algorithm. This study shows the existence of an equilibrium coordinated routing decision for the mixed-strategy routing game and the convergence of the distributed algorithm to the equilibrium routing decision, assuming individual smart vehicles are selfish players seeking to minimize their own travel time. Numerical experiments conducted based on Sioux Falls city network indicate that the proposed distributed algorithm converges quickly under different smart vehicle penetrations, thus it possesses a great potential for online applications. Moreover, the proposed coordinated routing mechanism outperforms traditional independent selfish-routing mechanism; it reduces travel time for both overall system and individual vehicles, which represents the core idea of Intelligent Transportation Systems (ITS).

Scheduled paratransit transport systems

- Transportation Research Part B: Methodological--2014---G. Dikas,I. Minis

In this paper we focus on ways to provide individualized services to people with mobility challenges using existing modes of public transport. We study the design of an interesting case, in which a bus operating in a public transport route may diverge from its nominal path to pick-up passengers with limited mobility and drop them off at their destination. We have modeled the design problem by a mixed integer-linear program, and we developed an exact Branch and Price approach to solve it to optimality. The proposed approach includes a labeling algorithm in which we introduced appropriate dominance rules, which do not compromise optimality. We have compared the efficiency of our approach with that of related algorithms from the literature. Furthermore, we have used the proposed approach to study key aspects of the system design problem, such as the effect of various constraints on the service level, and the tuning of the system's parameters to address different transport environments.

A new schedule-based transit assignment model with travel strategies and supply uncertainties

- Transportation Research Part B: Methodological--2014---Younes Hamdouch,W.Y. Szeto,Y. Jiang

This paper proposes a new scheduled-based transit assignment model. Unlike other schedule-based models in the literature, we consider supply uncertainties and assume that users adopt strategies to travel from their origins to their destinations. We present an analytical formulation to ensure that on-board passengers continuing to the next stop have priority and waiting passengers are loaded on a first-come-first-serve basis. We propose an analytical model that captures the stochastic nature of the transit schedules and in-vehicle travel times due to road conditions, incidents, or adverse weather. We adopt a mean variance approach that can consider the covariance of travel time between links in a space–time graph but still lead to a robust transit network loading procedure when optimal strategies are adopted. The proposed model is formulated as a user equilibrium problem and solved by an MSA-type algorithm. Numerical results are reported to show the effects of supply uncertainties on the travel strategies and departure times of passengers.

A new estimation approach to integrate latent psychological constructs in choice modeling

- Transportation Research Part B: Methodological---2014---Chandra R. Bhat,Subodh K. Dubey

In the current paper, we propose a new multinomial probit-based model formulation for integrated choice and latent variable (ICLV) models, which, as we show in the paper, has several important advantages relative to the traditional logit kernel-based ICLV formulation. Combining this MNP-based ICLV model formulation with Bhat's maximum approximate composite marginal likelihood (MACML) inference approach resolves the specification and estimation challenges that are typically encountered with the traditional ICLV formulation estimated using simulation approaches. Our proposed approach can provide very substantial computational time advantages, because the dimensionality of integration in the log-likelihood function is independent of the number of latent variables. Further, our proposed approach easily accommodates ordinal indicators for the latent variables, as well as combinations of ordinal and continuous response indicators. The approach can be extended in a relatively straightforward fashion to also include nominal indicator variables. A simulation exercise in the virtual context of travel mode choice shows that the MACML inference approach is very effective at recovering parameters. The time for convergence is of the order of 30–80min for sample sizes ranging from 500 observations to 2000 observations, in contrast to much longer times for convergence experienced in typical ICLV model estimations.

Braess paradox under the boundedly rational user equilibria

- Transportation Research Part B: Methodological---2014---Xuan Di,Xiaozheng He,Xiaolei Guo,Henry X. Liu

The Braess paradox and its variants have been studied under the perfectly rational behavior assumption. However, when the perfect rationality assumption is relaxed to bounded rationality, which assumes that travelers can take any route whose travel cost is within an 'indifference band' of the shortest path cost, it remains unclear under what conditions the Braess paradox occurs. This paper fills this gap by exploring relationships between the occurrence of the Braess paradox and the indifference band as well as the demand level in the setting of the boundedly rational user equilibrium (BRUE). The definition of the Braess paradox is extended based on planners' risk-taking attitudes, i.e., risk-averse, risk-prone and risk-neutral, due to the non-uniqueness of BRUE. The paradox occurrence conditions under different risk-taking attitudes are investigated using the classical Braess network and compared with those under the user equilibrium. Then we generalize the paradox conditions to simple and ordinary grid networks with regular Bureau of Public Roads (BPR) link performance functions. The impact of the link cost congestion sensitivity along with the indfference band on the occurrence of the Braess paradox is also studied.

The analysis of vehicle crash injury-severity data: A Markov switching approach with road-segment heterogeneity

- Transportation Research Part B: Methodological---2014---Yingge Xiong,Justin L. Tobias,Fred L. Mannering

Time-constant assumptions in discrete-response heterogeneity models can often be violated. To address this, a time-varying heterogeneity approach to model unobserved heterogeneity in ordered response data is considered. A Markov switching random parameters structure (which accounts for heterogeneity across observations) is proposed to accommodate both time-varying and time-constant (cross-sectional) unobserved heterogeneity in an ordered discrete-response probability model. A data augmented Markov Chain Monte

Carlo algorithm for non-linear model estimation is developed to facilitate model estimation. The performance of the cross-sectional heterogeneity model and time-varying heterogeneity model are examined with vehicle crash-injury severity data. The time-varying heterogeneity model (Markov switching random parameters ordered probit) is found to provide the best overall model fit. Two roadway safety states are shown to exist and roadway segments transition between these two states according to Markov transition probabilities. The results demonstrate considerable promise for Markov switching models in a wide variety of applications.

Public transport vehicle scheduling featuring multiple vehicle types

- Transportation Research Part B: Methodological--2014---Stephan Hassold,Ceder, Avishai (Avi)

Vehicle scheduling is a crucial step of the public transport planning process because it results in the number of vehicles required, thus it is directly related to fixed cost and labor cost. It is desirable, therefore, to minimize the number of vehicles used and operational cost. This paper proposes a new methodology for the multiple vehicle types vehicle scheduling problem (MVT-VSP). The methodology is based on a minimum-cost network flow model utilizing sets of Pareto-optimal timetables for individual bus lines. Given a fixed fleet size the suggested methodology also allows a selection of the optimal timetable. The method developed enables to stipulate the use of a particular vehicle type for a trip or to allow for a substitution either by a larger vehicle or a combination of smaller vehicles with the same or higher total capacity. Moreover, a variation of the method portrayed makes it possible to construct sub-optimal timetables given a reduction of the vehicle-scheduling cost. It is demonstrated that a substitution of vehicles is beneficial and can lead to significant cost reductions in the range of more than 27%. The suggested methodology is applied to a real-life case study in Auckland, New Zealand, and the results show improvements of greater than 15% in terms of the cost of fleet compared with vehicle schedules that are provided by standard models.

Optimal occupancy-driven parking pricing under demand uncertainties and traveler heterogeneity: A stochastic control approach

- Transportation Research Part B: Methodological--2014---Qian, Zhen (Sean),Ram Rajagopal

A novel parking pricing strategy dependent on real-time sensing is proposed to manage the parking demand. Parking pricing and information provision jointly serve as a dynamic stabilized controller to minimize the total travel time (TTT) of the system. Parking prices are adjusted in real time according to the real-time occupancy collected by parking sensors. All the parking information along with parking prices, is then provided for travelers to make real-time parking choices. We model the optimal parking pricing in the preferred (closer) parking cluster as a stochastic control problem. We take into account two types of randomness, demand uncertainties and user heterogeneity in Value of Time (VOT), both of which can be learned by taking real-time measurements. The optimal parking pricing policies are solved using the dynamic programming approach. There exists a critical occupancy for each time period, and the parking prices should be set effective (by diverting travelers to the farther parking lot) when the up-to-date occupancy is above the critical occupancy. From the numerical experiments, we find that the optimal parking policies based on stochastic control models are promising. They can deal with different demand levels (high, low or unstable) and generally outperform the deterministic pricing schemes. It can approach the minimum TTT in most of the cases as if we know the traffic demand in advance of the commuting time. Providing real-time occupancy information alone without setting proper parking prices, seems useful, but marginal, in reducing the parking congestion.

Exact and meta-heuristic approach for a general heterogeneous dial-a-ride problem with multiple depots

- Transportation Research Part B: Methodological---2014---Kris Braekers,An Caris,Gerrit K. Janssens

Dial-a-ride problems are concerned with the design of efficient vehicle routes for transporting individual persons from specific origin to specific destination locations. In real-life this operational planning problem is often complicated by several factors. Users may have special requirements (e.g. to be transported in a wheelchair) while service providers operate a heterogeneous fleet of vehicles from multiple depots in their service area. In this paper, a general dial-a-ride problem in which these three real-life aspects may simultaneously be taken into account is introduced: the Multi-Depot Heterogeneous Dial-A-Ride Problem (MD-H-DARP). Both a three- and two-index formulation are discussed. A branch-and-cut algorithm for the standard dial-a-ride problem is adapted to exactly solve small problem instances of the MD-H-DARP. To be able to solve larger problem instances, a new deterministic annealing meta-heuristic is proposed. Extensive numerical experiments are presented on different sets of benchmark instances for the homogeneous and the heterogeneous single depot dial-a-ride problem. Instances for the MD-H-DARP are introduced as well. The branch-and-cut algorithm provides considerably better results than an existing algorithm which uses a less compact formulation. All seven previously unsolved benchmark instances for the heterogeneous dial-a-ride problem could be solved to optimality within a matter of seconds. While computation times of the exact algorithm increase drastically with problem size, the proposed meta-heuristic algorithm provides near-optimal solutions within limited computation time for all instances. Several best known solutions for unsolved instances are improved and the algorithm clearly outperforms current state-of-the-art heuristics for the homogeneous and heterogeneous dial-a-ride problem, both in terms of solution quality and computation time.

Pre-trip information and route-choice decisions with stochastic travel conditions: Theory

- Transportation Research Part B: Methodological---2014---Charles Lindsey,Terry Daniel,Eyran Gisches,Amnon Rapoport

This paper studies the effects of pre-trip information on route-choice decisions when travel conditions are congested and stochastic. We adopt a model based on the classical two-route network in which free-flow travel times and/or capacities on each route vary unpredictably due to such shocks as bad weather, accidents, and special events. We show that the benefits of information depend on differences between routes in free-flow costs, the shape of the travel cost functions, the severity of congestion and capacity shocks, and the degree of correlation between routes in travel conditions. Information is more likely to be welfare-reducing when free-flow travel costs differ appreciably, travel cost functions are convex, shocks are similar in size on the routes, and route conditions are strongly and positively correlated.

Simultaneous train rerouting and rescheduling on an N-track network: A model reformulation with network-based cumulative flow variables

- Transportation Research Part B: Methodological---2014---Lingyun Meng,Xuesong Zhou

Train dispatching is critical for the punctuality and reliability of rail operations, especially for a complex rail network. This paper develops an innovative integer programming model for the problem of train dispatching on an N-track network by means of simultaneously rerouting and rescheduling trains. Based on a time–space network modeling framework, we first adapt a commonly used big-M method to represent complex “if-then” conditions for train safety headways in a multi-track context. The track occupancy consideration on typical single and double tracks is then reformulated using a vector of cumulative flow variables. This new reformulation technique can provide an efficient decomposition mechanism through modeling track capacities as side constraints which are further dualized through a proposed Lagrangian relaxation solution framework. We further decompose the original complex rerouting and rescheduling problem into a sequence of single train optimization subproblems. For each subproblem, a standard label correcting algorithm is embedded for finding the time dependent least cost path on a time–space network. The resulting dual solutions can be transformed to feasible solutions through priority rules. We present a set of numerical experiments to demonstrate the system-wide performance benefits of simultaneous train rerouting and rescheduling, compared to commonly-used sequential train rerouting and rescheduling approaches.

Transit route and frequency design: Bi-level modeling and hybrid artificial bee colony algorithm approach

- Transportation Research Part B: Methodological---2014---W.Y. Szeto,Y. Jiang

This paper proposes a bi-level transit network design problem where the transit routes and frequency settings are determined simultaneously. The upper-level problem is formulated as a mixed integer non-linear program with the objective of minimizing the number of passenger transfers, and the lower-level problem is the transit assignment problem with capacity constraints. A hybrid artificial bee colony (ABC) algorithm is developed to solve the bi-level problem. This algorithm relies on the ABC algorithm to design route structures and a proposed descent direction search method to determine an optimal frequency setting for a given route structure. The descent direction search method is developed by analyzing the optimality conditions of the lower-level problem and using the relationship between the lower- and upper-level objective functions. The step size for updating the frequency setting is determined by solving a linear integer program. To efficiently repair route structures, a node insertion and deletion strategy is proposed based on the average passenger demand for the direct services concerned. To increase the computation speed, a lower bound of the objective value for each route design solution is derived and used in the fitness evaluation of the proposed algorithm. Various experiments are set up to demonstrate the performance of our proposed algorithm and the properties of the problem.

The optimal design and cost implications of electric vehicle taxi systems

- Transportation Research Part B: Methodological---2014---Nakul Sathaye

In recent years, taxis in multiple cities and metropolitan areas around the world have shifted to utilizing alternative fuel options. Such change has significant potential to reduce environmental externalities and can contribute to alleviating energy policy concerns. However, little work has been conducted to assess the tradeoffs between selecting various fuels for taxis, or to design alternative fuel taxi systems. These tradeoffs exist as a result of the differing costs associated with fleet replacement, infrastructure deployment, operations and maintenance decisions, and costs to users. This paper aims to address this issue by providing an optimization framework for the design of electric taxi systems, and an assessment of optimal costs associated with various options. We focus on comparing the costs of taxi systems made up of gasoline vehicles, hybrid-electric vehicles, plug-in hybrid electric vehicles with AC Level 2 infrastructure, electric vehicles with battery switching infrastructure, and electric vehicles with DC Level 2 fast charging infrastructure. This approach is based on transit systems design methods and focuses on developing an approximate analytic model for electric taxi systems, which can be expanded upon in future research, to address large-scale taxi systems design problems. Scenario results are presented for various city types.

A method for designing centralized emergency supply network to respond to large-scale natural disasters

- Transportation Research Part B: Methodological---2014---Jiuh-Biing Sheu,Cheng Pan

This paper proposes a method for designing a seamless centralized emergency supply network by integrating three sub-networks (shelter network, medical network, and distribution network) to support emergency logistics operations in response to large-scale natural disasters. The proposed method primarily involves three stage multi-objective (travel distance minimization, operational cost minimization, and psychological cost minimization), mixed-integer linear programming models. The three sub-networks are designed using the proposed programming models. The distinctive features of the proposed method are as follows. (1) The proposed method is demand-driven. The order of the designed sub-networks is shelter, medical, and distribution, with the connections of the latter networks based on the arrangements for the former. (2) The objective functions of three stage programming models include not only traditional objectives such as minimizing total travel distance and operational cost, which supply-side members focus on, but also minimizing the psychological cost experienced by demand-side members. Model tests are conducted to demonstrate that the superiority of a centralized emergency supply network designed by the proposed method over a decentralized one, especially with regard to distribution network design.

Network equilibrium models with battery electric vehicles

- Transportation Research Part B: Methodological---2014---Fang He,Yafeng Yin,Siriphong Lawphongpanich

The limited driving ranges, the scarcity of recharging stations and potentially long battery recharging or swapping time inevitably affect route choices of drivers of battery electric vehicles (BEVs). When traveling between their origins and destinations, this paper assumes that BEV drivers select routes and decide battery recharging plans to minimize their trip times or costs while making sure to complete their trips without running out of charge. With different considerations of flow dependency of energy consumption of BEVs and recharging time, three mathematical models are formulated to describe the resulting network equilibrium flow distributions on regional or metropolitan road networks. Solution algorithms are proposed to solve these models efficiently. Numerical examples are presented to demonstrate the models and solution algorithms.

Airline route structure competition and network policy

- Transportation Research Part B: Methodological---2014---Hugo E. Silva,Erik Verhoef,Vincent van den Berg

We analyze the behavior of airlines in terms of route structure choice using a differentiated duopoly model that accounts for congestion externalities, passenger benefits from increased frequency, passenger connecting costs and airline endogenous hub location. We also examine the route structure configuration that maximizes welfare and whether it can arise as an equilibrium when a regulator implements optimal airport pricing, but does not regulate directly the route structure choice. We find that this is not always the case and that, therefore, an instrument directly aimed at regulating route structure choice may be needed to maximize welfare, in addition to per-passenger and per-flight tolls designed to correct output inefficiencies. This holds true when the regulator is constrained to set non-negative tolls, but also for unconstrained tolling. Finally, we also study the relative efficiency of airport pricing when the optimal route structure configuration cannot be decentralized by tolling.

A Granular Variable Tabu Neighborhood Search for the capacitated location-routing problem

- Transportation Research Part B: Methodological---2014---John Willmer Escobar,Rodrigo Linfati,Maria G. Baldoquin,Paolo Toth

This paper proposes a new heuristic algorithm for the Capacitated Location-Routing Problem (CLRP), called Granular Variable Tabu Neighborhood Search (GVTNS). This heuristic includes a Granular Tabu Search within a Variable Neighborhood Search algorithm. The proposed algorithm is experimentally compared on the benchmark instances from the literature with several of the most effective heuristics proposed for the solution of the CLRP, by taking into account the CPU time and the quality of the solutions obtained. The computational results show that GVTNS is able to obtain good average solutions in short CPU times, and to improve five best known solutions from the literature. The main contribution of this paper is to show a successful new heuristic for the CLRP, combining two known heuristic approaches to improve the global performance of the proposed algorithm for what concerns both the quality of the solutions and the computing times required to find them.

Dynamic and disequilibrium analysis of interdependent infrastructure systems

- Transportation Research Part B: Methodological---2014---Pengcheng Zhang,Srinivas Peeta

There is a growing awareness in recent years that the interdependencies among the civil infrastructure systems have significant economic, security and engineering implications that may influence their resiliency, efficiency and effectiveness. To capture the various types of infrastructure interdependencies and incorporate them into decision-making processes in various application domains, Zhang and Peeta (2011) propose a generalized modeling framework that combines a multilayer infrastructure network (MIN) concept and a market-based economic approach using computable general equilibrium (CGE) theory and its spatial extension (SCGE) to formulate a static equilibrium infrastructure interdependencies problem. This paper extends the framework to address the dynamic and disequilibrium aspects of the infrastructure interdependencies problems. It briefly reviews the static model, and proposes an alternative formulation for it using the variational inequality (VI) technique. Based on this equivalent VI formulation, a within-period equilibrium-tending dynamic model is proposed to illustrate how these systems evolve towards an equilibrium state within a short duration after a perturbation. To address a longer time scale, a multi-period dynamic model is proposed. This model explicitly considers the evolution of infrastructure interdependencies over time and the temporal interactions among the various systems through dynamic parameters that link the different time periods. Using this model, numerical experiments are conducted for a special case with a single region to analyze the sensitivity of the model to the various parameters, and demonstrate the ability of the modeling framework to formulate and solve practical problems such as cascading failures, disaster recovery, and budget allocation in a dynamic setting.

Port privatization in an international oligopoly

- Transportation Research Part B: Methodological---2014---Noriaki Matsushima,Kazuhiro Takauchi

We investigate the effects of port privatization on port usage fees, firm profits, and welfare. Our model consists of an international duopoly with two ports and two markets. When the unit transport cost is high, port privatization reduces port usage fees, although neither government has an incentive to privatize its port. The equilibrium governmental decisions are inconsistent with the desirable outcome if the unit transport cost is not high enough. The government of the smaller country, in terms of market size, is more likely to privatize its port, and the government of the larger country is more likely to nationalize its port to protect its domestic market.

A bi-objective user equilibrium model of travel time reliability in a road network

- Transportation Research Part B: Methodological---2014---Judith Y.T. Wang,Matthias Ehrgott,Anthony Chen

Travel time, travel time reliability and monetary cost have been empirically identified as the most important criteria influencing route choice behaviour. We concentrate on travel time and travel time reliability and review two prominent user equilibrium models incorporating these two factors. We discuss some shortcomings of these models and propose alternative bi-objective user equilibrium models that overcome the shortcomings. Finally, based on the observation that both models use standard deviation of travel time within their measure of travel time reliability, we propose a general travel time reliability bi-objective user equilibrium model. We prove that this model encompasses those discussed previously and hence forms a general framework for the study of reliability related user equilibrium. We demonstrate and validate our concepts on a small three-link example.

Pareto efficiency of reliability-based traffic equilibria and risk-taking behavior of travelers

- Transportation Research Part B: Methodological---2014---Zhijia Tan,Hai Yang,Renyong Guo

This paper investigates the Pareto efficiency of the various reliability-based traffic equilibria proposed in the literature and the risk-taking behavior of travelers. Reliability indexes such as the percentile travel time (PTT), travel time budget (TTB), mean excess travel time (METT) and the quadratic disutility function (QDF) are examined in terms of the mean and standard deviation (SD) of travel times. The downward sloping mean-SD indifference curve is introduced to geometrically analyze the risk-taking behavior of travelers. Both the diversifying and plunging behaviors of risk-averse travelers are investigated by examining the curvature of the mean-SD indifference curves at traffic equilibria based on the PTT, TTB, METT and QDF. Several specific probability distributions are adopted to elucidate the theoretical results obtained.

Modeling distribution tail in network performance assessment: A mean-excess total travel time risk measure and analytical estimation method

- Transportation Research Part B: Methodological---2014---Xiangdong Xu,Anthony Chen,Lin Cheng,Hong K. Lo

Risk measures are often used by decision makers (DMs) as a scalar risk characterization by integrating the statistical characteristics of risk as well as the DMs' risk strategy towards uncertainty. A good risk measure typically needs to have a risk preference control mechanism, a complete uncertainty characterization, and a practical implementation strategy. Total travel time reliability (TTTR) and total travel time budget (TTTB) are two risk measures recently proposed for assessing transportation network performance under uncertainty. In this paper, we propose the mean-excess total travel time (METTT) as an alternative network-wide risk measure to more cost-effectively capture the distribution tail, and develop an analytical method to estimate risk measures without knowing the explicit distribution form of TTT uncertainty. Methodologically, the METTT measure characterizes the distribution tail of exceeding the TTTB via the conditional expectation without requiring an extraordinary reliability level. It is able to account for the tradeoff between planners' risk-aversion attitude and the unacceptable risk, which avoids the need of setting a too conservative reliability requirement in the TTTB to reduce the unacceptable risk. The explicit distribution tail consideration in the METTT could lower the construction cost and substantially reduce the unacceptable risk of network capacity enhancement under uncertainty. To enhance the practicality of METTT, we develop an analytical estimation method to efficiently calculate the METTT by using the first four TTT moments as well as the planners' risk attitude. The TTTR and TTTB measures can also be analytically estimated as a byproduct of the proposed method for assessing the METTT. The analytical feature of the proposed method avoids the burdensome computation of simulation method and also circumvents the need of fitting the explicit TTT distribution form. Numerical results indicate that the proposed method has a desirable and comparable estimation quality in comparison with the theoretical derivation and curve fitting methods.

Consistent formulation of network equilibrium with stochastic flows

- Transportation Research Part B: Methodological---2014---Shoichiro Nakayama,David Watling

Traffic flows in real-life transportation systems vary on a daily basis. According to traffic flow theory, such variability should induce a similar variability in travel times, but this "internal consistency" is generally not captured by existing network equilibrium models. We present an internally-consistent network equilibrium approach, which considers two potential sources of flow variability: (i) daily variation in route choice and (ii) daily variation in origin–destination demand. We particularly aspire to a flexible formulation that permits alternative statistical assumptions, which allows the best fit to be made to observed variability data in particular applications. Joint probability distributions of route—and therefore link—flows are derived under several assumptions concerning stochastic driver behavior. A stochastic network equilibrium model with stochastic demands and route choices is formulated as a fixed point problem. We explore limiting cases which allow an equivalent convex optimization problem to be defined, and finally apply this method to a real-life network of Kanazawa City, Japan.

Ferry service network design with stochastic demand under user equilibrium flows

- Transportation Research Part B: Methodological---2014---Kun An,Hong K. Lo

This paper develops a service reliability-based formulation for ferry service network design with stochastic demand under user equilibrium flows while considering two types of services, regular and ad hoc. Regular services operate with a fixed schedule; whereas ad hoc services are those subcontracted or outsourced to a third party and have a higher unit cost. Two ad hoc provision schemes are studied. Scheme A considers that the demand information is known in advance by passenger reservation, and the company makes use of this information to plan for ad hoc services. In Scheme B, the demand realization is only known as passengers arrive at the piers and the company calls upon ad hoc services in case of demand overflow. In Scheme A, we utilize the notion of service reliability (SR) to address the issue of demand uncertainty and formulate the problem as a two-phase stochastic program in which the schedule of regular services and ad hoc services are derived sequentially. The user equilibrium (UE) assignment with capacity constraint is formulated via a linear programming (LP) approach considering overflow delays. A SR-based gradient solution approach is developed to solve the model. Scheme B, as expected, requires more resources to operate, for which a SR-based non-linear model is developed. The value of reservation to the company is defined as the operating cost difference between these two schemes. We apply the methods to ferry service network design in Hong Kong, and then compare the UE (Scheme A) and system optimal (SO) solutions, in terms of service deployment and computation time, to contrast the solution quality arising from the inclusion of equilibrium flows. The value of advance reservation information between Scheme A and Scheme B is presented as well.

On the stochastic network equilibrium with heterogeneous choice inertia

- Transportation Research Part B: Methodological---2014---Chi Xie,Zugang Liu

As an alternative effort for quantifying recurrent traffic dynamics caused by network variations and analyzing the impact on the network performance from information provision, we describe in this paper a new equilibrium modeling scheme for stochastic networks with a finite number of states, which takes into account the behavioral inertia. A finite-dimensional variational inequality model is formulated to describe the cross-state equilibrium conditions among heterogeneous travelers with different inertial degrees and knowledge structures. Our model allows for traveler’s partial understanding and inertial effect in perceiving varying network conditions and provides a different perspective (from existing stochastic and Markovian network equilibrium approaches) to describe traffic flow variations across multiple network scenarios. A disaggregate simplicial decomposition algorithm is suggested to solve the variational inequality problem. Numerical results from a few stochastic network examples demonstrate the validity and effectiveness of our methodology in modeling the inertia phenomenon within route choice behavior and the efficacy of using traveler information systems to eliminate the inertia effect.

Finding most reliable paths on networks with correlated and shifted log–normal travel times

- Transportation Research Part B: Methodological--2014---Karthik K. Srinivasan,A.A. Prakash,Ravi Seshadri

There is a growing interest in modeling travel time uncertainty in transportation networks in addition to optimizing the reliability of travel times at the path and network level. This paper focuses on the analysis and optimization of travel time (including stopped delays) Reliability on the Urban Road Network in Chennai. Specifically, two objectives are investigated. The first objective involves the quantification of travel time reliability at the link and path level. In particular, the distribution of link travel times is quantified for the Chennai Urban road network using empirical data. The results indicate that the shifted log–normal distribution (SLN) reasonably represents link travel time for all facility types and relevant facility wise distribution parameters are estimated. Further, the resulting path travel time distribution is approximated by a SLN distribution, which is computationally less expensive than traditional Monte-Carlo estimation techniques with an acceptable compromise on accuracy. The second objective addresses the optimal reliability path problem on a network with SLN link travel times with general correlation structure. For this problem, it is shown that the sub-path optimality property of shortest path problems does not hold making traditional label-setting/label correcting algorithms inapplicable. Consequently, a sufficient optimality condition based on reliability bounds is established and a new network optimization algorithm is proposed and proof of correctness is presented. The convergence rate of the algorithm was shown to increase at every iteration under some mild conditions. The computational performance of the proposed algorithm is investigated using synthetic and real-world networks and found to be reasonably accurate.

Estimating the value of travel time and of travel time reliability in road networks

- Transportation Research Part B: Methodological--2014---Kenetsu Uchida

This study proposes two network models which simultaneously estimate the value of travel time and of travel time reliability based on the risk-averse driver’s route choice behavior. The first model is formulated as a utility maximization problem under monotonic and separable link travel times, whereas the second model is formulated as a utility maximization problem under non-monotonic and non-separable link travel times. The proposed models have the same structure as a user equilibrium (UE) traffic assignment problem with elastic demand. It is shown that the first model, which addresses independent stochastic capacity, is formulated as an optimization problem with a unique solution and is solved by using an algorithm for a UE traffic assignment problem with fixed demand. The second model, which addresses both stochastic Origin–Destination (O–D) flow and stochastic link capacity, is formulated as a nonlinear complementary problem. O–D demand functions formulated in the proposed models are derived from the utility maximization behavior of the driver in the network. Therefore, the network models proposed in this study are consistent with those of studies that address the value of travel time and of travel time reliability based on utility maximization behavior without considering the driver’s route choice. Numerical experiments are carried out to demonstrate the models presented in this study.

Depot location in degradable transport networks

- Transportation Research Part B: Methodological--2014---Michael G.H. Bell,Achille Fonzone,Chrisanthi Polyzoni

Areas subject to natural or man-made disasters, such as earthquakes, fires, floods or attacks, are reliant on the residual transport network for the rescue of survivors and subsequent recovery. Pre-disaster planning requires assumptions about how the transport network may degrade. This paper presents a game theoretic approach modelling network degradation and applies this to depot location, with a case study based on Sichuan province in China, which is prone to earthquakes. To facilitate a cautious approach to depot location, the method assumes that the transport network is subject to attack by node-specific demons with the power to degrade links. The mixed strategy Nash equilibrium for the non-cooperative zero sum game between dispatchers and demons is used to define rescue hyperpaths. These in turn define the best depot locations. Two forms of the drop heuristic are used to find good depot locations.

System optimal dynamic traffic assignment: Properties and solution procedures in the case of a many-to-one network

- Transportation Research Part B: Methodological---2014---Wei Shen,H.M. Zhang

Thanks to its high dimensionality and a usually non-convex constraint set, system optimal dynamic traffic assignment remains one of the most challenging problems in transportation research. This paper identifies two fundamental properties of the problem and uses them to design an efficient solution procedure. We first show that the non-convexity of the problem can be circumvented by first solving a relaxed problem and then applying a traffic holding elimination procedure to obtain the solution(s) of the original problem. To efficiently solve the relaxed problem, we explore the relationship between the relaxed problems based on different traffic flow models (PQ, SQ, CTM) and a minimal cost flow (MCF) problem for a special space-expansion network. It is shown that all the four problem formulations produce the same minimal system cost and share one common solution which does not involve inside queues in the network. Efficient solution algorithms such as the network simplex method can be applied to solve the MCF problem and identify such an optimal traffic pattern. Numerical examples are also presented to demonstrate the efficiency of the proposed solution procedure.

A bilevel model for multivariate risk analysis of pedestrians’ crossing behavior at signalized intersections

- Transportation Research Part B: Methodological---2014---Baibing Li

Pedestrians who cross streets during the red-man phase of traffic light signals expose themselves to safety and health hazards and hence are considered to be at risk. Pedestrians’ street-crossing behavior is in general the outcome of interaction between pedestrians and vehicles: the gaps between vehicles provide an opportunity for pedestrians to cross the street, and pedestrians may or may not accept the street-crossing risk during the red-man phase. In this paper, we propose a multivariate method to investigate pedestrians’ risk exposure associated with unsafe crossings. The proposed method consists of two hierarchically interconnected generalized linear models that characterize two different facets of the unsafe crossing behavior. It gauges pedestrians’ attitudes toward risk-taking and also measures the impact of potential risk factors on pedestrians’ intended waiting times during the red-man phase of the traffic lights. A Bayesian approach with the data augmentation method is used to draw statistical inference for the parameters associated with risk exposure. The proposed method is illustrated using field traffic data.

Finding anonymous tolls to realize target flow pattern in networks with continuously distributed value of time

- Transportation Research Part B: Methodological---2014---Wen-Xiang Wu,Hai-Jun Huang

Considering user heterogeneity in terms of a continuously distributed value of time, we investigate, on the base of so-called Wardrop’s third principle, the time-versus-cost network equilibrium and system optimum problem with fixed demand. To realize a target flow pattern through imposing anonymous path tolls, we propose a time difference-based pricing in which every user is charged a toll computed from the time difference between adjacent paths ordered in the decreasing order of travel times. We find that, whenever travel disutility is measured in cost or time units, the anonymous marginal cost pricing does not exist. We further show that, if and only if the coefficient matrix of a linear system corresponding to the derived optimal path toll pattern and its augmented matrix have the same rank, an anonymous link toll pattern exists.

Efficient auctions for distributed transportation procurement

- Transportation Research Part B: Methodological---2014---Su Xiu Xu,George Q. Huang

The purpose of this paper is to propose allocatively efficient auction mechanisms for the distributed transportation procurement problem (DTPP), which is generally the problem of matching demands and supplies over a transportation network. We first construct a one-sided Vickrey–Clarke–Groves (O-VCG) combinatorial auction for the DTPP where carriers are allowed to bid on bundles of lanes. The O-VCG auction minimizes the total transportation cost (i.e., allocative efficiency) and induces truthful bidding from carriers (i.e., incentive compatibility). To simplify the execution of auction, we next propose a primal–dual Vickrey (PDV) auction based on insights from the known Ausubel auctions and the primal–dual algorithm. The PDV auction is actually a multi-round descending auction that seems simple enough for bidders. The PDV auction realizes VCG payments and truthful bidding under the condition of seller-submodularity, which implies that the effect of each individual carrier is decreasing when the coalition increases. Such is the case for the DTPP in an oversupplied transportation market. The winner determination problem of O-VCG auction is solved by the proposed primal–dual algorithm when seller-submodularity holds. Finally, carriers may reveal less private information in the PDV auction due to its dynamic procedures.

Transportation and economies of scale in recycling low-value materials

- Transportation Research Part B: Methodological---2014---Jiuh-Biing Sheu,Yenming J. Chen

This study investigates the economic incentive-drivers used in various configurations in green supply chains. The configurations of competitive suppliers and integrated transportation are studied for recycled materials with low economic value but high environmental impact. Arguments are embodied in a competitive game that manifests interactions among competing manufacturers, suppliers of virgin materials, suppliers of recycled materials, and the government. Because of market size and technology limitation, long hauling to few remote treatment facilities is observed in practice. Demand-dependent transportation efficiency arisen from economies of scale thus affects the equilibrium states in the game of this recycling system. Managerial insights are provided to encourage the use of low-value recycled materials. A tax-subsidy system is conditionally effective when using recycled materials maintains quality. When quality becomes compromised by mixing recycled materials, we find that integrating suppliers of recycled materials with those of virgin materials can make the tax-subsidy system effective again.

Airport congestion pricing when airlines price discriminate

- Transportation Research Part B: Methodological---2014---Achim I. Czerny,Anming Zhang

This paper extends the literature on airport congestion pricing by allowing carriers to price-discriminate between the business and leisure passengers when operating costs are the same for all passengers. The main results are: First, the second-best discriminating business fare exceeds the first-best uniform fare (which equals the external part of the marginal congestion costs), while the second-best discriminating leisure fare is lower than the first-best uniform fare. Second, the optimal airport charge implements the first-best uniform or second-best discriminating fares. Importantly, this charge can always be higher than what would be expected when all passengers were treated as having the same time valuation. This result provides some support to the finding that the welfare losses associated with an atomistic airport congestion charge may be low.

Extending travel-time based models for dynamic network loading and assignment, to achieve adherence to first-in-first-out and link capacities

- Transportation Research Part B: Methodological---2014---Malachy Carey,Paul Humphreys,Marie McHugh,Ronan McIvor

An important class of models for macroscopic dynamic network loading (DNL) and dynamic traffic assignment (DTA) is based on treating link travel times as a function of link occupancy. However, these models suffer from some problems or deficiencies namely (a) the link outflows can violate first-in-first-out (FIFO), (b) the link outflows can exceed the link outflow capacities, (c) the link inflows can exceed the link inflow capacities, and (d) the link occupancies can exceed the link occupancy capacities. In this paper we introduce methods to overcome each of these problems.

Implementing first-in–first-out in the cell transmission model for networks

- Transportation Research Part B: Methodological---2014---Malachy Carey,Hillel Bar-Gera,David Watling,Chandra Balijepalli

In traffic assignment models with time-varying flows (dynamic network loading or dynamic traffic assignment), overtaking behaviour is normally not included in the model and, in that case, it is important that the model at least approximates first-in–first-out (FIFO), to prevent deviations from FIFO that are arbitrary or unrealistic or not physically possible. For the cell transmission model (CTM) it has recently been shown that the usual recommended method for preserving FIFO will ensure FIFO for each cell taken separately but does not fully ensure FIFO in the transition between cells and hence does not fully ensure FIFO for sequences of cells or for links or for routes. As a result, deviations from FIFO can easily occur and cumulate along the links or routes. In view of that, we define and analyse three different levels of satisfaction or approximation of FIFO, together with corresponding methods for achieving them. Two of these are existing methods and one is new. We develop, analyse and compare the three methods and the extent to which each of them adheres to FIFO for sequences of cells and links or routes. Also, for two of the methods we present a more detailed algorithm for applying them within the CTM. The paper is concerned with how to implement FIFO in the CTM and not with testing for FIFO or measuring deviations from FIFO.

A functional approach to monitor and recognize patterns of daily traffic profiles

- Transportation Research Part B: Methodological---2014---I.G. Guardiola,T. Leon,F. Mallor

Functional Data Analysis (FDA) is a collection of statistical techniques for the analysis of information on curves or functions. This paper presents a new methodology for analyzing the daily traffic flow profiles based on the employment of FDA. A daily traffic profile corresponds to a single datum rather than a large set of traffic counts. This insight provides ideal information for strategic decision-making regarding road expansion, control, and other long-term decisions. Using Functional Principal Component Analysis the data are projected into a low dimensional space: the space of the first functional principal components. Each curve is represented by their vector of scores on this basis. The principal component scores are used for clustering and also to identify outliers (meaning that there was a bad performance in the recording of data or special circumstances affected the traffic) and to monitor the traffic profile by multivariate control charts. This paper introduces this new methodology and illustrates good results by using 1-min traffic data from the I-94 Freeway in the Twin Cities, Minnesota (U.S.) metroplex ranging from 2004 to 2011.

Coarse tolling with heterogeneous preferences

- Transportation Research Part B: Methodological---2014---Vincent van den Berg

This paper analyses optimal coarse tolling of congestion under heterogeneous preferences, and in particular its welfare and distributional effects. With coarse tolling, the toll equals a fixed value during the centre of the peak, whereas outside this period it is zero. This paper separately investigates three dimensions of heterogeneity. With the first, all values of time and schedule delay vary in fixed proportions, and this heterogeneity may stem from income differences. The second has differences in the flexibility of users in when to arrive. The third captures differences in willingness to arrive before or after the preferred arrival time. The paper uses three models of coarse tolling: the ‘Laih’, ‘ADL’ and ‘Braking’ model.

A spatial Difference-in-Differences estimator to evaluate the effect of change in public mass transit systems on house prices

- Transportation Research Part B: Methodological---2014---Jean Dubé,Diègo Legros,Marius Thériault,François Des Rosiers

Evaluating the impact of public mass transit systems on real-estate values is an important application of the hedonic price model (HPM). Recently, a mathematical transformation of this approach has been proposed to account for the potential omission of latent spatial variables that may overestimate the impact of accessibility to mass transit systems on values. The development of a Difference-in-Differences (DID) estimator, based on the repeat-sales approach, is a move in the right direction. However, such an estimator neglects the possibility that specification of the price equation may follow a spatial autoregressive process with respect to the dependent variable. The objective of this paper is to propose a spatial Difference-in-Differences (SDID) estimator accounting for possible spatial spillover effects. Particular emphasis is placed on the development of a suitable weights matrix accounting for spatial links between observations. Finally, an empirical application of the SDID estimator based on the development of a new commuter rail transit system for the suburban agglomeration of Montréal (Canada) is presented and compared to the usual DID estimator.

Analytical formulation and empirical evaluation of pre-signals for bus priority

- Transportation Research Part B: Methodological---2014---S. Ilgin Guler,Monica Menendez

One of the major causes of bus delays in urban environments are signalized intersections. A commonly used solution to give priority to buses at signalized intersections is to dedicate a lane for bus-use only. However this strategy can waste valuable green time at signals and impose additional delays to cars, especially when bus flows are low. Overall, the total person hours of delays in the system (i.e., buses and cars) can increase due to excessive delays experienced by car users. To this end, an additional signal upstream of the main signal, called a pre-signal, can be used to better utilize the capacity of the main signal while still providing bus priority to reduce the system-wide person hours of delays.

Reliable p-median facility location problem: two-stage robust models and algorithms

- Transportation Research Part B: Methodological---2014---Yu An,Bo Zeng,Yu Zhang,Long Zhao

In this paper, we propose a set of two-stage robust optimization models to design reliable p-median facility location networks subject to disruptions. We analyze their structural properties, and implement the column-and-constraint generation method with customized enhancement strategies, which is more effective than Benders cutting plane method. Numerical experiments are performed on real data and management insights on system design are presented. In particular, our study demonstrates the strong modeling capability of two-stage robust optimization scheme by including two practical issues, i.e., demand changes due to disruptions and facility capacities, which receive little attention in reliable distribution network design research. Results show the significant influence of the demand change on the network configuration.

An energy-efficient scheduling and speed control approach for metro rail operations

- Transportation Research Part B: Methodological---2014---Xiang Li,Hong K. Lo

Due to increasing environmental concerns and energy prices, what is very important but has not been given due consideration is the energy efficiency of metro rail systems. Train energy-efficient operation consists of timetable optimization and speed control. The former synchronizes the accelerating and braking actions of trains to maximize the utilization of regenerative energy, and the latter controls the train driving strategy to minimize the tractive energy consumption under the timetable constraints. To achieve a better performance on the net energy consumption, i.e., the difference between the tractive energy consumption and the utilization of regenerative energy, this paper formulates an integrated energy-efficient operation model to jointly optimize the timetable and speed profile. We design a genetic algorithm to solve the model and present some numerical experiments based on the actual operation data of Beijing Metro Yizhuang Line of China. It is shown that a larger headway leads to smaller energy saving rate, and the maximum energy saving rate achieved is around 25% when we use the minimum allowable headway of 90s. In addition, compared with the two-step approach optimizing the timetable and speed profile separately, the integrated approach can reduce the net energy consumption around 20%.

Preference endogeneity in discrete choice models

- Transportation Research Part B: Methodological---2014---Akshay Vij,Joan L. Walker

Existing models of disaggregate decision-making assume that preferences, as indicated by taste parameters and choice sets, are characteristics of the decision-maker that are exogenous to the choice situation and stable over time. Though the assumption has allowed travel demand analysts to use these models to forecast changes in observable behavior in response to changes in the decision-making environment, the assumption has overlooked the influence of these changes on the preferences underlying observable behavior. As a consequence, the use of these models has been limited to forecasting horizons over which preferences can reasonably be assumed to be stable. We build on Latent Class Choice Models (LCCMs) to allow for preference endogeneity. Conventional LCCMs formulate class membership as some function of the decision-maker’ s characteristics, but they ignore the impact of alternative attributes, which usually enter the class-specific choice models, on class membership. In this paper we introduce LCCMs with feedback from the class-specific choice models to the class membership model through the construct of consumer surplus. Class membership is hypothesized to be a function not only of the characteristics of the decision-maker but also of the consumer surplus offered by each class, which in turn is a function of alternative attributes, taste parameters and choice sets. The framework is applied to a case study on travel mode choice behavior. A comparison between LCCMs with feedback and traditional models that do not allow for preference endogeneity finds that the former performs better in terms of fit and offers greater behavioral insights, and that the latter can lead to biased forecasts.

Extended spectral envelope method for detecting and analyzing traffic oscillations

- Transportation Research Part B: Methodological---2014---Tingting Zhao,Nie, Yu (Marco),Yi Zhang

We propose using a spectral envelope method to analyze traffic oscillations using data collected from multiple sensors. Spectral envelops can reveal not only the salient frequencies of periodic oscillations of traffic flow, but also the relative strength of these oscillations at different locations. This paper first introduces time dimension into the existing spectral envelope method so that it can be applied to study the evolution of vehicular traffic oscillations. The extended spectral envelope method proposed in this paper, or ESPE, discards the normalization procedure in the standard method. A new Contributing Index (CI) is proposed to measure the relative strength of oscillations at different locations. The extended spectral envelops can be constructed on long-term or short-term time scales. While the long-term analysis helps extract salient frequencies of traffic oscillations, the short-term analysis promises to reveal their detailed spatial–temporal profiles. ESPE offers two distinctive advantages. First, it is more robust against the impacts of noises. Second, it is able to uncover complicated oscillatory behaviors which are otherwise difficult to notice. These advantages are demonstrated in case studies constructed on both simulated and real data.

Socially-oriented flight scheduling and fleet assignment model with an application to Norway

- Transportation Research Part B: Methodological--2014---João P. Pita,Nicole Adler,António P. Antunes

One of the direct results of air transport liberalization has been the development of publicly supported links on thin markets in remote regions when service is deemed necessary. We present a flight scheduling and fleet assignment optimization model that may assist public authorities to establish the level of service requirements for subsidized air transport networks. With the results of the optimization model, a welfare analysis of the network is carried out, distinguishing between passenger, airline, airport and government surpluses. The optimization model and subsequent welfare analysis were applied to the PSO network of Norway, which is currently the largest in Europe. The results indicate that improvements over the current network can be obtained for all relevant stakeholders simultaneously, with savings in the order of $1.2 million daily.

Multimodal pricing and optimal design of urban public transport: The interplay between traffic congestion and bus crowding

- Transportation Research Part B: Methodological--2014---Alejandro Tirachini,David Hensher,John Rose

The interplay between congestion and crowding externalities in the design of urban bus systems is identified and analysed. A multimodal social welfare maximisation model with spatially disaggregated demand is developed, in which users choose between travelling by bus, car or walking in a transport corridor. Optimisation variables are bus fare, congestion toll, bus frequency, bus size, fare collection system, bus boarding policy and the number of seats inside buses. We find that optimal bus frequency results from a trade-off between the level of congestion inside buses, i.e., passengers' crowding, and the level of congestion outside buses, i.e., the effect of frequency on slowing down both buses and cars in mixed-traffic roads. A numerical application shows that optimal frequency is quite sensitive to the assumptions on crowding costs, impact of buses on traffic congestion, and overall congestion level. If crowding matters to users, buses should have as many seats as possible, up to a minimum area that must be left free of seats. If for any other reason planners decide to have buses with fewer seats than optimal (e.g., to increase bus capacity), frequency should be increased to compensate for the discomfort imposed on public transport users. Finally, the consideration of crowding externalities (on both seating and standing) imposes a sizeable increase in the optimal bus fare, and consequently, a reduction of the optimal bus subsidy.

The train platforming problem: The infrastructure management company perspective

- Transportation Research Part B: Methodological--2014---P. Sels,P. Vansteenwegen,T. Dewilde,D. Cattrysse,B. Waquet,A. Joubert

If railway companies ask for station capacity numbers, their underlying question is in fact one about the platformability of extra trains. Train platformability depends not only on the infrastructure, buffer times, and the desired departure and arrival times of the trains, but also on route durations, which depend on train speeds and lengths, as well as on conflicts between routes at any given time. We consider all these factors in this paper. We assume a current train set and a future one, where the second is based on the expected traffic increase through the station considered. The platforming problem is about assigning a platform to each train, together with suitable in- and out-routes. Route choices lead to different route durations and imply different in-route-begin and out-route-end times. Our module platforms the maximum possible weighted sum of trains in the current and future train set. The resulting number of trains can be seen as the realistic capacity consumption of the schedule. Our goal function allows for current trains to be preferably allocated to their current platforms.

On the continuum approximation of the on-and-off signal control on dynamic traffic networks

- Transportation Research Part B: Methodological---2014---Ke Han,Vikash V. Gayah,Benedetto Piccoli,Terry L. Friesz,Tao Yao

In the modeling of traffic networks, a signalized junction is typically treated using a binary variable to model the on-and-off nature of signal operation. While accurate, the use of binary variables can cause problems when studying large networks with many intersections. Instead, the signal control can be approximated through a continuum approach where the on-and-off control variable is replaced by a continuous priority parameter. Advantages of such approximation include elimination of the need for binary variables, lower time resolution requirements, and more flexibility and robustness in a decision environment. It also resolves the issue of discontinuous travel time functions arising from the context of dynamic traffic assignment.

Fast algorithms to generate individualized designs for the mixed logit choice model

- Transportation Research Part B: Methodological---2014---Marjolein Crabbe,Deniz Akinc,Martina Vandebroek

The mixed logit choice model has become the common standard to analyze transport behavior. Moreover, more and more transport studies start to make use of stated preference data to obtain precise knowledge on travelers' preferences. Accounting for the individual-specific coefficients in the mixed logit choice model, this research advocates an individualized design approach to generate these stated choice experiments. Individualized designs are sequentially generated for each person separately, using the answers from previous choice sets to select the next best set in a survey. In this way they are adapted to the specific preferences of an individual and therefore more efficient than an aggregate design. In order for individual sequential designs to be practicable, the speed of designing an additional choice set in an experiment is obviously a key issue. This paper introduces three design criteria used in optimal test design, based on Kullback–Leibler information, and compares them with the well known D-efficiency criterion to obtain individually adapted choice designs for the mixed logit choice model. Being equally efficient to D-efficiency and at the same time much faster, the Kullback–Leibler criteria are well suited for the design of individualized choice experiments.

Recent developments and research needs in modeling lane changing

- Transportation Research Part B: Methodological---2014---Zuduo Zheng

This paper comprehensively reviews recent developments in modeling lane-changing behavior. The major lane changing models in the literature are categorized into two groups: models that aim to capture the lane changing decision-making process, and models that aim to quantify the impact of lane changing behavior on surrounding vehicles. The methodologies and important features (including their limitations) of representative models in each category are outlined and discussed. Future research needs are determined.

Effects of high-speed rail and airline cooperation under hub airport capacity constraint

- Transportation Research Part B: Methodological---2014---Changmin Jiang,Anming Zhang

This paper analyzes the effects of cooperation between a hub-and-spoke airline and a high-speed rail

(HSR) operator when the hub airport may be capacity-constrained. We find that such cooperation reduces traffic in markets where prior modal competition occurs, but may increase traffic in other markets of the network. The cooperation improves welfare, independent of whether or not the hub capacity is constrained, as long as the modal substitutability in the overlapping markets is low. However, if the modal substitutability is high, then hub capacity plays an important role in assessing the welfare impact: If the hub airports are significantly capacity-constrained, the cooperation improves welfare; otherwise, it is likely welfare reducing. Through simulations we further study the welfare effects of modal asymmetries in the demands and costs, heterogeneous passenger types, and economies of traffic density. Our analysis shows that the economies of traffic density alone cannot justify airline–HSR cooperation.

Stochastic service network design with rerouting

- Transportation Research Part B: Methodological---2014---Ruibin Bai,Stein Wallace,Jingpeng Li,Alain Yee-Loong Chong

Service network design under uncertainty is fundamentally crucial for all freight transportation companies. The main challenge is to strike a balance between two conflicting objectives: low network setup costs and low expected operational costs. Together these have a significant impact on the quality of freight services. Increasing redundancy at crucial network links is a common way to improve network flexibility. However, in a highly uncertain environment, a single predefined network is unlikely to suit all possible future scenarios, unless it is prohibitively costly. Hence, rescheduling is often an effective alternative. In this paper, we proposed a new stochastic freight service network design model with vehicle rerouting options. The proposed model explicitly introduces a set of integer variables for vehicle rerouting in the second stage of the stochastic program. Although computationally more expensive, the resultant model provides more options (i.e. rerouting) and flexibility for planners to deal with uncertainties more effectively. The new model was tested on a set of instances adapted from the literature and its performance and characteristics are studied through both comparative studies and detailed analyses at the solution structure level. Implications for practical applications are discussed and further research directions are also provided.

Metaheuristic procedure for a bi-objective supply chain design problem with uncertainty

- Transportation Research Part B: Methodological---2014---Y. Cardona-Valdés,A. Álvarez,J. Pacheco

We consider the design of a two echelon production distribution network with multiple manufacturing plants, distribution centers (DC' s) and a set of candidate warehouses. One of the main contributions of the study is to extend the existing literature by incorporating the demand uncertainty of DC' s within the warehouse location and transportation mode allocation decisions, as well as providing a network design satisfying the both economical and service quality objectives of the decision maker within two echelon supply network setting. In order to take into account the effects of the uncertainty we apply an scenario-based approach and a two-stage stochastic problem is formulated in order to minimize total cost and total service time, simultaneously. Another important contribution is the development of a solution procedure for this bi-objective stochastic problem by applying tabu search within the framework of Multi-objective Adaptive Memory Programming. Results are compared with the optimal Pareto fronts obtained for small instances using the -constraint method and standard branch and bound techniques. Numerical results demonstrate the computational effectiveness of the algorithm proposed. Finally, we include some results that confirm the convenience of including the randomness in the demand parameter.

Capacity optimization of an isolated intersection under the phase swap sorting strategy

- Transportation Research Part B: Methodological---2014---Chiwei Yan,Hai Jiang,Siyang Xie

It is well recognized that the left turn reduces the intersection capacity significantly, because some of the traffic lanes cannot be used to discharge vehicles during its green phases. In this paper, we operationalize the phase swap sorting strategy (Xuan, 2011) to use most, if not all, traffic lanes to discharge vehicles at the intersection cross-section to increase its capacity. We explicitly take into consideration all through, left- and right-turning movements on all arms and formulate the capacity maximization problem as a Binary-Mixed-Integer-Linear-Programming (BMILP) model. The model is efficiently solved by standard branch-and-bound algorithms and outputs optimal signal timings, lane allocations, and other decisions. Numerical experiments show that substantially higher reserve capacity can be obtained under our approach.

Optimal choices of fare collection systems for public transportations: Barrier versus barrier-free

- Transportation Research Part B: Methodological--2014---Yasuo Sasaki

The present study focuses on two major types of fare collection systems for public transportations, barrier and barrier-free, and provides a mathematical framework to evaluate optimal choices between them, i.e., which system can be more profitable for a transit agency. In particular, we consider game-theoretic interactions between the transit agency and passengers for the barrier-free system and suppose that frequencies of free rides of passengers as well as inspections of the transit agency are given as a Nash equilibrium. Then the optimal choice of fare collection system is described as a subgame perfection solution in an extensive form game. We also conduct a comparative static analysis and examine how each parameter can affect the choice. As an application, we use the framework to explain various choices of fare collection systems in our society depending on local circumstances or transportation types.

Airline ambidextrous competition under an emissions trading scheme – A reference-dependent behavioral perspective

- Transportation Research Part B: Methodological--2014---Jiuh-Biing Sheu

This study presents a reference-dependent Hotelling model for analyzing airline competition in pricing and green transportation investment, as well as the resulting financial performance under the European Union emission trading scheme. One feature of the proposed methodology is that it embeds psychological benefits/costs of consumers to characterize consumer attitudes to the increases in airline fare adjustments and improvements in green transportation. This study then investigates the equilibrium solutions for airfare adjustment and green transportation investment margins in different scenarios. The analytical results reveal specific operational conditions under which a cost-efficient airline can gain supreme competitive advantage by increasing both airfare and green transportation investment margins beyond the increases made by competitors under the emission trading scheme, whereas certain specific conditions may favor a cost leadership strategy. Conversely, a cost-inefficient airline can compete with a cost-efficient airline in both market share and profitability using the green transportation investment-differentiation strategy, particularly when consumers perceive the airfare difference as equaling the increased psychological benefit induced by the airline’s green effort.

Competition in complementary transport services

- Transportation Research Part B: Methodological--2014---Derek John Clark,Finn Jørgensen,Terje Andreas Mathisen

For passengers to reach the final destination of the trip it is often necessary to make use of the transport services provided by several firms. When these transport services follow in a natural transport chain they are characterized as complementarities and the firms providing the services can, as for substitutes, to some extent influence the demand facing the other firms by their own behaviour. A model is presented in this paper where two firms compete in complementary transport services differentiated by travel distance. Equilibria are derived for collusion and competition in price and quantity, and these are analyzed with respect to the degree of complementarity and distance. The analysis shows that the influence of type of competition on equilibrium price and quantity increases with the complementarity of the products. Moreover, it is discussed how marginal operating costs for the firms, marginal time cost for the passenger and the type of competition influences whether fares will increase with distance and which of the two firms will set the higher price. The commonly accepted ranking for complements that the collusive price is lower than the Bertrand price is not necessarily true. It is demonstrated that the collusive price of the shorter (longer) distance could be set above (lower) that of price competition. It is also addressed how mark-up of price over marginal cost is influenced by changes in own and competitors distance for the different types of competition.

Unconstrained weibit stochastic user equilibrium model with extensions

- Transportation Research Part B: Methodological---2014---Songyot Kitthamkesorn,Anthony Chen

This study provides an unconstrained minimization program as an alternative formulation for the multinomial weibit (MNW) stochastic user equilibrium (SUE) model that explicitly considers the heterogeneous perception variances with respect to different trip lengths under congested conditions. Qualitative properties of the unconstrained minimization program are given to establish the equivalency and uniqueness of the MNW-SUE solution. The advantage of the unconstrained minimization programming formulation is that it allows the development of a link-based algorithm, which obviates path storage and enumeration. The methodological contributions lie in the derivation of the expected perceived travel cost (or the satisfaction function) that enables the development of an unconstrained MNW-SUE minimization program and a link-based stochastic loading mechanism combined with recent advances in line search strategies in the link-based algorithm. Numerical examples are also provided to illustrate the features of the MNW-SUE model and the link-based algorithm along with several extensions for future research.

Constraint reformulation and a Lagrangian relaxation-based solution algorithm for a least expected time path problem

- Transportation Research Part B: Methodological---2014---Lixing Yang,Xuesong Zhou

Using a sample-based representation scheme to capture spatial and temporal travel time correlations, this article constructs an integer programming model for finding the a priori least expected time paths. We explicitly consider the non-anticipativity constraint associated with the a priori path in a time-dependent and stochastic network, and propose a number of reformulations to establish linear inequalities that can be easily dualized by a Lagrangian relaxation solution approach. The relaxed model is further decomposed into two sub-problems, which can be solved directly by using a modified label-correcting algorithm and a simple single-value linear programming method. Several solution algorithms, including a sub-gradient method, a branch and bound method, and heuristics with additional constraints on Lagrangian multipliers, are proposed to improve solution quality and find approximate optimal solutions. The numerical experiments investigate the quality and computational efficiency of the proposed solution approach.

Formulating the within-day dynamic stochastic traffic assignment problem from a Bayesian perspective

- Transportation Research Part B: Methodological---2014---Chong Wei,Yasuo Asakura,Takamasa Iryo

This study proposes a formulation of the within-day dynamic stochastic traffic assignment problem. Considering the stochastic nature of route choice behavior, we treat the solution to the assignment problem as the conditional joint distribution of route traffic, given that the network is in dynamic stochastic user equilibrium. We acquire the conditional joint probability distribution using Bayes' theorem. A Metropolis–Hastings sampling scheme is developed to estimate the characteristics (e.g., mean and variance) of the route traffic. The proposed formulation has no special requirements for the traffic flow models and user behavior models, and so is easily implemented.

Optimal train routing and scheduling for managing traffic perturbations in complex junctions

- Transportation Research Part B: Methodological---2014---Paola Pellegrini,Grégory Marlière,Joaquin Rodriguez

Real-time traffic management in railway aims to minimize delays after an unexpected event perturbs the operations. It can be formalized as the real-time railway traffic management problem, which seeks for the best train routing and scheduling in case of perturbation, in a given time horizon. We propose a mixed-integer linear programming formulation for tackling this problem, representing the infrastructure with fine granularity. This is seldom done in the literature, unless stringent artificial constraints are imposed for reducing the size of the search space. In a thorough experimental analysis, we assess the impact of the granularity of the representation of the infrastructure on the optimal solution. We tackle randomly generated instances representing traffic in the control area named triangle of Gagny, and instances obtained from the real timetable of the control area including the Lille-Flandres station (both in France) and we consider multiple perturbation scenarios. In these experiments, the negative impact of a rough granularity on the delay suffered by trains is remarkable and statistically significant.

Extreme values, invariance and choice probabilities

- Transportation Research Part B: Methodological---2014---Lars-Göran Mattsson,Jörgen Weibull,Per Olov Lindberg

Since the pioneering work of McFadden (1974), discrete choice random-utility models have become work horses in many areas in transportation analysis and economics. In these models, the random variables enter additively or multiplicatively and the noise distributions take a particular parametric form. We show that the same qualitative results, with closed-form choice probabilities, can be obtained for a wide class of distributions without such specifications. This class generalizes the statistically independent distributions where any two c.d.f.:s are powers of each others to a class that allows for statistical dependence, in a way analogous to how the independent distributions in the MNL models were generalized into the subclass of MEV distributions that generates the GEV choice models. We show that this generalization is sufficient, and under statistical independence also necessary, for the following invariance property: all conditional random variables, when conditioning upon a certain alternative having been chosen, are identically distributed. While some of these results have been published earlier, we place them in a general unified framework that allows us to extend several of the results and to provide proofs that are simpler, more direct and transparent. Well-known results are obtained as special cases, and we characterize the Gumbel, Fréchet and Weibull distributions.

Analysis of common-cause and special-cause variation in the deterioration of transportation infrastructure: A field application of statistical process control for structural health monitoring

- Transportation Research Part B: Methodological---2014---Yikai Chen,David J. Corr,Pablo L. Durango-Cohen

We present a statistical process control framework to support structural health monitoring of transportation infrastructure. We contribute an integrated, generally-applicable (to various types of structural response data) statistical approach that links the literatures on statistical performance modeling and on structural health monitoring. The framework consists of two parts: The first, estimation of statistical models to explain, predict, and control for common-cause variation in the data, i.e., changes, including serial dependence, that can be attributed to usual operating conditions. The ensuing standardized innovation series are analyzed in the second part of the framework, which consists of using Shewhart and Memory Control Charts to detect special-cause or unusual events.

On the periodicity of traffic oscillations and capacity drop: The role of driver characteristics

- Transportation Research Part B: Methodological---2014---Danjue Chen,Soyoung Ahn,Jorge Laval,Zuduo Zheng

This paper shows that traffic hysteresis arises due to variable driver characteristics within each driver and has a profound reproducible impact on the periodicity and development of traffic oscillations and the bottleneck discharge rate. Following an oscillation, traffic initially exhibits lower density and flow; then it evolves toward and eventually exceeds the equilibrium, whereupon another oscillation is instigated by an aggressive driver(s) with relatively small response time and minimum spacing. Thereafter, traffic reverts to lower density and flow and repeats the evolutionary cycle. Aggressive driver behavior also leads to hysteresis loops that induce the upstream propagation of oscillations; with larger hysteresis loops inducing larger oscillation growth. Our finding also suggests that the bottleneck discharge rate can diminish by 8–23% when drivers adopt larger response times in reaction to disturbances. This finding suggests that existing capacity-drop theories, with lane-changes as the main factor, may be incomplete.

A general unconstrained optimization formulation for the combined distribution and assignment problem

- Transportation Research Part B: Methodological---2014---Jia Yao,Anthony Chen,Seungkyu Ryu,Feng Shi

This paper proposes an alternate formulation for the combined distribution and assignment (CDA) problem, which seeks to determine consistent level-of-service and flow values of the trip distribution and traffic assignment steps. The CDA problem is modeled as a hierarchical travel choice problem based on random utility theory, which forms the basis for constructing as a general unconstrained optimization formulation. It has the flexibility to handle general probabilistic distributions (not just the Gumbel distribution) in a hierarchical travel choice structure. Qualitative properties of the general unconstrained CDA formulation are rigorously proved to ensure the equivalence and uniqueness of the solution. Particularly, the model is analyzed for two logit CDA models where the choice probability can be expressed in a closed form. The first logit CDA model with the independently and identically distributed (IID) Gumbel distribution is shown to be equivalent to several well-known existing CDA models. The second logit CDA model handles the independence assumption by accounting for the unobserved similarities among destinations in the destination choice level using a spatially correlated logit model and the route overlapping in the route choice level using the path size logit model. A descent direction algorithm with the self-regulated averaging (SRA) scheme is also developed for solving the unconstrained optimization formulation of two logit CDA models. Numerical experiments are conducted to demonstrate the features of the proposed general unconstrained CDA formulations and the computational performance of the descent SRA algorithm. The results reveal that route overlapping, destination similarity, congestion, and distribution errors can have a significant influence on the network equilibrium flow allocations.

Competitive transit network design in cities with radial street patterns

- Transportation Research Part B: Methodological---2014---Hugo Badia,Miquel Estrada,Francesc Robusté

This paper presents a reformulation of the hybrid model developed by Daganzo (2010) to extend its applicability to a greater number of cities, especially those characterized by a radial street pattern. The new transit network structure is also composed of two types of schemes: radial/circular in the central area and hub and spoke in the periphery. This analytical model defines the optimal network layout through minimizing its objective function, which is composed of agency and user costs. Its decision variables are central area size, headway, line spacing, and stop spacing. In this reformulation, stops with single coverage, those only served by one line, are introduced in the hybrid model to improve spatial accessibility to avoid an increase in agency investment. This model is a tool to design competitive transit systems topologically characterized by simple schemes adapted to the urban structure and concentrated transit flows, and also operatively by high frequencies and speeds. Ultimately, all this allows for easy use and management of transit networks.

The value of service reliability

- Transportation Research Part B: Methodological---2013---Vincent Benezech,Nicolas Coulombel

This paper studies the impact of service frequency and reliability on the choice of departure time and the travel cost of transit users. When the user has (α , β , γ) scheduling preferences, we show that the optimal head start decreases with service reliability, as expected. It does not necessarily decrease with service frequency, however. We derive the value of service headway (VoSH) and the value of service reliability (VoSR), which measure the marginal effect on the expected travel cost of a change in the mean and in the standard deviation of headways, respectively. The VoSH and the VoSR complete the value of time and the value of reliability for the economic appraisal of public transit projects by capturing the specific link between headways, waiting times, and congestion. An empirical illustration is provided, which considers two mass transit lines located in the Paris area.

Daily activity pattern recognition by using support vector machines with multiple classes

- Transportation Research Part B: Methodological---2013---Mahdieh Allahviranloo,Will Recker

The focus of this paper is to learn the daily activity engagement patterns of travelers using Support Vector Machines (SVMs), a modeling approach that is widely used in Artificial intelligence and Machine Learning. It is postulated that an individual' s choice of activities depends not only on socio-demographic characteristics but also on previous activities of individual on the same day. In the paper, Markov Chain models are used to study the sequential choice of activities. The dependencies among activity type, activity sequence and socio-demographic data are captured by employing hidden Markov models. In order to learn model parameters, we use sequential multinomial logit models (MNL) and multiclass Support Vector Machines (K-SVM) with two different dependency structures. In the first dependency structure, it is assumed that type of activity at time 't' depends on the last previous activity and socio-demographic data, whereas in the second structure we assume that activity selection at time 't' depends on all of the individual' s previous activity types on the same day and socio-demographic characteristics. The models are applied to data drawn from a set of California households and a comparison of the accuracy of estimation of activity types and their sequence in the agenda, indicates the superiority of K-SVM models over MNL. Additionally, we show that accuracy in estimating activity patterns increases using different sets of explanatory variables or tuning parameters of the kernel function in K-SVM.

Modeling the time to the next primary and secondary incident: A semi-Markov stochastic process approach

- Transportation Research Part B: Methodological---2013---ManWo Ng,Asad Khattak,Wayne K. Talley

Incidents are notorious for their delays to road users. Secondary incidents – i.e., incidents that occur within a certain temporal and spatial distance from the first/primary incident – can further complicate clearance and add to delays. While there are numerous studies on the empirical analysis of incident data, to the best of our knowledge, an analytical model that can be used for primary and secondary incident management planning that explicitly considers both the stochastic as well as the dynamic nature of traffic does not exist. In this paper, we present such a complementary model using a semi-Markov stochastic process approach. The model allows for unprecedented generality in the modeling of stochastics during incidents on freeways. Particularly, we relax the oftentimes restrictive Poisson assumption (in the modeling of vehicle arrivals, vehicle travel times, and incidence occurrence and recovery times) and explicitly model secondary incidents. Numerical case studies are provided to illustrate the proposed model.

A cost-based maritime container assignment model

- Transportation Research Part B: Methodological---2013---Michael G.H. Bell,Xin Liu,Jeremy Rioult,Panagiotis Angeloudis

A recently proposed frequency-based maritime container assignment model (Bell et al., 2011) seeks an assignment of full and empty containers to paths that minimises expected container travel time, whereas containers are in practice more likely to be assigned to minimise expected cost. A cost-based container assignment model is proposed here. It is assumed that routes and service frequencies are given so ship operating costs are also fixed. The objective is to assign containers to routes to minimise container handling costs, container rental and inventory costs. The constraints in the model are extended to include route as well as port capacities. It is shown that the problem remains a linear program. A numerical example is presented to illustrate the properties of the model. The paper concludes by considering the many applications of the proposed maritime container assignment model.

Optimization models for differentiating quality of service levels in probabilistic network capacity design problems

- Transportation Research Part B: Methodological---2013---Siqian Shen,Zhihao Chen

This paper develops various chance-constrained models for optimizing the probabilistic network design problem (PNDP), where we differentiate the quality of service (QoS) and measure the related network performance under uncertain demand. The upper level problem of PNDP designs continuous/discrete link capacities shared by multi-commodity flows, and the lower level problem differentiates the corresponding QoS for demand satisfaction, to prioritize customers and/or commodities. We consider PNDP variants that have either fixed flows (formulated at the upper level) or recourse flows (at the lower level) according to different applications. We transform each probabilistic model into a mixed-integer program, and derive polynomial-time algorithms for special cases with single-row chance constraints. The paper formulates benchmark stochastic programming models by either enforcing to meet all demand or penalizing unmet demand via a linear penalty function. We compare different models and approaches by testing randomly generated network instances and an instance built on the Sioux–Falls network. Numerical results demonstrate the computational efficacy of the solution approaches and derive managerial insights.

Two-stage stochastic bilevel programming over a transportation network

- Transportation Research Part B: Methodological---2013---S.M. Alizadeh,P. Marcotte,G. Savard

We consider a two-stage stochastic extension of the bilevel pricing model introduced by Labbé et al. (1998). In the first stage, the leader sets tariffs on a subset of arcs of a transportation network, with the aim of maximizing profits while, at the lower level, flows are assigned to cheapest paths of a multicommodity transportation network. In the second stage, the situation repeats itself under the constraint that tariffs should not differ too widely from those set at the first stage, a condition that frequently arises in practice. We analyze properties of the model, provide numerical illustrations, and open avenues for further research into this area.

On the morning commute problem with bottleneck congestion and parking space constraints

- Transportation Research Part B: Methodological---2013---Hai Yang,Wei Liu,Xiaolei Wang,Xiaoning Zhang

Morning commuters choose their departure times based on a combination of factors—the chances of running into bottleneck congestion, the likely schedule delays, and parking space availability. This study investigates the morning commute problem with both bottleneck congestion and parking space constraints. In particular, it considers the situation when some commuters have reserved parking spots while others have to compete for public ones on a first-come-first-served basis. Unlike the traditional pure bottleneck model, the rush-hour dynamic traffic pattern with a binding parking capacity constraint varies with the relative proportions of the two classes of commuters. It is found that an appropriate combination of reserved and unreserved parking spots can temporally relieve traffic congestion at the bottleneck and hence reduce the total system cost, because commuters without a reserved parking spot are compelled to leave home earlier in order to secure a public parking spot. System performance is quantified in terms of the relative proportions of the two classes of commuters and is compared with those in the extreme cases when all auto commuters have to compete for parking and when none of them have to compete for one.

Deconstructing delay: A non-parametric approach to analyzing delay changes in single server queuing systems

- Transportation Research Part B: Methodological---2013---Amy Kim,Mark Hansen

This paper introduces an empirically driven, non-parametric method to isolate and estimate the effects that changes in demand and changes in throughput have on delay – in particular, arrival and departure flight delay at airport runways. Classic queuing concepts were used to develop a method by which an intermediate, or counterfactual, queuing scenario could be constructed, to isolate the delay effects due to shifts in demand and throughput. This method includes the development of a stochastic throughput function that is based entirely on data and has three key features. Firstly, the function relies on non-parametric, empirically-based probability distributions of throughput counts. Secondly, facility capacity needs not be explicitly defined, as it is implicitly included in the probability distributions of throughput. Thirdly, the throughput performance function preserves the effect of factors that cause capacity (and, therefore, throughput) to fluctuate over a given period. Temporal sequences of high, moderate, and low capacity are maintained between the observed and counterfactual scenarios. The method was applied to a case study of the three major New York area airports of LaGuardia (LGA), Newark Liberty (EWR), and John F. Kennedy (JFK), using operational data extracted from the Federal Aviation Administration’s (FAA’s) Aviation System Performance Metrics (ASPM) database. The focus was on the peak summer travel seasons of 2006 and 2007, as these airports experienced record levels of delay in 2007. The results indicate that decreases in both demand and throughput were experienced at LGA and EWR, although the decreases in throughput had more significant effects on operational delays as they increased overall at these airports. At JFK, the increase in departure throughput was not sufficient to offset the increase in departure demands. For arrivals, demand increased and throughput decreased. These trends caused a significant growth in delay at JFK between 2006 and 2007.

Door-to-door travel times in RP departure time choice models: An approximation method using GPS data

- Transportation Research Part B: Methodological---2013---Stefanie Peer,Jasper Knockaert,Paul Koster,Yin-Yen Tseng,Erik Verhoef

A common way to determine values of travel time and schedule delay is to estimate departure time choice models, using stated preference (SP) or revealed preference (RP) data. The latter are used less frequently, mainly because of the difficulties to collect the data required for the model estimation. One main requirement is knowledge of the (expected) travel times for both chosen and unchosen departure time alternatives. As the availability of such data is limited, most RP-based scheduling models only take into account travel times on trip segments rather than door-to-door travel times, or use very rough measures of door-to-door travel times. We show that ignoring the temporal and spatial variation of travel times, and, in particular, the correlation of travel times across links may lead to biased estimates of the value of time (VOT). To approximate door-to-door travel times for which no complete measurement is possible, we develop a method that relates travel times on links with continuous speed measurements to travel times on links where relatively infrequent GPS-based speed measurements are available. We use geographically weighted regression to estimate the location-specific relation between the speeds on these two types of links, which is then used for travel time prediction at different locations, days, and times of the day. This method is not only useful for the approximation of door-to-door travel times in departure time choice models, but is generally relevant for predicting travel times in situations where continuous speed measurements can be enriched with GPS data.

A latent segmentation based multiple discrete continuous extreme value model

- Transportation Research Part B: Methodological--2013---Anae Sobhani,Naveen Eluru,Ahmadreza Faghih-Imani

We examine an alternative method to incorporate potential presence of population heterogeneity within the Multiple Discrete Continuous Extreme Value (MDCEV) model structure. Towards this end, an endogenous segmentation approach is proposed that allocates decision makers probabilistically to various segments as a function of exogenous variables. Within each endogenously determined segment, a segment specific MDCEV model is estimated. This approach provides insights on the various population segments present while evaluating distinct choice regimes for each of these segments. The segmentation approach addresses two concerns: (1) ensures that the parameters are estimated employing the full sample for each segment while using all the population records for model estimation, and (2) provides valuable insights on how the exogenous variables affect segmentation. An Expectation–Maximization algorithm is proposed to address the challenges of estimating the resulting endogenous segmentation based econometric model. A prediction procedure to employ the estimated latent MDCEV models for forecasting is also developed. The proposed model is estimated using data from 2009 National Household Travel Survey (NHTS) for the New York region. The results of the model estimates and prediction exercises illustrate the benefits of employing an endogenous segmentation based MDCEV model. The challenges associated with the estimation of latent MDCEV models are also documented.

Estimating GEV models with censored data

- Transportation Research Part B: Methodological--2013---Jeffrey P. Newman,Mark E. Ferguson,Laurie A. Garrow

We examine the problem of estimating parameters for Generalized Extreme Value (GEV) models when one or more alternatives are censored in the sample data, i.e., all decision makers who choose these censored alternatives are excluded from the sample; however, information about the censored alternatives is still available. This problem is common in marketing and revenue management applications, and is essentially an extreme form of choice-based sampling. We review estimators typically used with GEV models, describe why many of these estimators cannot be used for these censored samples, and present two approaches that can be used to estimate parameters associated with censored alternatives. We detail necessary conditions for the identification of parameters associated exclusively with the utility of censored alternatives. These conditions are derived for single-level nested logit, multi-level nested logit and cross-nested logit models. One of the more surprising results shows that alternative specific constants for multiple censored alternatives that belong to the same nest can still be separately identified in nested logit models. Empirical examples based on simulated datasets demonstrate the large-sample consistency of estimators and provide insights into data requirements needed to estimate these models for finite samples.

Sampling of alternatives in Logit Mixture models

- Transportation Research Part B: Methodological--2013---Cristian Guevara,Moshe E. Ben-Akiva

Employing a strategy of sampling of alternatives is necessary for various transportation models that have to deal with large choice-sets. In this article, we propose a method to obtain consistent, asymptotically normal and relatively efficient estimators for Logit Mixture models while sampling alternatives. Our method is an extension of previous results for Logit and MEV models. We show that the practical application of the proposed method for Logit Mixture can result in a Naïve approach, in which the kernel is replaced by the usual sampling correction for Logit. We give theoretical support for previous applications of the Naïve approach, showing not only that it yields consistent estimators, but also providing its asymptotic distribution for proper hypothesis testing. We illustrate the proposed method using Monte Carlo experimentation and real data. Results provide further evidence that the Naïve approach is suitable and practical. The article concludes by summarizing the findings of this research, assessing their potential impact, and suggesting extensions of the research in this area.

Confidence intervals of willingness-to-pay for random coefficient logit models

- Transportation Research Part B: Methodological--2013---Michiel Bliemer,John Rose

Random coefficient logit (RCL) models containing random parameters are increasingly used for modelling travel choices. Willingness-to-pay (WTP) measures, such as the value of travel time savings (VTTS) are, in the case of RCL models estimated in preference space, ratios of random parameters. In this paper we apply the Delta method to compute the confidence intervals of such WTP measures, taking into account the variance–covariance matrix of the estimates of the distributional parameters. The same Delta method can be applied when the model is estimated in WTP space. Compared to simulation methods such as proposed by Krinsky and Robb, the Delta method is able to avoid most of the simulations by deriving partly analytical expressions for the standard errors. Examples of such computations are shown for different combinations of random distributions.

Transition choice probabilities and welfare analysis in random utility models with imperfect before–after correlation

- Transportation Research Part B: Methodological--2013---Paolo Delle Site,Marco Valerio Salucci

Welfare in random utility models is used to be analysed on the basis of only the expectation of the compensating variation. De Palma and Kilani (De Palma, A., Kilani, K., 2011. Transition choice probabilities and welfare analysis in additive random utility models. Economic Theory 46(3), 427–454) have developed a framework for conditional welfare analysis which provides analytic expressions of transition choice probabilities and associated welfare measures. The contribution is of practical relevance in transportation because it allows to compute shares of shifters and non-shifters and attribute benefits to them in a rigorous way. In De Palma and Kilani (2011) the usual assumption of unchanged random terms before and after is made.

Simulation based population synthesis

- Transportation Research Part B: Methodological---2013---Bilal Farooq,Michel Bierlaire,Ricardo Hurtubia,Gunnar Flötteröd

Microsimulation of urban systems evolution requires synthetic population as a key input. Currently, the focus is on treating synthesis as a fitting problem and thus various techniques have been developed, including

Iterative Proportional Fitting (IPF) and Combinatorial Optimization based techniques. The key shortcomings of these procedures include: (a) fitting of one contingency table, while there may be other solutions matching the available data (b) due to cloning rather than true synthesis of the population, losing the heterogeneity that may not have been captured in the microdata (c) over reliance on the accuracy of the data to determine the cloning weights (d) poor scalability with respect to the increase in number of attributes of the synthesized agents. In order to overcome these shortcomings, we propose a Markov Chain Monte Carlo (MCMC) simulation based approach. Partial views of the joint distribution of agent's attributes that are available from various data sources can be used to simulate draws from the original distribution. The real population from Swiss census is used to compare the performance of simulation based synthesis with the standard IPF. The standard root mean square error statistics indicated that even the worst case simulation based synthesis (SRMSE=0.35) outperformed the best case IPF synthesis (SRMSE=0.64). We also used this methodology to generate the synthetic population for Brussels, Belgium where the data availability was highly limited.

A practically tractable expression of the covariances of the Cross-Nested Logit model

- Transportation Research Part B: Methodological---2013---Vittorio Marzano,Andrea Papola,Fulvio Simonelli,Roberta Vitillo

This paper proposes a practically tractable mathematical procedure for the calculation of the covariances underlying whatever given Cross-Nested Logit (CNL) model, based on the variance of a one-dimensional random variable, whose cumulative distribution function and density probability function are given in closed form. This allows expressing the CNL covariances as a function of just a one-dimensional integral, which can be evaluated easily and effectively by means of standard numerical techniques, implementable also in basic computer spreadsheets. Firstly, a formal theoretical proof of the procedure is illustrated. Then, a comparison with the calculations performed by Marzano and Papola [Marzano, V., Papola, ., 2008. On the covariance structure of the Cross-Nested Logit model. Transportation Research B 42(2), 83–98] is proposed, and details about the practical implementation of the procedure are discussed. Finally, estimation of the CNL model in contexts with prior expectations on covariances/correlations is addressed practically, thanks to the simplification achieved in the calculation of the CNL covariances.

Equilibrium at a bottleneck when long-run and short-run scheduling preferences diverge

- Transportation Research Part B: Methodological---2013---Stefanie Peer,Erik Verhoef

We consider the use of a Vickrey road bottleneck in the context of repetitive scheduling choices, distinguishing between long-run and short-run scheduling preferences. The preference structure reflects that there is a distinction between the (exogenous) 'long-run preferred arrival time', which would be relevant if consumers were unconstrained in the scheduling of their activities, and the 'short-run preferred arrival time', which is the result of an adaptation of travel routines in the face of constraints caused by, in particular, time-varying congestion levels. We characterize the unpriced equilibrium, the social optimum as well as second-best situations where the availability of the pricing instruments is restricted. All of them entail a dispersed distribution of short-run preferred arrival times. We obtain the intriguing results that the dispersion is lower in the social optimum than in the unpriced equilibrium, and that the application of first-best short-run tolls does not induce efficient long-run choices of travel routines.

Ridesharing: The state-of-the-art and future directions

- Transportation Research Part B: Methodological---2013---Masabumi Furuhata,Maged Dessouky,Fernando Ordóñez,Marc-Etienne Brunet,Xiaoqing Wang,Sven Koenig

Although ridesharing can provide a wealth of benefits, such as reduced travel costs, congestion, and consequently less pollution, there are a number of challenges that have restricted its widespread adoption. In fact, even at a time when improving communication systems provide real-time detailed information that could be used to facilitate ridesharing, the share of work trips that use ridesharing has decreased by almost 10% in the past 30years.

Tradable credit schemes on networks with mixed equilibrium behaviors

- Transportation Research Part B: Methodological---2013---Fang He,Yafeng Yin,Nima Shirmohammadi,Nie, Yu (Marco)

This paper analyzes and designs tradable credit schemes on networks with two types of players, namely, a finite number of Cournot–Nash (CN) players and an infinite number of (infinitesimal) Wardrop-equilibrium (WE) players. We first show that there are nonnegative anonymous credit schemes that yield system optimum, when transaction costs are not considered. We then analyze how transaction costs would affect the trading and route-choice behaviors of both CN and WE players, and discuss the equilibrium conditions on the coupled credit market and transportation network in the presence of transaction costs. A variational inequality is formulated to describe the equilibrium and is subsequently applied to a numerical example to assess the impacts of transaction costs on a tradable credit system. As expected, transaction costs reduce the trading volume of credits and change their market price. They also change the way how players respond to credit charges in their route choices and cause efficiency losses to the credit schemes that are previously designed without considering transaction costs. With transaction costs, travel costs of WE players will likely increase while those of CN players may decrease due to their higher adaptability in routing strategies.

Designing heterogeneous sensor networks for estimating and predicting path travel time dynamics: An information-theoretic modeling approach

- Transportation Research Part B: Methodological---2013---Tao Xing,Xuesong Zhou,Jeffrey Taylor

With a particular emphasis on the end-to-end travel time prediction problem, this paper proposes an information-theoretic sensor location model that aims to minimize total travel time uncertainties from a set of point, point-to-point and probe sensors in a traffic network. Based on a Kalman filtering structure, the proposed measurement and uncertainty quantification models explicitly take into account several important sources of errors in the travel time estimation/prediction process, such as the uncertainty associated with prior travel time estimates, measurement errors and sampling errors. By considering only critical paths and limited time intervals, this paper selects a path travel time uncertainty criterion to construct a joint sensor location and travel time estimation/prediction framework with a unified modeling of both recurring and non-recurring traffic conditions. An analytical determinant maximization model and heuristic beam-search algorithm are used to find an effective lower bound and solve the combinatorial sensor selection problem. A number of illustrative examples and one case study are used to demonstrate the effectiveness of the proposed methodology.

Demand uncertainty and airport capacity choice

- Transportation Research Part B: Methodological---2013---Yibin Xiao,Xiaowen Fu,Anming Zhang

This study analyzes the effects of demand uncertainty on airport capacity choices. It shows that demand uncertainty will not change optimal capacity choice if demand variation is low and capacity cost is high; otherwise the optimal airport capacity under demand uncertainty will be larger than the case when a deterministic mean demand is considered. These conclusions are robust with respect to the different market structures considered in this study and hold for both profit-maximizing and welfare-maximizing airports. The moderating effects of commercial revenue, capital cost, and airport operation cost on airport capacity choice are qualitatively the same in the cases of uncertain demand and deterministic demand.

Cost overruns and demand shortfalls – Deception or selection?

- Transportation Research Part B: Methodological---2013---Jonas Eliasson,Mogens Fosgerau

A number of highly cited papers by Flyvbjerg and associates have shown that ex ante infrastructure appraisals tend to be overly optimistic. Ex post evaluations indicate a bias where investment costs are higher and benefits lower on average than predicted ex ante. These authors argue that the bias must be attributed to intentional misrepresentation by project developers. This paper shows that the bias may arise simply as a selection bias, without there being any bias at all in predictions ex ante, and that such a bias is bound to arise whenever ex ante predictions are related to the decisions whether to implement projects. Using a database of projects we present examples indicating that the selection bias may be substantial. The examples also indicate that benefit–cost ratios remain a useful selection criterion even when cost and benefits are highly uncertain, gainsaying the argument that such uncertainties render cost-benefit analyses useless.

A kinematic wave approach to traffic statics and dynamics in a double-ring network

- Transportation Research Part B: Methodological---2013---Wen-Long Jin,Qi-Jian Gan,Vikash V. Gayah

Recently there has been much interest in understanding macroscopic fundamental diagrams of stationary road networks. However, there lacks a systematic method to define and solve stationary states in a road network with complex junctions. In this study we propose a kinematic wave approach to defining, analyzing, and simulating static and dynamic traffic characteristics in a network of two ring roads connected by a 2×2 junction, which can be either an uninterrupted interchange or a signalized intersection. This study is enabled by recently developed macroscopic junction models of general junctions. With a junction model based on fair merging and first-in-first-out diverging rules, we first define and solve stationary states and then derive the macroscopic fundamental diagram (MFD) of a stationary uninterrupted network. We conclude that the flow-density relationship of the uninterrupted double-ring network is not unique for high average network densities (i.e., when one ring becomes congested) and unveil the existence of infinitely many stationary states that can arise with a zero-speed shockwave. From simulation results with a corresponding Cell Transmission Model, we verify that all stationary states in the MFD are stable and can be reached, but show that randomness in the retaining ratio of each ring drives the network to more symmetric traffic patterns and higher flow-rates. Furthermore we model a signalized intersection as two alternate diverge junctions and demonstrate that the signalized double-ring network can reach asymptotically periodic traffic patterns, which are therefore defined as "stationary" states in signalized networks. With simulations we show that the flow-density relation is well defined in such "stationary" states, and asymptotic traffic patterns can be impacted by signal cycle lengths and retaining ratios. But compared with uninterrupted interchanges, signalized intersections lead to more asymmetric traffic patterns, lower flow-rates, and even gridlocks when the average density is higher than half of the jam density. The results are consistent between this study and existing studies, but the network kinematic wave model, with appropriate junction models, is mathematically tractable and physically meaningful. It has offered a more complete picture regarding the number and type of stationary states, their stability, and MFD in freeway and signalized networks.

Traffic state estimation and uncertainty quantification based on heterogeneous data sources: A three detector approach

- Transportation Research Part B: Methodological---2013---Wen Deng,Hao Lei,Xuesong Zhou

This study focuses on how to use multiple data sources, including loop detector counts, AVI Bluetooth travel time readings and GPS location samples, to estimate macroscopic traffic states on a homogeneous freeway segment. With a generalized least square estimation framework, this research constructs a number of linear equations that map the traffic measurements as functions of cumulative vehicle counts on both ends of a traffic segment. We extend Newell's method to solve a stochastic three-detector problem, where the mean and variance estimates of cell-based density and flow can be analytically derived through a multinomial probit model and an innovative use of Clark's approximation method. An information measure is further introduced to quantify the value of heterogeneous traffic measurements for improving traffic state estimation on a freeway segment.

Optimal biofuel supply chain design under consumption mandates with renewable identification numbers

- Transportation Research Part B: Methodological---2013---Xiaolei Wang,Yanfeng Ouyang,Hai Yang,Yun Bai

The Renewable Identification Number (RIN) system is a tracking mechanism that enforces the U.S. Renewable Fuel Standard by monitoring obligated parties' compliance with the biofuel consumption mandates. This paper incorporates the RIN system into the design of a biofuel supply chain that addresses independent decisions of non-cooperative farmers, biofuel manufacturers, and blenders. Game-theoretic models are developed to examine the impacts of the RIN system on individual stakeholders' decisions (e.g., on farmland use, bio-refinery investment, biofuel production) and the competition between food and biofuel industries, in both a perfectly competitive scenario and a monopoly scenario. For the perfectly competitive scenario, Nash equilibrium can be obtained by solving a convex optimization problem. For the monopoly scenario, a bi-level Stackelberg leader–follower model is developed, from which we found that a rigid mandate on blenders may suppress the total biofuel production. To avoid such unintended consequences, a relaxed unit-RIN based penalty scheme is proposed and shown to improve the overall biofuel supply chain performance. Managerial insights are drawn from a numerical case study for the state of Illinois.

A corridor-centric approach to planning electric vehicle charging infrastructure

- Transportation Research Part B: Methodological---2013---Nie, Yu (Marco),Mehrnaz Ghamami

The transition to electric vehicles (EV) faces two major barriers. On one hand, EV batteries are still expensive and limited by range, owing to the lack of technology breakthrough. On the other hand, the underdeveloped supporting infrastructure, particularly the lack of fast refueling facilities, makes EVs unsuitable for medium and long distance travel. The primary purpose of this study is to better understand these hurdles and to develop strategies to overcome them. To this end, a conceptual optimization model is proposed to analyze travel by EVs along a long corridor. The objective of the model is to select the battery size and charging capacity (in terms of both the charging power at each station and the number of stations needed along the corridor) to meet a given level of service in such a way that the total social cost is minimized. Two extensions of the base model are also considered. The first relaxes the assumption that the charging power at the stations is a continuous variable. The second variant considers battery swapping as an alternative to charging. Our analysis suggests that (1) the current paradigm of charging facility development that focuses on level 2 charging delivers poor level of service for long distance travel; (2) the level 3 charging method is necessary not only to achieve a reasonable level of service, but also to minimize the social cost; (3) investing on battery technology to reduce battery cost is likely to have larger impacts on reducing the charging cost; and (4) battery swapping promises high level of service, but it may not be socially optimal for a modest level of service, especially when the costs of constructing swapping and charging stations are close.

Stability and bifurcation in network traffic flow: A Poincaré map approach

- Transportation Research Part B: Methodological---2013---Wen-Long Jin

Previous studies have shown that, in a diverge-merge network with two intermediate links (the DM network), the kinematic wave model always admits stationary solutions under constant boundary conditions, but periodic oscillations can develop from empty initial conditions. Such contradictory observations suggest that the stationary states be unstable. In this study we develop a systematic approach to investigate the stability property of stationary states in this and other networks within the framework of network kinematic wave theories. Based on the observation that kinematic waves propagate in a circular path when only one of the two intermediate links is congested, we derive a one-dimensional, discrete Poincaré map in the out-flux at a Poincaré section. We then prove that the fixed points of the Poincaré map correspond to stationary flow-rates on the two links. With Lyapunov's first method, we demonstrate that the Poincaré map can be finite-time stable, asymptotically stable, or unstable. When unstable, the map is found to have periodical points of period two, but no chaotic solutions. We further analyze the bifurcation in the stability of the Poincaré map caused by varying route choice proportions. We apply the Poincaré map approach to analyzing traffic patterns in more general (DM)n and beltway networks, which are sufficient and necessary structures for network-induced unstable traffic and gridlock, respectively. This study demonstrates that the Poincaré map approach can be efficiently applied to analyze traffic dynamics in any road networks with circular information propagation and provides new insights into unstable traffic dynamics caused by interactions among network bottlenecks.

Rationing and pricing strategies for congestion mitigation: Behavioral theory, econometric model, and application in Beijing

- Transportation Research Part B: Methodological---2013---Shanjiang Zhu,Longyuan Du,Lei Zhang

Some travel demand management policies such as road pricing have been widely studied in literature. Rationing policies, including vehicle ownership quota and vehicle usage restrictions, have been implemented in several megaregions to address congestion and other negative transportation externalities, but not well explored in literature. Other strategies such as Vehicle Mileage Fee have not been well accepted by policy makers, but attract growing research interest. As policy makers face an increasing number of policy tools, a theoretical framework is needed to analyze these policies and provide a direct comparison of their welfare implications such as efficiency and equity. However, such a comprehensive framework does not exist in literature. To bridge this gap, this study develops an analytical framework for analyzing and comparing travel demand management policies, which consists of a mathematical model of joint household vehicle ownership and usage decisions and welfare analysis methods based on compensating variation and consumer surplus. Under the assumptions of homogenous users and single time period, this study finds that vehicle usage rationing performs better when relatively small percentages of users (i.e. low rationing ratio) are rationed off the roads and when induced demand elasticity resulting from congestion mitigation is low. When the amount of induced demand exceeds a certain level, it is shown analytically that vehicle usage restrictions will always cause welfare losses. When the policy goal is to reduce vehicle travel by a fixed portion, road pricing provides a larger welfare gain. The performance of different policies is influenced by network congestion and congestibility. This paper further generalizes the model to consider heterogenous users and demonstrates how it can be applied for policy analysis on a real network after careful calibration.

Sensitivity-based uncertainty analysis of a combined travel demand model

- Transportation Research Part B: Methodological---2013---Chao Yang,Anthony Chen,Xiangdong Xu,S.C. Wong

Travel demand forecasting is subject to great uncertainties. A systematic uncertainty analysis can provide insights into the level of confidence on the model outputs, and also identify critical sources of uncertainty for enhancing the robustness of the travel demand model. In this paper, we develop a systematic framework for quantitative uncertainty analysis of a combined travel demand model (CTDM) using the analytical sensitivity-based method. The CTDM overcomes limitations of the sequential four-step procedure since it is based on a single unifying rationale. The analytical sensitivity-based method requires less computational effort than the sampling-based method. Meanwhile, the uncertainties stemming from inputs and parameters can be treated separately so that the individual and collective effects of uncertainty on the outputs can be clearly assessed and quantified. Numerical examples are finally used to demonstrate the proposed sensitivity-based uncertainty analysis method for the CTDM.

A variational formulation for higher order macroscopic traffic flow models of the GSOM family

- Transportation Research Part B: Methodological---2013---Jean-Patrick Lebacque,Megan M. Khoshyaran

The GSOM (Generic second order modelling) family of traffic flow models combines the LWR model with dynamics of driver-specific attributes and can be expressed as a system of conservation laws. The object of the paper is to show that a proper Lagrangian formulation of the GSOM model can be recast as a Hamilton–Jacobi equation, the solution of which can be expressed as the value function of an optimal control problem. This value function is interpreted as the position of vehicles, and the optimal trajectories of the optimal control formulation can be identified with the characteristics. Further the paper analyzes the initial and boundary conditions, proposes a generalization of the inf-morphism and the Lax–Hopf formulas to the GSOM model, and considers numerical aspects.

Dynamic user equilibrium in public transport networks with passenger congestion and hyperpaths

- Transportation Research Part B: Methodological---2013---Valentina Trozzi,Guido Gentile,Michael G.H. Bell,Ioannis Kaparias

This paper presents a dynamic user equilibrium for bus networks where recurrent overcrowding results in queues at stops. The route-choice model embedded in the dynamic assignment explicitly considers common lines and strategies with alternative routes. As such, the shortest hyperpath problem is extended to a dynamic scenario with capacity constraints where the diversion probabilities depend on the time at which the stop is reached and on the expected congestion level at that time. In order to reproduce congestion for all the lines sharing a stop, the Bottleneck Queue Model with time-varying exit capacity, introduced in Meschini et al. (2007), is extended. The above is applied to separate queues for each line in order to satisfy the First-In-First-Out principle within every attractive set, while allowing overtaking among passengers with different attractive sets but queuing single file. The application of the proposed model to a small example network clearly reproduces the formation and dispersion of passenger queues due to capacity constraints and thus motivates the implementation of the methodology on a real-size network case as the next step for future research.

The evening commute with cars and transit: Duality results and user equilibrium for the combined morning and evening peaks

- Transportation Research Part B: Methodological---2013---Eric J. Gonzales,Carlos F. Daganzo

This paper extends Vickrey’s (1969) commute problem for commuters wishing to pass a bottleneck for both cars and transit that share finite road capacity.

In addition to this more general framework considering two modes, the paper focuses on the evening rush, when commuters travel from work to home. Commuters choose which mode to use and when to travel in order to minimize the generalized cost of their own trips, including queueing delay and penalties for deviation from a preferred schedule of arrival and departure to and from work. The user equilibrium for the isolated morning and evening commutes are shown to be asymmetric because the schedule penalty in the morning is the difference between the departure and wished curves, and the schedule penalty in the evening is the difference between the arrival and wished curves. It is shown that the system optimum in the morning and evening peaks are symmetric because queueing delay is eliminated and the optimal arrival curves are the same as the departure curves.

Boundedly rational user equilibria (BRUE): Mathematical formulation and solution sets

- Transportation Research Part B: Methodological---2013---Xuan Di,Henry X. Liu,Jong-Shi Pang,Ban, Xuegang (Jeff)

Boundedly rational user equilibria (BRUE) represent traffic flow distribution patterns where travellers can take any route whose travel cost is within an 'indifference band' of the shortest path cost. Those traffic flow patterns satisfying the above condition constitute a set, named the BRUE solution set. It is important to obtain all the BRUE flow patterns, because it can help predict the variation of the link flow pattern in a traffic network under the boundedly rational behavior assumption. However, the methodology of constructing the BRUE set has been lacking in the established literature. This paper fills the gap by constructing the BRUE solution set on traffic networks with fixed demands. After defining ε-BRUE, where ε is the indifference band for the perceived travel cost, we formulate the ε-BRUE problem as a nonlinear complementarity problem (NCP), so that a BRUE solution can be obtained by solving a BRUE–NCP formulation. To obtain the BRUE solution set encompassing all BRUE flow patterns, we propose a methodology of generating acceptable path set which may be utilized under the boundedly rational behavior assumption. We show that with the increase of the indifference band, the acceptable path set that contains boundedly rational equilibrium flows will be augmented, and the critical values of indifference band to augment these path sets can be identified by solving a family of mathematical programs with equilibrium constraints (MPEC) sequentially. The BRUE solution set can then be obtained by assigning all traffic demands to the acceptable path set. Various numerical examples are given to illustrate our findings.

The variational formulation of a non-equilibrium traffic flow model: Theory and implications

- Transportation Research Part B: Methodological---2013---Jia Li,H.M. Zhang

The analysis and numerical solution of non-equilibrium traffic flow models in current literature are almost exclusively carried out in the hyperbolic conservation law framework, which requires a good understanding of the delicate and non-trivial Riemann problems for conservation laws. In this paper, we present a novel formulation of certain non-equilibrium traffic flow models based on their isomorphic relation with optimal control problems. This formulation extends the minimum principle observed by the LWR model. We demonstrate that with the new formulation, generic initial-boundary conditions can be conveniently handled and a simplified numerical solution scheme for non-equilibrium models can be devised. Besides deriving the variational formulation, we provide a comprehensive discussion on its mathematical properties and physical implications.

On the distribution of urban road space for multimodal congested networks

- Transportation Research Part B: Methodological---2013---Nan Zheng,Nikolas Geroliminis

Transport systems in real cities are complex with many modes of transport sharing and competing for limited road space. This work intends to understand how space distributions for modes and interactions among modes affect network traffic performance. While the connection between performance of transport systems and general land allocation is the subject of extensive research, space allocation for interacting modes of transport is an open research question. Quantifying the impact of road space distribution on the performance of a congested multimodal transport system with a dynamic aggregated model remains a challenge. In this paper, a multimodal macroscopic fundamental diagram (MFD) is developed to represent the traffic dynamics of a multimodal transport system. Optimization is performed with the objective of minimizing the total passenger hours traveled (PHT) to serve the total demand by redistributing road space among modes. Pricing strategies are also investigated to provide a higher demand shift to more efficient modes. We find by an application to a bi-modal two-region city that (i) the proposed model captures the operational characteristics of each mode, and (ii) optimal dynamic space distribution strategies can be developed. In practice, the approach can serve as a physical dynamic model to inform space distribution strategies for policy makers with different goals of mobility.

Modelling route choice behaviour in a tolled road network with a time surplus maximisation bi-objective user equilibrium model

- Transportation Research Part B: Methodological---2013---Judith Y.T. Wang,Matthias Ehrgott

In this paper, we propose a novel approach to model route choice behaviour in a tolled road network with a bi-objective approach, assuming that all users have two objectives: (1) minimise travel time; and (2) minimise toll cost. We assume further that users have different preferences in the sense that for any given path with a specific toll, there is a limit on the time that an individual would be willing to spend. Different users can have different preferences represented by this indifference curve between toll and time. Time surplus is defined as the maximum time minus the actual time. Given a set of paths, the one with the highest (or least negative) time surplus will be the preferred path for the individual. This will result in a bi-objective equilibrium solution satisfying the time surplus maximisation bi-objective user equilibrium (TSmaxBUE) condition. That is, for each O–D pair, all individuals are travelling on the path with the highest time surplus value among all the efficient paths between this O–D pair.

A multi-commodity Lighthill–Whitham–Richards model of lane-changing traffic flow

- Transportation Research Part B: Methodological---2013---Wen-Long Jin

Systematic lane changes can seriously deteriorate traffic safety and efficiency inside lane-drop, merge, and other bottleneck areas. In our previous studies (Jin, 2010a,b), a phenomenological model of lane-changing traffic flow was proposed, calibrated, and analyzed based on a new concept of lane-changing intensity. In this study, we further consider weaving and non-weaving vehicles as two commodities and develop a multi-commodity, behavioral Lighthill–Whitham–Richards (LWR) model of lane-changing traffic flow. Based on a macroscopic model of lane-changing behaviors, we derive a fundamental diagram with parameters determined by car-following and lane-changing characteristics as well as road geometry and traffic composition. We further calibrate and validate fundamental diagrams corresponding to a triangular car-following fundamental diagram with NGSIM data. We introduce an entropy condition for the multi-commodity LWR model and solve the Riemann problem inside a homogeneous lane-changing area. From the Riemann solutions, we derive a flux function in terms of traffic demand and supply. Then we apply the model to study lane-changing traffic dynamics inside a lane-drop area and show that the smoothing effect of HOV lanes is consistent with observations in existing studies. The new theory of lane-changing traffic flow can be readily incorporated into Cell Transmission Model, and this study could lead to better strategies for mitigating bottleneck effects of lane-changing traffic flow.

A path-size weibit stochastic user equilibrium model

- Transportation Research Part B: Methodological---2013---Songyot Kitthamkesorn,Anthony Chen

The aim of this paper is to develop a path-size weibit (PSW) route choice model with an equivalent mathematical programming (MP) formulation under the stochastic user equilibrium (SUE) principle that can account for both route overlapping and route-specific perception variance problems. Specifically, the Weibull distributed random error term handles the identically distributed assumption such that the perception variance with respect to different trip lengths can be distinguished, and a path-size factor term is introduced to resolve the route overlapping issue by adjusting the choice probabilities for routes with strong couplings with other routes. A multiplicative Beckmann's transformation (MBec) combined with an entropy term are used to develop the MP formulation for the PSW-SUE model. A path-based algorithm based on the partial linearization method is adopted for solving the PSW-SUE model. Numerical examples are also provided to illustrate features of the PSW-SUE model and its differences compared to some existing SUE models as well as its applicability on a real-size network.

On activity-based network design problems

- Transportation Research Part B: Methodological---2013---Jee Eun Kang,Joseph Y.J. Chow,Will W. Recker

This paper examines network design where OD demand is not known a priori, but is the subject of responses in household or user itinerary choices to infrastructure improvements. Using simple examples, we show that falsely assuming that household itineraries are not elastic can result in a lack in understanding of certain phenomena; e.g., increasing traffic even without increasing economic activity due to relaxing of space–time prism constraints, or worsening of utility despite infrastructure investments in cases where household objectives may conflict. An activity-based network design problem is proposed using the location routing problem (LRP) as inspiration. The bilevel formulation includes an upper level network design and shortest path problem while the lower level includes a set of disaggregate household itinerary optimization problems, posed as household activity pattern problem (HAPP) (or in the case with location choice, as generalized HAPP) models. As a bilevel problem with an NP-hard lower level problem, there is no algorithm for solving the model exactly. Simple numerical examples show optimality gaps of as much as 5% for a decomposition heuristic algorithm derived from the LRP. A large numerical case study based on Southern California data and setting suggest that even if infrastructure investments do not result in major changes in link investment decisions compared to a conventional model, the results provide much higher resolution temporal OD information to a decision maker. Whereas a conventional model would output the best set of links to invest given an assumed OD matrix, the proposed model can output the same best set of links, the same daily OD matrix, and a detailed temporal distribution of activity participation and travel from which changes in peak period OD patterns can be observed.

Bicriterion shortest path problem with a general nonadditive cost

- Transportation Research Part B: Methodological---2013---Peng Chen,Nie, Yu (Marco)

A bicriterion shortest path problem with a general nonadditive cost seeks to optimize a combination of two path costs, one of which is evaluated by a nonlinear function. This paper first identifies a number of emerging transportation applications for which such a shortest path problem might be considered a core subproblem. We propose to first approximate the general nonlinear cost function with a piecewise linear counterpart, and then solve each linear subproblem sequentially. A specialized algorithm is developed to solve the subproblems, which makes use of the efficient path set (or the convex hull) to update upper and lower bounds of the original problem. Conditions under which the solution to a subproblem must belong to the efficient path set are specified. Accordingly, we show that the optimal path must be efficient if the nonlinear cost function is concave. If the optimal path to a subproblem is not efficient, partial path enumeration, implemented using a simple K-shortest path ranking procedure, is conducted to close the gap. The proposed algorithm includes strategies aiming to expedite path enumeration by using upper bounds derived from the efficient path set. Numerical experiments are conducted to demonstrate correctness and effectiveness of the proposed algorithm.

Continuous price and flow dynamics of tradable mobility credits

- Transportation Research Part B: Methodological---2013---Hongbo Ye,Hai Yang

This study examines the price and flow dynamics under a tradable credit scheme, when the credits can be traded in a free market. A continuous dynamic model in a finite time horizon is proposed to describe the travelers' learning behavior and the evolution of network flows and credit price, and then the existence and uniqueness of the equilibria are established. The conditions for stability and convergence of the dynamic system as the time horizon extends to infinity and the impact of limited implementation time horizon on the system behavior are investigated.

On joint railway and housing development strategy

- Transportation Research Part B: Methodological---2013---Xiaosu Ma,Hong K. Lo

Transit Oriented Development (TOD) with railway service is recognized as a sustainable mode of development for highly dense megacities. In addition to providing safe and efficient transit services, reducing auto dependence and therefore less need for highway expansions, the improved accessibility of TOD influences commuters' residential location choices and the resultant housing value. Traditionally, statistical approaches have been used to estimate the relationship between railway development and housing value for individual sites. To some degree, TOD has also been studied with integrated land-use transport models. While useful, they lack an analytical framework to study the region-wide impacts of TOD on residential location and travel choices and the resultant land value changes. In this study, the joint railway and housing development strategy is modeled based on a combined equilibrium formulation with the bid-rent process. The problem is formulated as a mathematical program with equilibrium constraints, in which the upper level optimizes the objective for the joint development strategy by deciding on the combination of housing supplies and railway service levels. Analytical results are obtained for a single corridor in a multi-modal transport network, which are further illustrated by sensitivity analyses. A numerical example is constructed to demonstrate the approach and compare with other separate development strategies. The results generally confirm the synergy between railway and housing developments.

Estimating MFDs in simple networks with route choice

- Transportation Research Part B: Methodological---2013---Ludovic Leclercq,Nikolas Geroliminis

The concept of the Macroscopic Fundamental Diagram (MFD) is elegant and attractive because it provides a global view of traffic behavior and performance at a network level. However, recent research shows that the MFD shape can be influenced by local traffic heterogeneities. Notably, route choices and heterogeneous local capacities may drive uneven (in space) or inconsistent (in time) distributions of congestion and then affect the shape and the scatter of the MFD. We are far from having a global understanding of the connections between local phenomena and the resulting MFD. This paper first aims to improve existing MFD estimation method for a succession of links with traffic signals. The new method overcomes previous limitations, notably regarding to the topology and signal settings regularities, by fully utilizing the receipts of the variational theory. Then, a single network with several parallel routes is investigated. MFDs on different routes are estimated with the variational method and then aggregated in a unified MFD for stationary and dynamic conditions and different sorts of equilibria (user and system optimum). It appears that the flow distribution among routes smoothly varies with respect to the total flow either in free-flow or congestion situations. Such a distribution is much more rough for system optimum, where it presents some discontinuities and is far from equity. This means that a control strategy able to lead such a network to the perfect system optimum would be hard to tune, especially in the congested regime. However, being able to determine the MFD corresponding to the system optimum provides a valuable reference to estimate the current efficiency of the considered network. Case studies for different simple networks and insights for generalization at the city level are proposed.

Computational precision of traffic equilibria sensitivities in automatic network design and road pricing

- Transportation Research Part B: Methodological---2013---Hillel Bar-Gera,Fredrik Hellman,Michael Patriksson

Recent studies demonstrate the importance of computational precision of user equilibrium traffic assignment solutions for scenario comparisons. When traffic assignment is hierarchically embedded in a model for network design and/or road pricing, not only the precision of the solution itself becomes more important, but also the precision of its derivatives with respect to the design parameters should be considered.

Managing bottleneck congestion with tradable credits

- Transportation Research Part B: Methodological---2013---Feng Xiao,Qian, Zhen (Sean),H. Michael Zhang

We demonstrate the efficiency and effectiveness of a tradable credit system in managing the morning commute congestion with identical and nonidentical commuters. The credit system consists of a time-varying credit charged at the bottleneck and an initial credit distribution to the commuters, where the credits are universal in terms of time. Credits are tradable between the commuters and the credit price is determined by a competitive market. Under the assumption that late-arrival is not allowed, we prove that an optimal credit charging scheme, which completely eliminates the bottleneck queue, always exists despite how commuters vary in their value-of-time (VOT). The optimal charge rate is strictly increasing and convex with time, which therefore drives the commuters to depart in the increasing order of their VOT. The optimal credit charging scheme is pareto-improving, but may cause undesirable welfare distribution among the commuters. Our study shows that a combination of an initial credit distribution and an optimal credit charging scheme can simultaneously achieve system optimum and certain forms of equality (e.g., “numerical” or “proportional” equality), and that the commuters in the middle VOT bracket will receive the most credits under the proportionally equitable credit distribution.

Quadratic approximation and convergence of some bush-based algorithms for the traffic assignment problem

- Transportation Research Part B: Methodological---2013---Jun Xie,Nie, Yu (Marco),Xiaoguang Yang

This paper first shows that LUCE (Gentile, 2012), a recent addition to the family of bush-based algorithms, is closely related to OBA (Bar-Gera, 2002). LUCE’s promise comes mainly from its use of the greedy method for solving the quadratic approximation of node-based subproblems, which determines the search direction. While the greedy algorithm accelerates the solution of the subproblems and reduces the cost of line search, it unexpectedly disrupts the overall convergence performance in our experiments, which consistently show that LUCE failed to converge beyond certain threshold of relative gap. Our analysis suggests that the root cause to this interesting behavior is the inaccurate quadratic approximation constructed on faulty information of second-order derivatives. Because the quadratic approximations themselves are inaccurate, the search directions generated from them are sub-optimal. Unlike OBA, however, LUCE does not have a mechanism to correct these search directions through line search, which explains why its convergence performance suffers the observed breakdowns. We also attempt to improve LUCE using the ideas that have been experimented for the improvement of OBA. While these improvements do work, their effects are not enough to counteract the inability to adjust sub-optimal search directions. Importantly, the fact that the search direction has to be corrected in line search to ensure smooth convergence attests to the limitation of origin-based flow aggregation shared by both OBA and LUCE. These findings offer guidelines for the design of high performance traffic assignment algorithms.

Optimal pricing for build-to-order supply chain design under price-dependent stochastic demand

- Transportation Research Part B: Methodological---2013---Cheng-Chang Lin,Yi-Chen Wu

Build to order (BTO) is a supply chain disruption mitigation strategy. Whereas cost minimization is an operational objective, the goal of the BTO manufacturer is to maximize its profit by using pricing as its competitive decision-making strategy. In this paper, we study a BTO manufacturer who simultaneously determines its product prices and designs its supply chain network to maximize its expected profit under price-dependent stochastic demand. We propose an L-shaped decomposition with complete enumeration to solve for optimality and show that the expanded master problem remains convex programming, although the optimality cuts are quadratic inequalities. The computational results demonstrate that stocking up on differentiated components and allocating modules appropriately to meet realized demand is a resilient policy that sustains variations in demand. Furthermore, the pricing decision balances the expected revenue and expected operating cost with an increase in expected profit. The integration of pricing and operational planning results in a higher expected profit than by individual decisions. We also demonstrate that cost minimization may not provide the same level of profit if the manufacturer overestimates or underestimates its most profitable demand.

Privacy protection method for fine-grained urban traffic modeling using mobile sensors

- Transportation Research Part B: Methodological---2013---Zhanbo Sun,Bin Zan,Ban, Xuegang (Jeff),Marco Gruteser

With the ubiquitous nature of mobile sensing technologies, privacy issues are becoming increasingly important, and need to be carefully addressed. Data needs for transportation modeling and privacy protection should be deliberately balanced for different applications. This paper focuses on developing privacy mechanisms that would simultaneously satisfy privacy protection and data needs for fine-grained urban traffic modeling applications using mobile sensors. To accomplish this, a virtual trip lines (VTLs) zone-based system and related filtering approaches are developed. Traffic-knowledge-based adversary models are proposed and tested to evaluate the effectiveness of such a privacy protection system by making privacy attacks. The results show that in addition to ensuring an acceptable level of privacy, the released datasets from the privacy-enhancing system can also be applied to urban traffic modeling with satisfactory results. Albeit application-specific, such a “Privacy-by-Design” approach would hopefully shed some light on other transportation applications using mobile sensors.

A link based network route choice model with unrestricted choice set

- Transportation Research Part B: Methodological---2013---Mogens Fosgerau,Emma Frejinger,Anders Karlstrom

This paper considers the path choice problem, formulating and discussing an econometric random utility model for the choice of path in a network with no restriction on the choice set. Starting from a dynamic specification of link choices we show that it is equivalent to a static model of the multinomial logit form but with infinitely many alternatives. The model can be consistently estimated and used for prediction in a computationally efficient way. Similarly to the path size logit model, we propose an attribute called link size that corrects utilities of overlapping paths but that is link additive. The model is applied to data recording path choices in a network with more than 3000 nodes and 7000 links.

Prospect Theory for joint time and money consequences in risk and ambiguity

- Transportation Research Part B: Methodological---2013---Emmanuel Kemel,Corina Paraschiv

Transport users face complex decisions. Not only are the consequences of their choices uncertain, but they generally involve several attributes, such as time and money. Time-money tradeoffs have been studied in depth in transport economics, and research is now paying increasing attention to the role of uncertainty and information in transport decisions. This paper aims to measure the impact of uncertainty and information on multi-attribute decisions using Prospect Theory. In doing so, the study makes two contributions to transportation literature: one methodological and the other empirical. First, we propose a fast and tractable method for measuring Prospect Theory parameters that capture attitudes towards probabilities (probability weighting function) and attitudes towards losses (loss aversion). The elicitation method does not require the elicitation of the utility function. This makes it particularly suitable in complex multi-attribute decisions where the shape of the utility function is unknown. Second, we present the results of an experiment that uses the proposed method to measure, at the individual level, probability weighting in decisions involving joint time and money consequences in two decision contexts: risk (where probabilities are given) and ambiguity (where the probability distribution is unknown). An experimental setup that exposes subjects to real gains and losses for money and time has been built for this purpose. We observe inverse S-shaped probability weighting and loss aversion for risk. Probability weighting is even more pronounced in ambiguity, where subjects do not have precise information about the probability distribution. We explain how these results and the analysis of ambiguity attitudes in general can offer a better understanding of travelers' route or transport mode choices.

Revisiting Jiang's dynamic continuum model for urban cities

- Transportation Research Part B: Methodological---2013---Jie Du,S.C. Wong,Chi-Wang Shu,Tao Xiong,Mengping Zhang,Keechoo Choi

Jiang et al. (Jiang, Y.Q., Wong, S.C., Ho, H.W., Zhang, P., Liu, R.X., Sumalee, A., 2011. A dynamic traffic assignment model for a continuum transportation system. Transportation Research Part B 45 (2), 343–363) proposed a predictive continuum dynamic user-optimaDUO-l to investigate the dynamic characteristics of traffic flow and the corresponding route-choice behavior of travelers. Their modeled region is a dense urban city that is arbitrary in shape and has a single central business district (CBD). However, we argue that the model is not well posed due to an inconsistency in the route-choice strategy under certain conditions. To overcome this inconsistency, we revisit the PDUO-C problem, and construct an improved path-choice strategy. The improved model consists of a conservation law to govern the density, in which the flow direction is determined by the improved path-choice strategy, and a Hamilton–Jacobi equation to compute the total travel cost. The simultaneous satisfaction of both equations can be treated as a fixed-point problem. A self-adaptive method of successive averages (MSA) is proposed to solve this fixed-point problem. This method can automatically determine the optimal MSA step size using the least squares approach. Numerical examples are used to demonstrate the effectiveness of the model and the solution algorithm.

A Granular Tabu Search algorithm for the Dial-a-Ride Problem

- Transportation Research Part B: Methodological---2013---Dominik Kirchler,Roberto Wolfler Calvo

In a Dial-a-Ride system, a fleet of vehicles without fixed routes and schedules carries people from their pick-up point to their delivery point. Pre-specified time windows must be respected, and service levels for passengers as well as operation costs should be optimized. The resulting routing and scheduling problem is NP-hard and can be modeled by a mixed integer linear programming formulation. In this paper, we propose a Granular Tabu Search algorithm for the static Dial-a-Ride Problem with the objective of producing good solutions in a short amount of time (up to 3min). We evaluate the algorithm on test instances from the literature. Our new algorithm performs well in comparison with a classical Tabu Search algorithm, a Genetic Algorithm, and a Variable Neighborhood Search.

Transportation service procurement in periodic sealed double auctions with stochastic demand and supply

- Transportation Research Part B: Methodological---2013---Su Xiu Xu,George Q. Huang

This paper presents a double auction model to study transportation service procurement (TSP) in a dynamic single-lane transportation environment. Although this paper is motivated by a third-party logistics e-marketplace, the underlying model is applicable in the general bilateral exchange contexts. We first address TSP in a transportation spot market with stochastic but balanced or "symmetric" demand and supply. A periodic sealed double auction (PSDA) is proposed for TSP. Using a packing approach that considers possible bids and/or asks in an integral manner, we then devise a modified PSDA (M-PSDA) to address TSP with "asymmetric" demand and supply.

A fault tolerance approach for railway scheduling and train control

- Transportation Research Part B: Methodological---2013---Ziauddin Ursani,T.X. Mei,Anthony Whiteing

This paper makes two contributions. It firstly proposes the use of a fault tolerance approach for railway operations and secondly it develops a minimum time gap matrix model for capacity computation and the study of perturbation effects through the generation of a compressed timetable. A fault tolerance approach is proposed to improve the operational efficiency of the railway network in terms of the network capacity and the robustness of train timetables. The term fault tolerance is used in a broad sense, to represent any abnormalities or unexpected events in operations or equipment. Enhanced fault tolerance capability provides safety assurance so that, in normal operating conditions, trains can adopt much faster speed profiles when approaching a 'to-be-cleared' signal block at stations and junctions than those currently permitted, effectively turning the status of 'be ready to stop' to that of 'proceed with caution'. In the rare event of a 'fault' in the system, e.g. if a conflicting train fails to move out of a signalling block as expected or a switch fails to operate as required, the train would be re-routed to take an alternative path. In this study, the new approach is developed on three scenarios i.e., a standard classic right turn junction, a terminus station, and a small network combining both of these elements to demonstrate the performance gains, but the concept can be readily extended for other types of junctions/stations. Results so far show great potential in the proposed fault tolerance approach to increase the capacity and enhance operational robustness to perturbations at such locations. A novel method for capacity computation called minimum time gap matrix model is also introduced that has capability to produce compressed timetables directly from a given train sequence.

Evolutionary crew scheduling with adaptive chromosomes

- Transportation Research Part B: Methodological---2013---Yindong Shen,Kunkun Peng,Kai Chen,Jingpeng Li

This paper presents an adaptive evolutionary approach incorporating a hybrid genetic algorithm (GA) for public transport crew scheduling problems, which are well-known to be NP-hard. To ensure the search efficiency, a suitable chromosome representation has to be determined first. Unlike a canonical GA for crew scheduling where the chromosome length is fixed, the chromosome length in the proposed approach may vary adaptively during the iterative process, and its initial value is elaborately designated as the lower bound of the number of shifts to be used in an unachievable optimal solution. Next, the hybrid GA with such a short chromosome length is employed to find a feasible schedule. During the GA process, the adaptation on chromosome lengths is achieved by genetic operations of crossover and mutation with removal and replenishment strategies aided by a simple greedy algorithm. If a feasible schedule cannot be found when the GA' s termination condition is met, the GA will restart with one more gene added. The above process is repeated until a feasible solution is found. Computational experiments based on 11 real-world crew scheduling problems in China show that, compared to a fuzzy GA known to be well performed for crew scheduling, better solutions are found for all the testing problems. Moreover, the algorithm works fast, has achieved results close to the lower bounds obtained by a standard linear programming solver in terms of the number of shifts, and has much potential for future developments.

Serial private infrastructures

- Transportation Research Part B: Methodological---2013---Vincent van den Berg

This paper investigates private supply of two congestible infrastructures that are serial, where the consumer has to use both in order to consume. Four market structures are analysed: a monopoly and 3 duopolies that differ in how firms interact. It is well known that private supply leads too high usage fees, and that a serial duopoly leads to even higher fees than a monopoly, as firms are monopolists on their sections. But, as this paper finds, a duopoly can also lead to a different capacity rule than the first-best one, and this distortion differs from with two parallel facilities. Finally, four auction formats for the right to build and operate facilities are investigated. With a bid auction, the competition is on how much to pay the government. This auction leads to the same outcome as no auction. An auction on the facility' s capacity leads to an even lower welfare than no auction, as firms set overly large high capacities. Conversely, an auction on the generalised price or number of users leads to the first-best outcome, which they do when the facilities go to one or two winners and both with serial as with parallel facilities.

Toll sequence operation to realize target flow pattern under bounded rationality

- Transportation Research Part B: Methodological---2013---Xiaolei Guo

Because boundedly rational user equilibrium (BRUE) always has a set of solutions instead of a unique one, from a static network equilibrium viewpoint, under BRUE there is no guarantee of attainability of any specific target flow by implementing tolls. In this study, from a disequilibrium flow evolution perspective, we design toll sequence operations (TS-operations) to guide the network flow to evolve towards the traditional Wardrop user equilibrium (UE) flow pattern. Under homogeneous bounded rationality (BR), iteratively implementing our TS-operations can make the network flow pattern converge to UE, which essentially solves the nonuniqueness problem of BRUE and re-establishes the effectiveness of link tolls in realizing any target link flow pattern. In particular we show that under homogenous BR the best-case untolled link-based BRUE can be realized as the untolled equilibrium. Under heterogeneous BR among different OD pairs, our TS-operations can make the flow converge to reduced BRUE and/or sub-network UE, which give smaller estimate intervals of the equilibrium flow pattern as compared to the original BRUE.

Development of an indicator to assess the spatial fit of discrete choice models

- Transportation Research Part B: Methodological---2013---Antonio Páez,Lopez Fernando A,Manuel Ruiz,Catherine Morency

Discrete choice models are increasingly implemented using geographical data. When this is the case, it may not be sufficient to project market shares accurately, but also to correctly replicate the spatial pattern of choices. Analysts might then be interested in assessing the results of a model’s fit relative to the spatial distribution of the observed responses. While canonical approaches exist for the exploratory spatial analysis of continuous variables, similar tools have not been widely implemented for discrete choice models, where the variable of interest is categorical. For this reason, despite recent progress with spatial models for discrete outcomes, there is still not a simple and intuitive tool to assess the quality of the spatial fit of a discrete choice model. The objective of this paper is to introduce a new indicator of spatial fit that can be applied to the results of discrete choice models. Utility of the indicator is explored by means of numerical experiments and then demonstrated by means of a case study of vehicle ownership in Montreal, Canada.

Specification issues in a generalised random parameters attribute nonattendance model

- Transportation Research Part B: Methodological---2013---Andrew Collins,John Rose,David Hensher

An extensive literature has recognised that when travel choices are made, only a subset of the attributes of the choice alternatives may be considered or attended to by each decision maker. Numerous econometric approaches have been employed to identify attribute nonattendance (ANA), with the most prevalent in the literature being an adaptation of the latent class model. However, the two latent class structures so far employed either incur a potentially very high parametric cost, or rely on an assumption that nonattendance is independent across all attributes. We present a generalised model that allows for an arbitrary degree of correlation of nonattendance across attributes. In the presented stated choice study investigating short haul flights, this generalised model outperforms the existing approaches. Like two recent papers, the model handles both ANA and preference heterogeneity by combining continuously distributed random parameters with latent classes. However, we present recommendations regarding a number of identification issues stemming from the combination of these two forms of random parameters not covered in those papers. Further, covariates can be introduced into our generalised model to allow insights to be gained into ANA behaviour. We investigate stated ANA as a covariate, and find inferred ANA rates to be more aligned with stated ANA responses than alternative methods.

Maximizing bus discharge flows from multi-berth stops by regulating exit maneuvers

- Transportation Research Part B: Methodological---2013---Weihua Gu,Michael J. Cassidy

Upon having loaded and unloaded their passengers, buses are often free to exit a multi-berth bus stop without delay. A bus need not wait to perform this exit maneuver, even if it requires circumventing one or more other buses that are still dwelling in the stop’s downstream berths. Yet, many jurisdictions impose restrictions on bus entry maneuvers into a stop to limit disruptions to cars and other buses. Buses are typically prohibited from entering a stop whenever this would require maneuvering around other buses still dwelling in upstream berths. An entering bus is instead required to wait in queue until the upstream berths are vacated.

The time-dependent pollution-routing problem

- Transportation Research Part B: Methodological---2013---Anna Franceschetti,Dorothée Honhon,Tom van Woensel,Tolga Bektaş,Gilbert Laporte

The Time-Dependent Pollution-Routing Problem (TDPRP) consists of routing a fleet of vehicles in order to serve a set of customers and determining the speeds on each leg of the routes. The cost function includes emissions and driver costs, taking into account traffic congestion which, at peak periods, significantly restricts vehicle speeds and increases emissions. We describe an integer linear programming formulation of the TDPRP and provide illustrative examples to motivate the problem and give insights about the tradeoffs it involves. We also provide an analytical characterization of the optimal solutions for a single-arc version of the problem, identifying conditions under which it is optimal to wait idly at certain locations in order to avoid congestion and to reduce the cost of emissions. Building on these analytical results we describe a novel departure time and speed optimization algorithm for the cases when the route is fixed. Finally, using benchmark instances, we present results on the computational performance of the proposed formulation and on the speed optimization procedure.

Location planning for transit-based evacuation under the risk of service disruptions

- Transportation Research Part B: Methodological---2013---Shi An,Na Cui,Xiaopeng Li,Yanfeng Ouyang

The effectiveness of transit-based emergency evacuation highly depends on the location of pick-up facilities, resource allocation, and management. These facilities themselves are often subject to service disruptions during or after the emergency. This paper proposes a reliable emergency facility location model that determines both pre-emergency facility location planning and the evacuation operations afterwards, while facilities are subject to the risk of disruptions. We analyze how evacuation resource availability leverages individual evacuees' response to service disruptions, and show how equilibrium of the evacuee arrival process could be reached at a functioning pick-up facility. Based on this equilibrium, an optimal resource allocation strategy is found to balance the tradeoff between the evacuees' risks and the evacuation agency's operation costs. This leads to the development of a compact polynomial-size linear integer programming formulation that minimizes the total expected system cost from both pre-emergency planning (e.g., facility set-up) and the evacuation operations (e.g., fleet management, transportation, and exposure to hazardous surroundings) across an exponential number of possible disruption scenarios. We also show how the model can be flexibly used to plan not only pre-disaster evacuation but also post-disaster rescue actions. Numerical experiments and an empirical case study for three coastal cities in the State of Mississippi (Biloxi, Gulfport, and D'lberville) are conducted to study the performance of the proposed models and to draw managerial insights.

Cooperative traffic control of a mixed network with two urban regions and a freeway

- Transportation Research Part B: Methodological---2013---Jack Haddad,Mohsen Ramezani,Nikolas Geroliminis

Currently most optimization methods for urban transport networks (i) are suited for networks with simplified dynamics that are far from real-sized networks or (ii) apply decentralized control, which is not appropriate for heterogeneously loaded networks or (iii) investigate good-quality solutions through micro-simulation models and scenario analysis, which make the problem intractable in real time. In principle, traffic management decisions for different sub-systems of a transport network (urban, freeway) are controlled by operational rules that are network specific and independent from one traffic authority to another. In this paper, the macroscopic traffic modeling and control of a large-scale mixed transportation network consisting of a freeway and an urban network is tackled. The urban network is partitioned into two regions, each one with a well-defined Macroscopic Fundamental Diagram (MFD), i.e. a unimodal and low-scatter relationship between region density and outflow. The freeway is regarded as one alternative commuting route which has one on-ramp and one off-ramp within each urban region. The urban and freeway flow dynamics are formulated with the tool of MFD and asymmetric cell transmission model, respectively. Perimeter controllers on the border of the urban regions operating to manipulate the perimeter interflow between the two regions, and controllers at the on-ramps for ramp metering are considered to control the flow distribution in the mixed network. The optimal traffic control problem is solved by a Model Predictive Control (MPC) approach in order to minimize total delay in the entire network. Several control policies with different levels of urban-freeway control coordination are introduced and tested to scrutinize the characteristics of the proposed controllers. Numerical results demonstrate how different levels of coordination improve the performance once compared with independent control for freeway and urban network. The approach presented in this paper can be extended to implement efficient real-world control strategies for large-scale mixed traffic networks.

A model of the vicious cycle of a bus line

- Transportation Research Part B: Methodological---2013---Asaf Bar-Yosef,Karel Martens,Itzhak Benenson

It has been frequently noted that in a non-regulated environment the development of public transport service is self-adjusting: Faced with decreasing demand, operators will tend to reduce service to cut costs, resulting in a decrease in the level-of-service, which then triggers a further drop in demand. The opposite may also occur: high demand will induce the operator to increase supply, e.g. through an increase in frequency, which results in a higher level-of-service and a subsequent increase in passenger numbers, triggering another round of service improvements. This paper adds to the literature by presenting an analytic model for analyzing these phenomena that we call vicious and virtuous cycles. Based on field data regarding passengers' variation in willingness-to-wait for a public transport service, we investigate the dynamics of the line service and show how the emergence of a vicious or virtuous cycle depends on the total number of potential passengers, the share of captive riders, and bus capacity. The paper ends with a discussion of the implications of the findings for the planning of public transport services.

Airport privatization in congested hub–spoke networks

- Transportation Research Part B: Methodological---2013---Ming Hsin Lin

This paper investigates the airport privatization issue. One congested hub and two linked local airports serve symmetric hub carriers. Passengers valuate the congestion delay cost and benefit from greater frequencies. The government considers privatizing either the hub or local airports. We find that in each privatizing scenario, welfare-maximizing public airport(s) set a charge below their operating costs in order to fully coordinate the high charge of privatized airport(s). If this fiscal deficit is not allowed, each scenario causes distortion. Interestingly, the distortion—and hence welfare losses—in privatizing a hub are smaller (larger) than those in privatizing both local airports when both passengers' valuations are small (large); this is exactly the case when privatized local airports are strategic substitutes (complements). We also surprisingly find that retaining the hub airport as public and privatizing one or both local airports achieves the same market outcomes. We further find that if all airports are privatized, welfare becomes worse than the other scenarios; the hub airport charges lower (higher) prices than local airports when both local airports are strategic substitutes (complements).

Containership scheduling with transit-time-sensitive container shipment demand

- Transportation Research Part B: Methodological---2013---Shuaian Wang,Qiang Meng,Zhiyuan Liu

This paper examines the optimal containership schedule with transit-time-sensitive demand that is assumed to be a decreasing continuous function of transit time. A mixed-integer nonlinear non-convex optimization model is first formulated to maximize the total profit of a ship route. In view of the problem structure, a branch-and-bound based holistic solution method is developed. It is rigorously demonstrated that this solution method can obtain an ε-optimal solution in a finite number of iterations for general forms of transit-time-sensitive demand. Computational results based on a trans-Pacific liner ship route demonstrate the applicability and efficiency of the solution method.

Essential elements in tactical planning models for container liner shipping

- Transportation Research Part B: Methodological---2013---Shuaian Wang

Tactical planning models for liner shipping problems such as network design and fleet deployment usually minimize the total cost or maximize the total profit subject to constraints including ship availability, service frequency, ship capacity, and transshipment. Most models in the literature do not consider slot-purchasing, multi-type containers, empty container repositioning, or ship repositioning, and they formulate the numbers of containers to transport as continuous variables. This paper develops a mixed-integer linear programming model that captures all these elements. It further examines from the theoretical point of view the additional computational burden introduced by incorporating these elements in the planning model. Extensive numerical experiments are conducted to evaluate the effects of the elements on tactical planning decisions. Results demonstrate that slot-purchasing and empty container repositioning have the largest impact on tactical planning decisions and relaxing the numbers of containers as continuous variables has little impact on the decisions.

A continuous approximation model for time definite many-to-many transportation

- Transportation Research Part B: Methodological---2013---James F. Campbell

Time definite freight transportation carriers provide very reliable scheduled services between origin and destination terminals. They seek to reduce transportation costs through consolidation of shipments at hubs, but are restricted by the high levels of service to provide less circuitous routings. This paper develops a continuous approximation model for time definite transportation from many origins to many destinations. We consider a transportation carrier serving a fixed geographic region in which demand is modeled as a continuous distribution and time definite service levels are imposed by limiting the maximum travel distance via the hub network. Analytical expressions are developed for the optimal number of hubs, hub locations, and transportation costs. Computational results for an analogous discrete demand model are presented to illustrate the behavior observed with the continuous approximation models.

Modeling space–time inhomogeneities with the kinematic wave theory

- Transportation Research Part B: Methodological---2013---Jia Li,H.M. Zhang

In this paper, we are concerned with modeling space–time inhomogeneities with the kinematic wave (LWR) model. The notion of space–time inhomogeneity refers to the fact that governing laws of traffic, essentially dictated by fundamental diagrams (FD), differ from each other in distinct space–time regions. Such a scenario is common when exogenous inputs, e.g. a group of slowly moving vehicles, emerge in the modeling process. We will prove the well-posedness of this class of problems. More importantly, we show that if the boundary delineating two neighboring regions is continuous and has bounded speed, this problem can be greatly simplified by introducing a piecewise linear approximation to the boundary. In particular, we utilize the variational formulation of the kinematic wave model and prove that this approximation results in uniformly bounded errors in cumulative flow N which are proportional to the L^∞ deviation of the approximation. The numerical solution of this simplified problem is well understood, and this result means that a kinematic wave model with space–time inhomogeneity can be solved accurately with any existing Godunov type scheme. Finally, using the inhomogeneous LWR model, we explain the capacity drop as a natural result of space–time inhomogeneity.

Total unimodularity and decomposition method for large-scale air traffic cell transmission model

- Transportation Research Part B: Methodological---2013---P. Wei,Y. Cao,D. Sun

In an earlier work, Sun and Bayen built a Large-Capacity Cell Transmission Model for air traffic flow management. They formulated an integer programming problem of minimizing the total travel time of flights in the National Airspace System of the United States subject to sector capacity constraints. The integer program was relaxed to a linear program for computational efficiency. In this paper the authors formulate the optimization problem in a standard linear programming form. We analyze the total unimodular property of the constraint matrix, and prove that the linear programming relaxation generates an optimal integral solution for the original integer program. It is guaranteed to be optimal and integral if solved by a simplex related method. In order to speed up the computation, we apply the Dantzig–Wolfe Decomposition algorithm, which is shown to preserve the total unimodularity of the constraint matrix. Finally, we evaluate the performances of Sun and Bayen’s relaxation solved by the interior point method and our decomposition algorithm with large-scale air traffic data.

Existence of simultaneous route and departure choice dynamic user equilibrium

- Transportation Research Part B: Methodological--2013---Ke Han,Terry L. Friesz,Tao Yao

This paper is concerned with the existence of the simultaneous route-and-departure choice dynamic user equilibrium (SRDC-DUE) in continuous time, first formulated as an infinite-dimensional variational inequality in Friesz et al. (1993). In deriving our existence result, we employ the generalized Vickrey model (GVM) introduced in Han et al. (2013a,b) to formulate the underlying network loading problem. As we explain, the GVM corresponds to a path delay operator that is provably strongly continuous on the Hilbert space of interest. Finally, we provide the desired SRDC-DUE existence result for general constraints relating path flows to a table of fixed trip volumes without invocation of a priori bounds on the path flows.

Competition in multi-modal transport networks: A dynamic approach

- Transportation Research Part B: Methodological--2013---Adriaan van der Weijde,Erik Verhoef,Vincent van den Berg

We analyze the behavior of market participants in a multi-modal commuter network, where roads are not priced, but public transport has a usage fee, which is set while taking the effects on the roads into account. In particular, we analyze the difference between markets with a monopolistic public transport operator, which operates all public transport links, and markets in which separate operators own each public transport link. To do so, we consider a simple dynamic transport network consisting of two serial segments and two parallel congestible modes of transport. We obtain a reduced form of the public transport operator’s optimal fare setting problem and show that, even if the total travel demand is inelastic, serial Bertrand–Nash competition on the public transport links leads to different fares than a serial monopoly; a result not observed in a static model. This results from the fact that trip timing decisions, and therefore the generalized prices of all commuters, are influenced by all fares in the network. We then use numerical simulations to show that, contrary to the results obtained in classic studies on vertical competition, monopolistic fares are not always lower than duopolistic fares; the opposite can also occur. We also explore how different parameters influence the price differential, and how this affects welfare.

Experienced travel time prediction for congested freeways

- Transportation Research Part B: Methodological--2013---Mehmet Yildirimoglu,Nikolas Geroliminis

Travel time is an important performance measure for transportation systems, and dissemination of travel time information can help travelers make reliable travel decisions such as route choice or departure time. Since the traffic data collected in real time reflects the past or current conditions on the roadway, a predictive travel time methodology should be used to obtain the information to be disseminated. However, an important part of the literature either uses instantaneous travel time assumption, and sums the travel time of roadway segments at the starting time of the trip, or uses statistical forecasting algorithms to predict the future travel time. This study benefits from the available traffic flow fundamentals (e.g. shockwave analysis and bottleneck identification), and makes use of both historical and real time traffic information to provide travel time prediction. The methodological framework of this approach sequentially includes a bottleneck identification algorithm, clustering of traffic data in traffic regimes with similar characteristics, development of stochastic congestion maps for clustered data and an online congestion search algorithm, which combines historical data analysis and real-time data to predict experienced travel times at the starting time of the trip. The experimental results based on the loop detector data on Californian freeways indicate that the proposed method provides promising travel time predictions under varying traffic conditions.

Travel time estimation for urban road networks using low frequency probe vehicle data

- Transportation Research Part B: Methodological---2013---Erik Jenelius,Haris N. Koutsopoulos

The paper presents a statistical model for urban road network travel time estimation using vehicle trajectories obtained from low frequency GPS probes as observations, where the vehicles typically cover multiple network links between reports. The network model separates trip travel times into link travel times and intersection delays and allows correlation between travel times on different network links based on a spatial moving average (SMA) structure. The observation model presents a way to estimate the parameters of the network model, including the correlation structure, through low frequency sampling of vehicle traces. Link-specific effects are combined with link attributes (speed limit, functional class, etc.) and trip conditions (day of week, season, weather, etc.) as explanatory variables. The approach captures the underlying factors behind spatial and temporal variations in speeds, which is useful for traffic management, planning and forecasting. The model is estimated using maximum likelihood. The model is applied in a case study for the network of Stockholm, Sweden. Link attributes and trip conditions (including recent snowfall) have significant effects on travel times and there is significant positive correlation between segments. The case study highlights the potential of using sparse probe vehicle data for monitoring the performance of the urban transport system.

Measuring the environmental efficiency of the global aviation fleet

- Transportation Research Part B: Methodological---2013---Nicole Adler,Gianmaria Martini,Nicola Volta

This research analyses the environmental footprint of the airline industry in an attempt to highlight potential paths for improvement. We develop a directional economic-environmental distance function (DEED) which accounts for the production of both desirable and undesirable output and the potential for constrained increases in input utilization. This research applies the modeling framework to analyze the potential to reduce noise and airborne pollutants emitted by aircraft–engine combinations given the current state of aeronautical technology. The global aircraft–engine market is viewed from the regulatory perspective in order to compare the single environmental and operational efficient frontier to that of the airline carriers, and environmental objectives. The results of DEED are then applied in order to substitute the fleets serving Schipol, Amsterdam and Arlanda, Stockholm airports in June 2010 with the benchmark aircraft. The results highlight the inefficiencies of the current airline fleets and that the IPCC values of externalities are a magnitude of TEN too low to encourage changes in the global fleet hence the need for government intervention.

Combining multicriteria analysis and tabu search for dial-a-ride problems

- Transportation Research Part B: Methodological---2013---Julie Paquette,Jean-François Cordeau,Gilbert Laporte,Marta M.B. Pascoal

In the Dial-a-Ride Problem (DARP) the aim is to design vehicle routes for a set of users who must be transported between given origin and destination pairs, subject to a variety of side constraints. The standard

DARP objective is cost minimization. In addition to cost, the objectives considered in this paper include three terms related to quality of service. This gives rise to a multicriteria problem. The problem is solved by means of a flexible and simple metaheuristic which efficiently integrates the reference point method for multicriteria optimization within a tabu search mechanism. Extensive tests were performed on randomly generated data and on real-life data provided by a major transporter in the Montreal area. Results indicate that the algorithm can yield a rich set of non-dominated solutions. It can also be employed to determine good trade-offs between cost and quality of service.

The Hamilton–Jacobi partial differential equation and the three representations of traffic flow

- Transportation Research Part B: Methodological---2013---Jorge A. Laval,Ludovic Leclercq

This paper applies the theory of Hamilton–Jacobi partial differential equations to the case of first-order traffic flow models. The traffic flow surface is analyzed with respect to the three 2-dimensional coordinate systems arising in the space of vehicle number, time and distance. In each case, the solution to the initial and boundary value problems are presented. Explicit solution methods and examples are shown for the triangular flow-density diagram case. This unveils new models and shows how a number of existing models are cast as special cases.

Phase transition model of non-stationary traffic flow: Definition, properties and solution method

- Transportation Research Part B: Methodological---2013---Sébastien Blandin,Juan Argote,Alexandre M. Bayen,Daniel B. Work

We consider the problem of modeling traffic phenomena at a macroscopic level. Increasing availability of streaming probe data allowing the observation of non-stationary traffic motivates the development of models capable of leveraging this information. We propose a phase transition model of non-stationary traffic in conservation form, capable of propagating joint measurements from fixed and mobile sensors, to model complex traffic phenomena such as hysteresis and phantom jams, and to account for forward propagation of information in congested traffic. The model is shown to reduce to the Lighthill–Whitham–Richards model within each traffic phase for the case of stationary states, and to have a physical mesoscopic interpretation in terms of drivers’ behavior. A corresponding discrete formulation appropriate for practical implementation is shown to provide accurate numerical solution to the proposed model. The performance of the model introduced is assessed on benchmark cases and on experimental vehicle trajectories from the NGSIM datasets.

Intercontinental-airport regulation

- Transportation Research Part B: Methodological---2013---W. Benoot,Jan Brueckner,Stef Proost

This paper analyzes strategic interaction between intercontinental airport regulators, each of which levies airport charges paid by airlines and chooses its airport capacity under conditions of congestion. Congestion from intercontinental flights is common across intercontinental airports since departure and arrival airports are linked one to one, while purely domestic traffic also uses each airport. The paper focuses on two questions. First, if both continents can strategically set separate airport charges for domestic and intercontinental flights, how will the outcome differ from the first-best solution? Second, how is strategic airport behavior affected by the extent of market power of the airlines serving the intercontinental market? We see that strategic airport pricing and capacity choices by regulators lead to a welfare loss: the regulators both behave as monopolists in the market for intercontinental flights, charging a mark-up and decreasing capacity. This welfare loss even overshadows possible negative effects from imperfect competition within the intercontinental airline market. We further discuss how the presence of multiple regulators on one continent or a simple pricing rule might constrain the welfare loss created by strategic airport regulation.

A model for estimating the optimal cycle length of demand responsive feeder transit services

- Transportation Research Part B: Methodological---2013---Shailesh Chandra,Luca Quadrifoglio

The general lack of first/last mile connectivity is one of the main challenges faced by today’s public transit. One of the possible actions towards a solution to this problem is the planning, design and implementation of efficient feeder transit services. This paper develops an analytical model which allows for an easy computation of near optimal terminal-to-terminal cycle length of a demand responsive feeder service to maximize service quality provided to customers, defined as the inverse of a weighted sum of waiting and riding times. The model estimates the recommended cycle length by only plugging in geometrical parameters and demand data, without relying on extensive simulation analyses or rule of thumbs. Simulation experiments and comparisons with real services validate our model, which would allow planners, decision makers and practitioners to quickly identify the best feeder transit operating design of any given residential area.

A model of pedestrians’ intended waiting times for street crossings at signalized intersections

- Transportation Research Part B: Methodological---2013---Baibing Li

For the purposes of both traffic-light control and the design of roadway layouts, it is important to understand pedestrian street-crossing behavior because it is not only crucial for improving pedestrian safety but also helps to optimize vehicle flow. This paper explores the mechanism of pedestrian street crossings during the red-man phase of traffic light signals and proposes a model for pedestrians’ waiting times at signalized intersections. We start from a simplified scenario for a particular pedestrian under specific traffic conditions. Then we take into account the interaction between vehicles and pedestrians via statistical unconditioning. We show that this in general leads to a U-shaped distribution of the pedestrians’ intended waiting time. This U-shaped distribution characterizes the nature of pedestrian street-crossing behavior, showing that in general there are a large proportion of pedestrians who cross the street immediately after arriving at the crossing point, and a large proportion of pedestrians who are willing to wait for the entire red-man phase. The U-shaped distribution is shown to reduce to a J-shaped or L-shaped distribution for certain traffic scenarios. The proposed statistical model was applied to analyze real field data.

Stochastic transit equilibrium

- Transportation Research Part B: Methodological---2013---Cristián E. Cortés,Pedro Jara-Moroni,Eduardo Moreno,Cristobal Pineda

We present a transit equilibrium model in which boarding decisions are stochastic. The model incorporates congestion, reflected in higher waiting times at bus stops and increasing in-vehicle travel time. The stochastic behavior of passengers is introduced through a probability for passengers to choose boarding a specific bus of a certain service. The modeling approach generates a stochastic common-lines problem, in which every line has a chance to be chosen by each passenger. The formulation is a generalization of deterministic transit assignment models where passengers are assumed to travel according to shortest hyperpaths. We prove existence of equilibrium in the simplified case of parallel lines (stochastic common-lines problem) and provide a formulation for a more general network problem (stochastic transit equilibrium). The resulting waiting time and network load expressions are validated through simulation. An algorithm to solve the general stochastic transit equilibrium is proposed and applied to a sample network; the algorithm works well and generates consistent results when considering the stochastic nature of the decisions, which motivates the implementation of the methodology on a real-size network case as the next step of this research.

Efficient dispatching rules on double tracks with heterogeneous train traffic

- Transportation Research Part B: Methodological---2013---Shi Mu,Maged Dessouky

The most natural and popular dispatching rule for double-track segments is to dedicate one track for trains traveling in one direction. However, sometimes passenger trains have to share some portions of the railway with freight trains and passenger trains are traveling faster and faster nowadays. The major drawback of this dedicated rule is that a fast train can be caught behind a slow train and experience significant knock-on delay. In this paper, we propose a switchable dispatching policy for a double-track segment. The new dispatching rule enables the fast train to pass the slow train by using the track traveled by trains in the opposite direction if the track is empty. We use queueing theory techniques to derive the delay functions of this policy. The numerical experiments show that a switchable policy can reduce the fast train knock-on delay by as high as 30% compared to a dedicated policy. When there are crossovers at the middle of the double-track segment, our proposed switchable policy can reduce the delay of the fast trains by as high as 65%.

A graphical approach to identify sensor locations for link flow inference

- Transportation Research Part B: Methodological---2013---Sheng-xue He

Information of link flows in a traffic network becomes increasingly critical in contemporary transportation practice and researches. The network sensor installation is carried out to supply such information. In this paper, we present a graphical approach to determine the smallest subset of links in a traffic network for counting sensor installation, so as to infer the flows on all remaining links. The elegant assumption-free character of the problem introduced by Hu, Peeta and Chu is still kept in this approach. This study points out the topological tree feature of solutions that makes it possible for traffic management agencies to easily and flexibly select links for sensor installation in practice. Addressing from the same graphical perspective, we provide solutions to four other important problems about sensor locations. The preceding two problems are, in traffic networks that already have sensors installed on some links, to identify the subset of links on which link flows can be inferred from sensor measurements and to determine the smallest subset of links on which counting sensors also need to be installed so as to infer link flows on all remaining non-equipped links. The third is to identify the optimal locations for a given number of sensors so as to infer flows on as many links as possible by gradually enlarging the number of links included in circuits. The last one is to determine the smallest subset of links on which to install sensors, in such a way that it becomes possible at the same time to satisfy prior requirements and infer the flows on all remaining links, through building a minimum spanning tree. These methods can be applied to all kinds of long-term planning and link-based applications in traffic networks.

Managing rush hour travel choices with tradable credit scheme

- Transportation Research Part B: Methodological---2013---Nie, Yu (Marco),Yafeng Yin

This paper Analyzes a new tradable credit scheme (TCS) for managing commuters' travel choices, which seeks to persuade commuters to spread evenly within the rush hour and between primary and alternative routes so that excessive traffic congestion can be alleviated. The scheme defines a peak time window and charges those who use the primary route within that window in the form of mobility credits. Those who avoid the peak-time window, by either traveling outside the peak time window or switching to the alternative route, may be rewarded credits. A market is created such that those who need to pay credits can purchase them from those who acquire them from their rewarding travel choices. A general analytical framework is proposed for a system of two parallel routes. The framework (1) considers a variety of assumptions about commuters' behavior in response to the discontinuous credit charge introduced at the boundary of the peak-time window, (2) allows modeling congestion effects (or demand elasticity) on the alternative route, and (3) enables both the design of system optimal TCS and the analysis of the efficiency of any given TCS. Our analyses indicate that the proposed TCS not only achieves up to 33% efficiency gains in the base scenario, but also distributes the benefits among all the commuters directly through the credit trading. The results also suggest that very simple TCS schemes could provide substantial efficiency gains for a wide range of scenarios. Such simplicity and robustness are important to practicability of the proposed scheme. Numerical experiments are conducted to examine the sensitivity of TCS designs to various system parameters.

A continuous approximation approach for assessment routing in disaster relief

- Transportation Research Part B: Methodological---2013---Michael Huang,Karen R. Smilowitz,Burcu Balcik

In this paper, we focus on the assessment routing problem which routes teams to different communities to assess damage and relief needs following a disaster. To address time-sensitivity, the routing problem is modeled with the objective of minimizing the sum of arrival times to beneficiaries. We propose a continuous approximation approach which uses aggregated instance data to develop routing policies and cost approximations. Numerical tests are performed that demonstrate the effectiveness of the cost approximations at predicting the true implementation costs of the policies and compare the policies against more complex solution approaches. The continuous approximation approach yields solutions which can be easily implemented; further, this approach reduces the need for detailed data and the computational requirements to solve the problem.

Global optimization methods for the discrete network design problem

- Transportation Research Part B: Methodological---2013---Shuaian Wang,Qiang Meng,Hai Yang

This paper addresses the discrete network design problem (DNDP) with multiple capacity levels, or multi-capacity DNDP for short, which determines the optimal number of lanes to add to each candidate link in a road network. We formulate the problem as a bi-level programming model, where the upper level aims to minimize the total travel time via adding new lanes to candidate links and the lower level is a traditional Wardrop user equilibrium (UE) problem. We propose two global optimization methods by taking advantage of the relationship between UE and system optimal (SO) traffic assignment principles. The first method, termed as SO-relaxation, exploits the property that an optimal network design solution under SO principle can be a good approximate solution under UE principle, and successively sorts the solutions in the order of increasing total travel time under SO principle. Optimality is guaranteed when the lower bound of the total travel time of the unexplored solutions under UE principle is not less than the total travel time of a known solution under UE principle. The second method, termed as UE-reduction, adds the objective function of the Beckmann-McGuire-Winsten transformation of UE traffic assignment to the constraints of the SO-relaxation formulation of the multi-capacity DNDP. This constraint is convex and strengthens the SO-relaxation formulation. We also develop a dynamic outer-approximation scheme to make use of the state-of-the-art mixed-integer linear programming solvers to solve the SO-relaxation formulation. Numerical experiments based on a two-link network and the Sioux-Falls network are conducted.

Reversing port rotation directions in a container liner shipping network

- Transportation Research Part B: Methodological---2013---Shuaian Wang,Qiang Meng

Reversing port rotation directions of ship routes is a practical alteration of container liner shipping networks. The port rotation directions of ship routes not only affect the transit time of containers, as has been recognized by the literature, but also the shipping capacity and transshipment cost. This paper aims to obtain the optimal port rotation directions that minimize the generalized network-wide cost including transshipment cost, slot-purchasing cost and inventory cost. A mixed-integer linear programming model is proposed for the optimal port rotation direction optimization problem and it nests a minimum cost multi-commodity network flow model. The proposed model is applied to a liner shipping network operated by a global liner shipping company. Results demonstrate that real-case instances could be efficiently solved and significant cost reductions are gained by optimization of port rotation directions.

The joint analysis of injury severity of drivers in two-vehicle crashes accommodating seat belt use endogeneity

- Transportation Research Part B: Methodological---2013---Kibrom Abay,Rajesh Paleti,Chandra R. Bhat

The current study contributes to the existing injury severity modeling literature by developing a multivariate probit model of injury severity and seat belt use decisions of both drivers involved in two-vehicle crashes. The modeling approach enables the joint modeling of the injury severity of multiple individuals involved in a crash, while also recognizing the endogeneity of seat belt use in predicting injury severity levels as well as accommodating unobserved heterogeneity in the effects of variables. The proposed model is applied to analyze the injury severity of drivers involved in two-vehicle road crashes in Denmark.

A continuum approximation approach to competitive facility location design under facility disruption risks

- Transportation Research Part B: Methodological---2013---Xin Wang,Yanfeng Ouyang

This paper presents game-theoretical models based on a continuous approximation (CA) scheme to optimize service facility location design under spatial competition and facility disruption risks. The share of customer demand in a market depends on the functionality of service facilities and the presence of nearby competitors, as customers normally seek the nearest functioning facility for service. Our game-theoretical models incorporate these complicating factors into an integrated framework, and use continuous and differentiable density functions to represent discrete location decisions. We first analyze the existence of Nash equilibria in a symmetric two-company competition case. Then we build a leader–follower Stackelberg competition model to derive the optimal facility location design when one of the companies has the first mover advantage over its competitor. Both models are solved effectively, and closed-form analytical solutions can be obtained for special cases. Numerical experiments (with hypothetical and empirical data) are conducted to show the impacts of competition, facility disruption risks and transportation cost metrics on the optimal design. Properties of the models are analyzed to cast interesting managerial insights.

Bayesian inference for day-to-day dynamic traffic models

- Transportation Research Part B: Methodological---2013---Katharina Parry,Martin L. Hazelton

There is significant current interest in the development of models to describe the day-to-day evolution of traffic flows over a network. We consider the problem of statistical inference for such models based on daily observations of traffic counts on a subset of network links. Like other inference problems for network-based models, the critical difficulty lies in the underdetermined nature of the linear system of equations that relates link flows to the latent path flows. In particular, Bayesian inference implemented using Markov chain Monte Carlo methods requires that we sample from the set of route flows consistent with the observed link flows, but enumeration of this set is usually computationally infeasible.

Theory of jam-absorption driving

- Transportation Research Part B: Methodological---2013---Ryosuke Nishi,Akiyasu Tomoeda,Kenichiro Shimura,Katsuhiro Nishinari

“Can a single car really absorb a traffic jam without making new jams?” In this paper, we focus on this frequently-discussed question, and have succeeded in making a theoretical framework of a driving technique how to absorb a traffic jam by using a minimal microscopic model. Jam-absorption driving comes from Beaty (Beaty, 1998; Beaty, 2013), and it is composed of a sequence of two actions termed the “slow-in” and “fast-out”. The “slow-in” is the action to avoid being captured by a jam and remove it by decelerating and taking a longer headway in advance. The “fast-out” is performed after the “slow-in”, and it is the action to follow the car in front without unnecessary time gaps by accelerating quickly. In our theoretical framework, we have represented the recipe of the actions such as the time–space points and the velocity. Moreover, we have clarified the condition of no secondary jams due to this driving, i.e., the condition that compression and expansion waves caused by this driving meet each other and disappear. Particularly, we have calculated how these waves propagates to the following cars and the point where and when they disappear. Besides, we have analyzed how this point moves in time–space diagrams by varying the timing to start the jam-absorption, and revealed that the pattern of this movement is not constant but changes greatly by the velocity-headway relationships. Furthermore, as a more realistic problem, we have formulated the driving for jam-absorption in two steps of deceleration, which brings rich patterns of collisions among compression and expansion waves.

A comparative study of Macroscopic Fundamental Diagrams of arterial road networks governed by adaptive traffic signal systems

- Transportation Research Part B: Methodological---2013---Lele Zhang,Timothy M Garoni,Jan de Gier

Using a stochastic cellular automaton model for urban traffic flow, we study and compare Macroscopic Fundamental Diagrams (MFDs) of arterial road networks governed by different types of adaptive traffic signal systems, under various boundary conditions. In particular, we simulate realistic signal systems that include signal linking and adaptive cycle times, and compare their performance against a highly adaptive system of self-organizing traffic signals which is designed to uniformly distribute the network density. We find that for networks with time-independent boundary conditions, well-defined stationary MFDs are observed, whose shape depends on the particular signal system used, and also on the level of heterogeneity in the system. We find that the spatial heterogeneity of both density and flow provide important indicators of network performance. We also study networks with time-dependent boundary conditions, containing morning and afternoon peaks. In this case, intricate hysteresis loops are observed in the MFDs which are strongly correlated with the density heterogeneity. Our results show that the MFD of the self-organizing traffic signals lies above the MFD for the realistic systems, suggesting that by adaptively homogenizing the network density, overall better performance and higher capacity can be achieved.

Estimating the demand responses for different sizes of air passenger groups

- Transportation Research Part B: Methodological---2013---David Gillen,Hamed Hasheminia

This paper investigates the sensitivity of demand for air travel by singleton passengers, couples, and families. It examines how the demand for air travel by these groups is potentially different. In this study, a compound Poisson structure of the demand of different passenger groups is considered, and aggregate demand observations and maximum likelihood procedures are used to decompound the processes and estimate demand sensitivity of each group of customers to price, time, season, and the economic cycle. The methodology is applied to Canadian market data and the results indicate there are significant differences among the different groups of customers.

The heterogeneous effects of guardian supervision on adolescent driver-injury severities: A finite-mixture random-parameters approach

- Transportation Research Part B: Methodological---2013---Yingge Xiong,Fred L. Mannering

One of the key aspects of graduated driver licensing programs is the new-driver experience gained in the presence of a guardian (a person providing mandatory supervision from the passenger seat). However, the effect that this guardian-supervising practice has on adolescent drivers' crash-injury severity (should a crash occur) is not well understood. This paper seeks to provide insights into the injury-prevention effectiveness of guardian supervision by developing an appropriate econometric structure to account for the complex interactions that are likely to occur in the study of the heterogeneous effects of guardian supervision on crash-injury severities. As opposed to conventional heterogeneity models with standard distributional assumptions, this paper deals with the heterogeneous effects by accounting for the possible multivariate characteristics of parameter distributions in addition to allowing for multimodality, skewness and kurtosis. A Markov Chain Monte Carlo (MCMC) algorithm is developed for estimation and the permutation sampler proposed by Frühwirth-Schnatter (2001) is extended for model identification. The econometric analysis shows the presence of two distinct driving environments (defined by roadway geometric and traffic conditions). Model estimation results show that, in both of these driving environments, the presence of guardian supervision reduces the crash-injury severity, but in interestingly different ways. Based on the findings of this research, a case could easily be made for extending the time-requirement for guardian supervision in current graduated driver license programs.

A partial differential equation formulation of Vickrey's bottleneck model, part I: Methodology and theoretical analysis

- Transportation Research Part B: Methodological---2013---Ke Han,Terry L. Friesz,Tao Yao

This paper is concerned with the continuous-time Vickrey model, which was first introduced in Vickrey (1969). This model can be described by an ordinary differential equation (ODE) with a right-hand side which is discontinuous in the unknown variable. Such a formulation induces difficulties with both theoretical analysis and numerical computation. Moreover it is widely suspected that an explicit solution to this ODE does not exist. In this paper, we advance the knowledge and understanding of the continuous-time Vickrey model by reformulating it as a partial differential equation (PDE) and by applying a variational method to obtain an explicit solution representation. Such an explicit solution is then shown to be the strong solution to the ODE in full mathematical rigor. Our methodology also leads to the notion of generalized Vickrey model (GVM), which allows the flow to be a distribution, instead of an integrable function. As explained by Han et al. (in press), this feature of traffic modeling is desirable in the context of analytical dynamic traffic assignment (DTA). The proposed PDE formulation provides new insights into the physics of The Vickrey model, which leads to a number of modeling extensions as well as connection with first-order traffic models such as the Lighthill–Whitham–Richards (LWR) model. The explicit solution representation also leads to a new computational method, which will be discussed in an accompanying paper, Han et al. (in press).

A partial differential equation formulation of Vickrey's bottleneck model, part II: Numerical analysis and computation

- Transportation Research Part B: Methodological---2013---Ke Han,Terry L. Friesz,Tao Yao

The Vickrey model, originally introduced in Vickrey (1969), is one of the most widely used link-based models in the current literature in dynamic traffic assignment (DTA). One popular formulation of this model is an ordinary differential equation (ODE) that is discontinuous with respect to its state variable. As explained in Ban et al. (2011) and Han et al. (2013), such an irregularity induces difficulties in both continuous-time analysis and discrete-time computation. In Han et al. (2013), the authors proposed a reformulation of the Vickrey model as a partial differential equation (PDE) and derived a closed-form solution to the aforementioned ODE. This reformulation enables us to rigorously prove analytical properties of the Vickrey model and related DTA models.

An instantaneous kinematic wave theory of diverging traffic

- Transportation Research Part B: Methodological--2013---Wen-Long Jin,H. Michael Zhang

Diverging junctions are an important type of bottlenecks, which can reduce capacities and initiate and propagate traffic congestion in a road network. In this paper, we propose a kinematic wave theory for modeling dynamics of non-cooperative diverging traffic, in which traffic dynamics of vehicles to one direction are assumed to be independent of those to other directions instantaneously. During a short time interval, the kinematic wave model of diverging traffic is decoupled into a number of nonlinear resonant systems. From analytical solutions to the Riemann problem of a decoupled system, a new definition of partial traffic demand is introduced, so that diverging flows can be easily computed with the supply–demand method. Then a Cell Transmission Model is proposed to solve the kinematic wave model of diverging traffic by taking into account of the interactions among different traffic streams. Simulation results demonstrate that vehicles follow the First-In-First-Out principle in the long run, and the model converges when we decrease the cell and time-step sizes. In addition, it is shown that traffic streams to different directions segregate in a selfish manner, and the total throughput of a diverging junction is not maximized as in existing diverge models. In the future, more theoretical and empirical studies are needed for a better understanding of this and other diverge models.

Integrated modeling framework for leasing urban roads: A case study of Fresno, California

- Transportation Research Part B: Methodological--2013---Omid M. Rouhani,Debbie Niemeier,Christopher Knittel,Kaveh Madani

Increasing private sector involvement in transportation services has significant implications for the management of road networks. This paper examines a concession model’s effects on a road network in the mid-sized city of Fresno, California. Using the existing transportation planning models of Fresno, we examine the effects of privatization on a number of typical system performance measures including total travel time and vehicle miles traveled (VMT), the possibility of including arterials, and the differences between social cost prices and profit maximizing prices. Some interesting insights emerge from our analysis: (1) roads cannot be considered as isolated elements in a concession model for a road network; (2) roads can function as complements at some levels of demand and become substitutes at other levels; (3) policy makers/officials should consider privatizing/pricing arterials along with privatizing highways; (4) temporally flexible but limited price schedule regulations should be part of leasing agreements; and (5) non-restricted pricing may actually worsen system performance, while limited pricing can raise enormous profits as well as improve system performance.

Sampling of alternatives in Multivariate Extreme Value (MEV) models

- Transportation Research Part B: Methodological--2013---Cristian Guevara,Moshe E. Ben-Akiva

We propose a methodology to achieve consistency, asymptotic normality and efficiency, while sampling alternatives in Multivariate Extreme Value (MEV) models, extending a previous result for Logit. We illustrate the methodology and study the finite sample properties of the estimators using Monte Carlo experimentation and real data on residential location choice from Lisbon, Portugal. Experiments show that the proposed methodology is practical, that it outperforms the uncorrected model, and that it yields acceptable results, even for relatively small samples of alternatives. The paper finishes with a synthesis and an analysis of the impact, limitations and potential extensions of this research.

Metropolis–Hastings sampling of paths

- Transportation Research Part B: Methodological--2013---Gunnar Flötteröd,Michel Bierlaire

We consider the previously unsolved problem of sampling paths according to a given distribution from a general network. The problem is difficult because of the combinatorial number of alternatives, which prohibits a complete enumeration of all paths and hence also forbids to compute the normalizing constant of the sampling distribution. The problem is important because the ability to sample from a known distribution introduces mathematical rigor into many applications, including the estimation of choice models with sampling of alternatives that can be formalized as paths in a decision network (most obviously route choice), probabilistic map matching, dynamic traffic assignment, and route guidance.

Risk-neutral second best toll pricing

- Transportation Research Part B: Methodological---2013---(Jeff) Ban, Xuegang,Michael C. Ferris,Lisa Tang,Shu Lu

We propose a risk-neutral second best toll pricing (SBTP) scheme to account for the possible nonuniqueness of user equilibrium solutions. The scheme is designed to optimize for the expected objective value as the UE solution varies within the solution set. We show that such a risk-neutral scheme can be formulated as a stochastic program, which complements the traditional risk-prone SBTP approach and the risk-averse SBTP approach we developed recently. The proposed model can be solved by a simulation-based optimization algorithm that contains three major steps: characterization of the UE solution set, random sampling over the solution set, and a two-phase simulation optimization step. Numerical results illustrate that the proposed risk-neutral design scheme is less aggressive than the risk-prone scheme and less conservative than the risk-averse scheme, and may thus be more preferable from a toll designer's point of view.

Analysis of asymmetric driving behavior using a self-learning approach

- Transportation Research Part B: Methodological---2013---Dali Wei,Hongchao Liu

This paper presents a self-learning Support Vector Regression (SVR) approach to investigate the asymmetric characteristic in car-following and its impacts on traffic flow evolution. At the microscopic level, we find that the intensity difference between acceleration and deceleration will lead to a 'neutral line', which separates the speed-space diagram into acceleration and deceleration dominant areas. This property is then used to discuss the characteristics and magnitudes of microscopic hysteresis in stop-and-go traffic. At the macroscopic level, according to the distribution of neutral lines for heterogeneous drivers, different congestion propagation patterns are reproduced and found to be consistent with Newell's car following theory. The connection between the asymmetric driving behavior and macroscopic hysteresis in the flow-density diagram is also analyzed and their magnitudes are shown to be positively related.

A stochastic model of traffic flow: Gaussian approximation and estimation

- Transportation Research Part B: Methodological---2013---Saif Eddin Jabari,Henry X. Liu

A Gaussian approximation of the stochastic traffic flow model of Jabari and Liu (2012) is proposed. The Gaussian approximation is characterized by deterministic mean and covariance dynamics; the mean dynamics are those of the Godunov scheme. By deriving the Gaussian model, as opposed to assuming Gaussian noise arbitrarily, covariance matrices of traffic variables follow from the physics of traffic flow and can be computed using only few parameters, regardless of system size or how finely the system is discretized. Stationary behavior of the covariance dynamics is analyzed and it is shown that the covariance matrices are bounded. Consequently, Kalman filters that use the proposed model are stochastically observable, which is a critical issue in real time estimation of traffic dynamics. Model validation was carried out in a real-world signalized arterial setting, where cycle-by-cycle maximum queue sizes were estimated using the Gaussian model as a description of state dynamics. The estimated queue sizes were compared to observed maximum queue sizes and the results indicate very good agreement between estimated and observed queue sizes.

Mitigating negative impacts of near-side bus stops on cars

- Transportation Research Part B: Methodological---2013---Weihua Gu,Michael J. Cassidy,Vikash V. Gayah,Yanfeng Ouyang

Bus stops are often placed short distances upstream of signalized intersections. Buses that dwell at one of these so-called near-side stops can impede queued cars upstream from discharging through the intersection during green times. Residual car queues can form at the intersection as a result. The smaller the distance between a stop and its intersection, the greater the problem can be.

Liner ship route capacity utilization estimation with a bounded polyhedral container shipment demand pattern

- Transportation Research Part B: Methodological---2013---Shuaian Wang,Qiang Meng,Michael G.H. Bell

This paper aims to estimate capacity utilization of a liner ship route with a bounded polyhedral container shipment demand pattern, arising in the liner container shipping industry. The proposed maximum and minimum liner ship route capacity utilization problems are formulated as a linear programming model and a min–max model, respectively. We examine two fundamental properties of the min–max model. These two nice properties enable us to develop two ε-optimal global optimization algorithms for solving the min–max model, which find a globally ε-optimal solution by iteratively cutting off the bounded polyhedral container shipment demand set with a cut. The latter algorithm overcomes non-convexity of the remaining feasible demand set generated by the former algorithm via a novel hyperplane cut. Each hyperplane cut can assure that the current vertex of the polyhedral demand set is cut off, whereas solutions that may improve the current one by more than a factor of ε are retained. Extensive numerical experiments for problems larger than those encountered in real applications demonstrate the computational efficacy of the latter algorithm.

Fundamental properties of volume–capacity ratio of a private toll road in general networks

- Transportation Research Part B: Methodological---2013---Shuaian Wang,Qiang Meng,Zhiyuan Liu

It has been addressed in the existing literature that the volume–capacity (v/c) ratio on a private toll road is constant, regardless of the toll value and capacity set by the private companies for each toll road in the network. The previous derivation depends on the assumption that the user equilibrium flow on the private toll road is continuously differentiable with respect to its capacity and toll charge. In this paper, it is shown that the constant v/c ratio phenomenon still holds via relaxing this assumption. Such phenomenon is further examined in different scenarios: the v/c ratio remains constant under the demand regulation, markup charge regulation, and social cost minimization scheme; it may change under the rate-of-return regulation; it may decrease under capacity regulation and increase under the price-cap regulation. Moreover, this paper demonstrates that the v/c ratio may change if there are decreasing or increasing returns to scale in road construction, or the road capacity can only take discrete values, or link flow interactions are involved, whereas the v/c ratio remains constant in case of elastic demand.

Optimal deployment of public charging stations for plug-in hybrid electric vehicles

- Transportation Research Part B: Methodological---2013---Fang He,Di Wu,Yafeng Yin,Yongpei Guan

This paper develops an equilibrium modeling framework that captures the interactions among availability of public charging opportunities, prices of electricity, and destination and route choices of plug-in hybrid electric vehicles (PHEVs) at regional transportation and power transmission networks coupled by PHEVs. The modeling framework is then applied to determine an optimal allocation of a given number of public charging stations among metropolitan areas in the region to maximize social welfare associated with the coupled networks. The allocation model is formulated as a mathematical program with complementarity constraints, and is solved by an active-set algorithm. Numerical examples are presented to demonstrate the models and offer insights on the equilibrium of the coupled transportation and power networks, and optimally allocating resource for public charging infrastructure.

Dynamic user equilibrium based on a hydrodynamic model

- Transportation Research Part B: Methodological---2013---Terry L. Friesz,Ke Han,Pedro A. Neto,Amir Meimand,Tao Yao

In this paper we present a continuous-time network loading procedure based on the Lighthill–Whitham–Richards model proposed by Lighthill and Whitham (1955) and Richards (1956). A system of differential algebraic equations (DAEs) is proposed for describing traffic flow propagation, travel delay and route choices. We employ a novel numerical apparatus to reformulate the scalar conservation law as a flow-based partial differential equation (PDE), which is then solved semi-analytically with the Lax–Hopf formula. This approach allows for an efficient computational scheme for large-scale networks. We embed this network loading procedure into the dynamic user equilibrium (DUE) model proposed by Friesz et al. (1993). The DUE model is solved as a differential variational inequality (DVI) using a fixed-point algorithm. Several numerical examples of DUE on networks of varying sizes are presented, including the Sioux Falls network with a significant number of paths and origin–destination pairs (OD).

Truthful multi-unit transportation procurement auctions for logistics e-marketplaces

- Transportation Research Part B: Methodological---2013---George Q. Huang,Su Xiu Xu

This paper is among the first contributions that incorporate bilateral bidding into auction mechanism design for multi-unit transportation procurement in logistics e-marketplaces. Proposed mechanisms ensure incentive compatibility, individual rationality, budget balance and asymptotical efficiency. We first consider one-sided VCG (Vickrey–Clarke–Groves) combinatorial auctions for a complex transportation marketplace with multiple lanes, realizing the maximal social welfare. We then design three alternative multi-unit trade reduction (MTR) mechanisms for the bilateral exchange transportation marketplace where all the lanes are partitioned into distinct markets. Compared to the base MTR mechanism, more buyers/shippers win the "tickets" for competing in the final trade in the MTR-BA (buyer augment) mechanism; likewise, more sellers/carriers win these tickets in the MTR-SA (seller augment) mechanism. Under the buyer and seller augment mechanisms, both shippers' and carriers' expected utilities are higher than those in the base MTR mechanism. Numerical study further shows that MTR-BA and MTR-SA mechanisms lead to higher expected utilities for shippers and carriers respectively than social welfare maximization. However, the base MTR mechanism provides a higher payoff to the market broker than MTR-BA and MTR-SA mechanisms. Finally, we propose a randomized mechanism that integrates one-sided VCG mechanisms and MTR mechanisms. As a result, this randomized mechanism is practical in both the one-sided and bilateral exchange transportation marketplaces, even with the less-than-truckload constraint.

The impact of speed limits on traffic equilibrium and system performance in networks

- Transportation Research Part B: Methodological---2012---Hai Yang,Xiaolei Wang,Yafeng Yin

Speed limits are usually imposed on roads in an attempt to enhance safety and sometimes serve the purpose of reducing fuel consumption and vehicular emissions as well. Most previous studies up to date focus on investigation of the effects of speed limits from a local perspective, while network-wide traffic reallocation effects are overlooked. This paper makes the first attempt to investigate how a link-specific speed limit law reallocates traffic flow in an equilibrium manner at a macroscopic network level. We find that, although the link travel time–flow relationship is altered after a speed limit is imposed, the standard traffic assignment method still applies. With the commonly adopted assumptions, the uniqueness of link travel times at user equilibrium (UE) remains valid, and the UE flows on links with non-binding speed limits are still unique. The UE flows on other links with binding speed limits may not be unique but can be explicitly characterized by a polyhedron or a linear system of equalities and inequalities. Furthermore, taking into account the traffic reallocation effects of speed limits, we compare the capability of speed limits and road pricing for decentralizing desirable network flow patterns. Although from a different perspective for regulating traffic flows with a different mechanism, a speed limit law may play the same role as a toll charge scheme and perform better than some negative (rebate) toll schemes under certain conditions for network flow management.

On the capacity of highway checkpoints: Models for unconventional configurations

- Transportation Research Part B: Methodological---2012---Weihua Gu,Michael J. Cassidy,Yuwei Li

Widening a highway toll plaza, border crossing or other checkpoint by adding travel lanes and vehicle-processing stations in parallel fashion can be expensive, and sometimes even infeasible. Rather than expanding laterally, checkpoint capacities can be increased by branching or staggering the vehicle-processing stations, or by placing them in tandem. Analytical models are formulated to estimate the vehicle-processing capacities achievable via these layouts. The models indicate that tandem designs tend to produce the highest capacities among the three alternatives. Other insights are unveiled as well.

Effects of high-speed rail and air transport competition on prices, profits and welfare

- Transportation Research Part B: Methodological---2012---Hangjun Yang,Anming Zhang

This paper investigates the effects of competition between air transport and high-speed rail (HSR). While airlines are assumed to maximize profit, HSR may maximize a weighted sum of profit and social welfare. We show that both airfare and HSR fare fall as the weight of welfare in the HSR’s objective function increases, while airfare decreases, and rail fare increases, in the airport access time. Furthermore, airfare decreases in rail speed if the impact of HSR marginal cost with respect to rail speed is not too large. On the other hand, whether rail fare increases in rail speed depends not only on the HSR marginal cost but also on the weight of welfare. We further compare prices, profits and welfare between “with price discrimination” in which airlines price discriminate business from leisure passengers, and “without price discrimination”. Welfare in the HSR system can be either higher or lower with price discrimination: In particular, it is higher under price discrimination when the difference of gain from travel is sufficiently larger than the time value difference between business and leisure passengers. Finally, a numerical study on China’s markets is conducted in which both price and schedule frequency are considered as decision variables.

Strategies for sharing bottleneck capacity among buses and cars

- Transportation Research Part B: Methodological---2012---S. Ilgin Guler,Michael J. Cassidy

In urban settings where space is at a premium, bus lanes can often times be created only via the conversion of existing general-use lanes. If buses are dispatched at low rates, the converted lanes will be under-utilized and squander road space. The bottlenecks within the city’s road network would then impart even greater delays to cars.

The morning commute under flat toll and tactical waiting

- Transportation Research Part B: Methodological---2012---Feng Xiao,Wei Shen,H. Michael Zhang

This paper studies the morning commute problem under "tactical waiting", a phenomenon observable under situations when sudden drops in travel costs are present. Under such situations, travelers may find it advantageous to delay reaching the bottleneck by slowing down or waiting beside, even when there is still capacity left to serve them without delay. In this paper, we show that a flat toll during the morning commute potentially incurs tactical waiting under the assumptions of First-In-First-Out (FIFO) queue discipline and identical commuters, and derive all the possible equilibrium traffic patterns resulting from different choices of toll level and tolling period. Under the optimal toll pattern which minimizes the total system cost, we prove that there is no queue at the bottleneck at the starting or ending point of the tolling period and bottleneck capacity is fully utilized except during the period of tactical waiting. The optimal flat toll can reduce up to half of the queuing delay, but is in general not pareto-improving. However, if the revenue collected by the optimal flat toll is redistributed to the road users in the form of capacity expansion, the trip cost of each commuter will be reduced in the long-run. We also show that when building a new highway, the revenue from the optimal flat toll can never cover the capital cost of constructing the optimal capacity.

The traffic statics problem in a road network

- Transportation Research Part B: Methodological---2012---Wen-Long Jin

In this study we define and solve the traffic statics problem in an open diverge-merge network based on a multi-commodity kinematic wave model, whose entropy conditions are given by invariant junction flux functions derived from macroscopic merging and diverging rules. In this problem, we are interested in finding stationary states on all links when origin demands, destination supplies, and route choice proportions are constant. After discussing the properties of four types of stationary states on a road link and presenting stationary entropy conditions at both the merging and diverging junctions, we derive a system of algebraic equations as necessary conditions for all 16 combinations of stationary states on the two intermediate links. Under different network conditions in road capacities, route choice proportions, and merging priorities, we analytically show that the traffic statics problem always admits stationary solutions, which, however, may not be unique. In particular, such stationary solutions exist even under network conditions when an initially empty diverge-merge network can settle in persistent periodic oscillations after a long time. In the future, we will be interested in discussing the stability property of the stationary states and studying the traffic statics problem in general networks. Analytical insights from the simpler traffic statics problems would be helpful for understanding complex traffic dynamics in a road network.

Practical and empirical identifiability of hybrid discrete choice models

- Transportation Research Part B: Methodological---2012---Sebastián Raveau,María Francisca Yáñez,Juan de Dios Ortúzar

The formulation of hybrid discrete choice (HDC) models including both observable alternative attributes and latent variables associated with attitudes and perceptions has become a renewed topic of discussion in recent years. Even though there have been developments related to HDC model estimation and theoretical parameter identification, many practical and empirical issues related with HDC modelling have not been treated yet. In particular, it is known that as the HDC model estimates are not unique, it is necessary to impose some constraints on the model estimation process. In this paper we analyse the impact of different normalization approaches on parameter recovery in a simulated environment, identifying their advantages and disadvantages; we also analyse the impact of data variability on parameter recovery. We found serious problems when arbitrary values are used for normalization and when data variability is low, especially regarding the generation of the latent variables. The discrete choice model component appears to be more robust to these issues. Regarding parameter normalization, we recommend to normalize the variances associated with the HDC model' s structural equations instead of the parameters of its measurement equations, as it is done more often in practice.

Analyzing fluctuations in car-following

- Transportation Research Part B: Methodological---2012---Peter Wagner

Many car-following models predict a stable car-following behavior with a very small fluctuation around an equilibrium value g of the net headway g with zero speed-difference Δv between the following and the lead vehicle. However, it is well-known and additionally demonstrated by data in this paper, that the fluctuations are much larger than these models predict. Typically, the fluctuation in speed difference is around ±2m/s, while the fluctuation in the net time headway T=g/v can be as big as one or even two seconds, which is as large as the mean time headway itself. By analyzing data from loop detectors as well as data from vehicle trajectories, evidence is provided that this randomness is not due to driver heterogeneity, but can be attributed to an internal stochasticity of the driver itself. A final model-based analysis supports the hypothesis, that the preferred headway of the driver is the parameter that is not kept constant but fluctuates strongly, thus causing the even macroscopically observable randomness in traffic flow.

Exploiting the fundamental diagram of urban networks for feedback-based gating

- Transportation Research Part B: Methodological---2012---Mehdi Keyvan-Ekbatani,Anastasios Kouvelas,Ioannis Papamichail,Markos Papageorgiou

Traffic signal control for urban road networks has been an area of intensive research efforts for several decades, and various algorithms and tools have been developed and implemented to increase the network traffic flow efficiency. Despite the continuous advances in the field of traffic control under saturated conditions, novel and promising developments of simple concepts in this area remains a significant objective, because some proposed approaches that are based on various meta-heuristic optimization algorithms can hardly be used in a real-time environment. To address this problem, the recently developed notion of network fundamental diagram for urban networks is exploited to improve mobility in saturated traffic conditions via application of gating measures, based on an appropriate simple feedback control structure. As a case study, the proposed methodology is applied to the urban network of Chania, Greece, using microscopic simulation. The results show that the total delay in the network decreases significantly and the mean speed increases accordingly.

Optimal advance detector location for green termination systems on high-speed isolated rural intersections

- Transportation Research Part B: Methodological---2012---Lili Du,Anuj Sharma,Srinivas Peeta

This study seeks to identify the optimal location of an advance point traffic detector (APTD) to support green termination algorithms for enhanced dilemma zone protection systems at high-speed isolated signalized rural intersections. This is done by developing a nonlinear optimization model with the objective to maximize the opportunities to predict empty dilemma zones during a look-ahead time period subject to the prediction accuracy which is manifested through prediction efficiency and safety constraints in the model. The distance of the APTD from the stop bar of the intersection represents the decision variable. The Golden–Section line search algorithm combined with numerical integration techniques is proposed to identify the feasible region and the optimal solution. The proposed methodology is analyzed using field data from a high-speed isolated intersection in Lincoln, Nebraska. The numerical experiments demonstrate that as the constraints associated with prediction efficiency and safety are relaxed, the feasible range to deploy the APTD increases. The optimal solution is influenced by the relationship between the prediction error and the location of the APTD, illustrating the need to robustly calibrate the function used to estimate the variance of the prediction error using field data. From a practice standpoint, the study confirms the potential concerns related to the performance efficiency of green termination systems using a point detector; typical field implementations locate the detector 750–1000ft from the stop bar, which can potentially lead to significant levels of missed opportunities to terminate green safely. Overall, the proposed approach not only provides a systematic analytical methodology to determine the optimal location of the advance detector, but also to identify its feasible range based on user-specified thresholds related to efficiency and safety.

Flexible build-operate-transfer contracts for road franchising under demand uncertainty

- Transportation Research Part B: Methodological---2012---Zhijia Tan,Hai Yang

As highway franchising programs are being introduced worldwide through the so-called build-operate-transfer (BOT) contracts, both the government and the private investor are facing a critical issue of how to make a BOT contract under the uncertainty of future traffic demand using the new highway. This paper investigates the full and partial flexibility of the BOT contract according to the instruments adopted by the government and the private investor. Full flexibility refers to the case in which the government promises an exogenous rate of return on the private investment and in turn can freely ex post adjust the contract in a socially optimal manner according to the observed demand curve. Partial flexibility refers to the case in which the government and the private investor agree on an ex ante demand risk allocation by contract and the ex post contract adjustment can be made contingent on a Pareto-improvement to both parties. A preferred Pareto-improvement can be selected from the Pareto-optimal solution set of a bi-objective programming problem equipped with a rational preference. The optimal BOT contracts with the two types of flexibility are examined by assuming that the government chooses the original contract variables to maximize the expected total social welfare under demand uncertainty while taking account of the ex post optimal contract adjustments.

Microscopic traffic hysteresis in traffic oscillations: A behavioral perspective

- Transportation Research Part B: Methodological---2012---Danjue Chen,Jorge A. Laval,Soyoung Ahn,Zuduo Zheng

This paper studies traffic hysteresis arising in traffic oscillations from a behavioral perspective. It is found that the occurrence and type of traffic hysteresis is closely correlated with driver behavior when experiencing traffic oscillations and with the time driver reaction begins relative to the starting deceleration wave. Statistical results suggest that driver behavior is different depending on its position along the oscillation. This suggests that different car-following models should be used inside the different stages of an oscillation in order to replicate realistic congestion features.

Congestion derivatives for a traffic bottleneck with heterogeneous commuters

- Transportation Research Part B: Methodological---2012---Tao Yao,Mike Mingcheng Wei,Bo Zhang,Terry Friesz

Deterministic congestion pricing has attracted most attentions in the literature. But little attention has been given to pricing under uncertainty, especially for heterogeneous commuters. In this paper, we investigate congestion externalities by considering commuters' risk preferences and heterogeneity. In particular, when price involves exogenous uncertainty which is independent of both central authority and individual commuters, we are able to express commuters' departure equilibria and the total social cost in closed-form in terms of the departure time and uncertainty. Moreover, we find that uncertainty will lead heterogeneous risk-averse commuters not only to avoid traveling at the time when uncertainty level is high, but also to deviate from their optimal departure sequence. Hence, we are able to show that uncertainty can tremendously increase the total social cost. Furthermore, we also prove that both the central planner and the market-base mechanism have the potential to reduce the total social cost and alter commuters' departure behavior.

Specifically, we find out that the central planner can always find a class of financial derivatives to induce the socially optimal departure behavior, while the market-based mechanism may do so at specific cases. Finally, numerical formulation and experiments are given to assess the robustness of our results for more general forms of uncertainties and derivatives.

Track maintenance production team scheduling in railroad networks

- Transportation Research Part B: Methodological---2012---Fan Peng,Yanfeng Ouyang

US railroad companies spend billions of dollars every year on track maintenance in order to ensure safety and operational efficiency. Optimizing the production team (i.e., large maintenance team) schedule is a very complex problem with major cost implications. In current practice, the decision making process for production team scheduling is largely manual and primarily relies on the knowledge and judgment of experts. This paper addressed the production team scheduling problem by formulating it as a time–space network model with many types of challenging side constraints. Some of these constraints are identified from industry practice and formulated for the first time. Multiple neighborhood search and other enhancement algorithms were proposed to solve the model. The proposed modeling approach has been tested through numerical experiments and also applied to large-scale real-world problem instances, and superior computational performances were found. The proposed approach has been adopted by a Class I railroad to help make annual network maintenance scheduling decisions.

On centroid connectors in static traffic assignment: Their effects on flow patterns and how to optimize their selections

- Transportation Research Part B: Methodological---2012---(Sean) Qian, Zhen,H.M. Zhang

In this paper, we investigate to what extent the results of static traffic assignment (STA) are influenced by centroid connectors and how to optimize their selections. Three networks are used to evaluate the impact of different centroid connector configurations on the resulting traffic flow pattern: a synthetic grid network, the California SR-41 corridor network and a large Sacramento area network. From the STA results of these three networks, we observe large fluctuations on resultant link volumes, maximum volume capacity (V/C) ratios, average V/C ratios and total travel time with respect to randomized connector selections. The fluctuations seem to indicate that STA results are unstable with respect to arbitrary connector selections, and this cannot be improved by simply changing the number of connectors. In fact, more connectors often result in serious under-estimation of total travel time and average link load. We infer that, if provided little information of access/egress nodes of trips, randomly generated connectors lead to artificial over- or under-utilization on network links. We therefore propose a connector optimization algorithm in which the connectors and their travel times are chosen in such a way that the maximum V/C ratio of some characteristic links is minimized. As the numerical example on the SR-41 network indicates, this connector optimization algorithm reduces the artificial over- and under-utilization of network links, and obtains a flow pattern more consistent with the one derived from a refined network where trip access/egress nodes are known in details.

Dynamic congestion pricing with demand uncertainty: A robust optimization approach

- Transportation Research Part B: Methodological---2012---Byung Do Chung,Tao Yao,Terry L. Friesz,Hongcheng Liu

In this paper, we consider dynamic congestion pricing in the presence of demand uncertainty. In particular, we apply a robust optimization (RO) approach based on a bi-level cellular particle swarm optimization (BCPSO) to optimal congestion pricing problems when flows correspond to dynamic user equilibrium on the network of interest. Such a formulation is recognized as a second-best pricing problem, and we refer to it as the dynamic optimal toll problem with equilibrium constraints (DOTPEC). We then present numerical experiments in which BCPSO is compared with two alternative robust dynamic solution approaches: bi-level simulated annealing (BSA) and cutting plane-based simulated annealing (CPSA), as well as a nominal dynamic solution and a robust static solution. We show that robust dynamic solutions improve the worst case, average, and stability of total travel cost in comparison with the nominal dynamic and the robust static solutions. The numerical results also show that BCPSO outperforms BSA and CPSA in terms of solution quality and computational efficiency.

Morning commute with competing modes and distributed demand: User equilibrium, system optimum, and pricing

- Transportation Research Part B: Methodological---2012---Eric J. Gonzales,Carlos F. Daganzo

The morning commute problem for a single bottleneck, introduced in Vickrey (1969), is extended to model mode choice in an urban area with time-dependent demand. This extension recognizes that street space is shared by cars and public transit. It is assumed that transit is operated independently of traffic conditions, and that when it is operated it consumes a fixed amount of space.

A new one-level convex optimization approach for estimating origin–destination demand

- Transportation Research Part B: Methodological---2012---Wei Shen,Laura Wynter

Accurately estimating Origin–Destination (OD) trip tables based on traffic data has become crucial in many real-time traffic applications. The problem of OD estimation is traditionally modeled as a bilevel network design problem (NDP), which is challenging to solve in large-scale networks. In this paper, we propose a new one-level convex optimization formulation to reasonably approximate the bilevel structure, thus allowing the development of more efficient solution algorithms. This one-level approach is consistent with user equilibrium conditions, and improves previous one-level relaxed OD estimation formulations in the literature by ‘equilibrating’ path flows using external path cost parameters. Our new formulation can, in fact, be viewed as a special case of the user equilibrium assignment problem with elastic demand, and hence can be solved efficiently by standard path-based traffic assignment algorithms with an iterative parameter updating scheme. Numerical experiments indicate that this new one-level approach performs very well. Estimation results are robust to network topology, sensor coverage, and observation error, and can achieve further improvements when additional data sources are included.

Cargo routing and empty container repositioning in multiple shipping service routes

- Transportation Research Part B: Methodological---2012---Dong-Ping Song,Jing-Xin Dong

This paper considers the problem of joint cargo routing and empty container repositioning at the operational level for a shipping network with multiple service routes, multiple deployed vessels and multiple regular voyages. The objective is to minimize the total relevant costs in the planning horizon including: container lifting on/off costs at ports, customer demand backlog costs, the demurrage (or waiting) costs at the transhipment ports for temporarily storing laden containers, the empty container inventory costs at ports, and the empty container transportation costs. The laden container routing from the original port to the destination port is limited with at most three service routes. Two solution methods are proposed to solve the optimization problem. The first is a two-stage shortest-path based integer programming method, which combines a cargo routing algorithm with an integer programming of the dynamic system. The second is a two-stage heuristic-rules based integer programming method, which combines an integer programming of the static system with a heuristic implementation algorithm in dynamic system. The two solution methods are applied to two case studies with 30 different scenarios and compared with a practical policy. The results show that two solution methods perform substantially better than the practical policy. The shortest-path based method is preferable for relatively small-scale problems as it yields slightly better solution than the heuristic-rules based method. However, the heuristic-rules based method has advantages in its applicability to large-scale realistic systems while producing good performance, to which the shortest-path based method may be computationally inapplicable. Moreover, the heuristic-rules based method can also be applied to stochastic situations because its second stage is rule-based and dynamical.

On the estimation of arterial route travel time distribution with Markov chains

- Transportation Research Part B: Methodological---2012---Mohsen Ramezani,Nikolas Geroliminis

Recent advances in the probe vehicle deployment offer an innovative prospect for research in arterial travel time estimation. Specifically, we focus on the estimation of probability distribution of arterial route travel time, which contains more information regarding arterial performance measurements and travel time reliability. One of the fundamental contributions of this work is the integration of travel time correlation of route' s successive links within the methodology. In the proposed technique, given probe vehicles travel times of the traversing links, a two-dimensional (2D) diagram is established with data points representing travel times of a probe vehicle crossing two consecutive links. A heuristic grid clustering method is developed to cluster each 2D diagram to rectangular sub spaces (states) with regard to travel time homogeneity. By applying a Markov chain procedure, we integrate the correlation between states of 2D diagrams for successive links. We then compute the transition probabilities and link partial travel time distributions to obtain the arterial route travel time distribution. The procedure with various probe vehicle sample sizes is tested on two study sites with time dependent conditions, with field measurements and simulated data. The results are very close to the Markov chain procedure and more accurate once compared to the convolution of links travel time distributions for different levels of congestion, even for small penetration rates of probe vehicles.

A continuous approximation model for the fleet composition problem

- Transportation Research Part B: Methodological---2012---Ola Jabali,Michel Gendreau,Gilbert Laporte

This paper presents a continuous approximation model to determine the long-term vehicle fleet composition needed to perform distribution activities. The problem is a realistic variant of the vehicle routing problem, in which the fleet size and mix are also decision variables. The types of vehicles differ in terms of their capacities, fixed costs and variable costs. The objective is to minimize the total cost, subject to capacity and route duration constraints. We assume customers are distributed over a circular service region partitioned into zones, each of which is serviced by a single vehicle. The routing costs are assessed through a continuous approximation model. We present a mixed integer non-linear formulation for the problem, followed by computationally efficient upper and lower bounding procedures. The performance of the model and of its bounds is assessed on several test instances.

The effect of variability of urban systems characteristics in the network capacity

- Transportation Research Part B: Methodological---2012---Nikolas Geroliminis,Burak Boyacı

Recent experimental analysis has shown that some types of urban networks exhibit a low scatter reproducible relationship between average network flow and density, known as the macroscopic fundamental diagram (MFD). It has also been shown that heterogeneity in the spatial distribution of density can significantly decrease the network flow for the same value of density. Analytical theories have been developed to explore the connection between network structure and an MFD for urban neighborhoods with cars controlled by traffic signals. However these theories have been applied only in cities with deterministic values of topological and control variables for the whole network and by ignoring the effect of turns. In our study we are aiming to generate an MFD for streets with variable link lengths and signal characteristics and understand the effect of variability for different cities and signal structures. Furthermore, this variability gives the opportunity to mimic the effect of turning movements. Route or network capacity can be significantly smaller than the capacity of a single link, because of the correlations developed through the different values of offsets. The above analysis would not be possible using standard traffic engineering techniques. This will be a key issue in planning the signal regimes such a way that maximizes the network capacity and/or the density range of the maximum capacity.

A network sensor location procedure accounting for o–d matrix estimate variability

- Transportation Research Part B: Methodological---2012---Fulvio Simonelli,Vittorio Marzano,Andrea Papola,Iolanda Vitiello

The paper illustrates an innovative and theoretically founded methodology for solving the network sensor location problem (NSLP), explicitly accounting for the variability of the o–d matrix estimate. The proposed approach is based on a specific measure, termed synthetic dispersion measure (SDM), related to the trace of the covariance matrix of the posterior demand estimate conditional upon a set of sensor locations. Under the mild assumption of multivariate normal distribution for the prior demand estimate, the proposed SDM does not depend on the specific values of the counted flows – unknown in the planning stage – but just on the locations of such sensors. From a practical standpoint, a stepwise algorithm is implemented for calculating the proposed measure given a set of link counts, which avoids matrix inversion. In addition, a sequential heuristic algorithm is presented for the application of the proposed NSLP to real contexts. The methodology also allows a formal budget allocation problem to be set between surveys and counts in the planning stage, in order to maximize the overall quality of the demand estimation process.

On the spatial partitioning of urban transportation networks

- Transportation Research Part B: Methodological---2012---Yuxuan Ji,Nikolas Geroliminis

It has been recently shown that a macroscopic fundamental diagram (MFD) linking space-mean network flow, density and speed exists in the urban transportation networks under some conditions. An MFD is further well defined if the network is homogeneous with links of similar properties. This collective behavior concept can also be utilized to introduce simple control strategies to improve mobility in homogeneous city centers without the need for details in individual links. However many real urban transportation networks are heterogeneous with different levels of congestion. In order to study the existence of MFD and the feasibility of simple control strategies to improve network performance in heterogeneously congested networks, this paper focuses on the clustering of transportation networks based on the spatial features of congestion during a specific time period. Insights are provided on how to extend this framework in the dynamic case. The objectives of partitioning are to obtain (i) small variance of link densities within a cluster which increases the network flow for the same average density and (ii) spatial compactness of each cluster which makes feasible the application of perimeter control strategies. Therefore, a partitioning mechanism which consists of three consecutive algorithms, is designed to minimize the variance of link densities while maintaining the spatial compactness of the clusters. Firstly, an over segmenting of the network is provided by a sophisticated algorithm (Normalized Cut). Secondly, a merging algorithm is developed based on initial segmenting and a rough partitioning of the network is obtained. Finally, a boundary adjustment algorithm is designed to further improve the quality of partitioning by decreasing the variance of link densities while keeping the spatial compactness of the clusters. In addition, both density variance and shape smoothness metrics are introduced to identify the desired number of clusters and evaluate the partitioning results. These results show that both the objectives of small variance and spatial compactness can be achieved with this partitioning mechanism. A simulation in a real urban transportation network further demonstrates the superiority of the proposed method in effectiveness and robustness compared with other clustering algorithms.

Dynamic user equilibrium with a path based cell transmission model for general traffic networks

- Transportation Research Part B: Methodological---2012---Satish V. Ukkusuri,Lanshan Han,Kien Doan

This paper develops a formulation for the network level dynamic traffic equilibrium model with departure time choice and route choice. The embedded network loading procedure follows the cell transmission model without the holding-back issues by using detailed representations of flows at merges and diverges. The problem is modeled using a complementarity approach. The existence of the equilibrium solution is discussed using techniques from generalized variational inequalities. Computational results are performed using state of the art solvers. Since these solvers fail to solve any reasonable size networks, a specialized projection algorithm is developed to solve the problem. Numerical results are presented to demonstrate the performance of the algorithm in various starting with simple networks and extending to reasonable size networks with different traffic parameters. It is shown that the solution procedure produces good dynamic equilibrium solutions for general transportation networks.

Bisection-based trial-and-error implementation of marginal cost pricing and tradable credit scheme

- Transportation Research Part B: Methodological---2012---Xiaolei Wang,Hai Yang

The purpose of this paper is three fold: First, it demonstrates the non-convergence of the bisection method proposed in the literature for the trial-and-error implementation of the marginal-cost pricing in the absence of a demand function. Second, it provides a modified version of the bisection method and establishes its convergence. Third, it adapts the modified bisection method for the trial-and-error implementation of the tradable credit scheme proposed recently, which can emulate a congestion pricing system in a revenue-neutral manner.

Arterial travel time forecast with streaming data: A hybrid approach of flow modeling and machine learning

- Transportation Research Part B: Methodological---2012---Aude Hofleitner,Ryan Herring,Alexandre Bayen

This article presents a hybrid modeling framework for estimating and predicting arterial traffic conditions using streaming GPS probe data. The model is based on a well-established theory of traffic flow through signalized intersections and is combined with a machine learning framework to both learn static parameters of the roadways (such as free flow velocity or traffic signal parameters) as well as to estimate and predict travel times through the arterial network. The machine learning component of the approach uses the significant amount of historical data collected by the Mobile Millennium system since March 2009 with over 500 probe vehicles reporting their position once per minute in San Francisco, CA.

Optimal threshold-based network-level transportation infrastructure life-cycle management with heterogeneous maintenance actions

- Transportation Research Part B: Methodological---2012---James C. Chu,Yin-Jay Chen

Transportation infrastructure life-cycle management deals with maintenance decision making of transportation facilities such as pavement, bridges, and railways under budget constraints. In practice, transportation agencies adopt threshold-based rules for maintenance planning because they are intuitive and easy to implement. However, the thresholds are often determined based on engineering judgment without any systematic approach. Therefore, maintenance budgets cannot be used effectively and facility conditions are not optimized. This research uses hybrid dynamic models to represent threshold-based maintenance for transportation infrastructure in a realistic manner. Hybrid dynamic models combine continuous states such as pavement roughness and age with discrete states such as maintenance history. These models are also capable of considering multiple maintenance actions with heterogeneous effects. Based on facility conditions and maintenance thresholds, corresponding maintenance actions are selected automatically and the facility switches between deterioration modes to reflect the effects of the chosen action. Furthermore, to consider users' reactions to maintenance actions and accurately predict deterioration for a network of facilities, threshold-based maintenance is formulated as an upper-level problem, and user response is incorporated as a lower-level problem. This leads to a bi-level programming problem where maintenance thresholds are decision variables, which is solved with a modified tabu search algorithm. The proposed methodology is validated with the road network of an urban area and the generated maintenance thresholds are reasonable and robust, which shows that the methodology has great potential to support transportation infrastructure life-cycle management in practice.

A global optimization method for continuous network design problems

- Transportation Research Part B: Methodological---2012---Changmin Li,Hai Yang,Daoli Zhu,Qiang Meng

The continuous network design problem (CNDP) is generally formulated as a mathematical program with equilibrium constraints (MPEC). It aims to optimize the network performance via expansion of existing links subject to the Wardrop user equilibrium constraint. As one of the extremely challenging problems in the transportation research field, various solution methods have been proposed for solving the CNDP. However, most of the algorithms developed up to date can only find a local optimum due to inherent nonconvexity of the MPEC. This paper proposes a viable global optimization method for the CNDP. Based on the concepts of gap function and penalty, the CNDP is transferred into a sequence of single level concave programs, which is amenable to a global solution. It is proved that any accumulation of the solutions to the sequence of concave programs is a globally optimal solution to the original CNDP. Owing to their special structure, all concave programs can be solved by a multicutting plane method. The penalty term in each step of the inner subproblem can be calculated by simply executing an all-or-nothing assignment.

On the stability of traffic perimeter control in two-region urban cities

- Transportation Research Part B: Methodological---2012---Jack Haddad,Nikolas Geroliminis

In this paper, stability analysis of traffic control for two-region urban cities is treated. It is known in control theory that optimality does not imply stability. If the optimal control is applied in a heavily congested system with high demand, traffic conditions might not change or the network might still lead to gridlock. A city partitioned in two regions with a Macroscopic Fundamental Diagram (MFD) for each of the regions is considered. Under the assumption of triangular MFDs, the two-region MFDs system is modeled as a piecewise second-order system. Necessary and sufficient conditions are derived for stable equilibrium accumulations in the undersaturated regimes for both MFDs. Moreover, the traffic perimeter control problem for the two-region MFDs system is formulated. Phase portraits and stability analysis are conducted, and a new algorithm is proposed to derive the boundaries of the stable and unstable regions. Based on these regions, a state-feedback control strategy is derived. Trapezoidal shape of MFDs are also addressed with numerical solutions.

Linking discrete choice to continuous demand within the framework of a computable general equilibrium model

- Transportation Research Part B: Methodological---2012---Truong Truong,David Hensher

Discrete choice (DC) models are commonly used as basic building blocks in 'bottom-up' models which seek to describe consumer and producer behaviour at a disaggregate level, in contrast to continuous demand (CD) models which are used to describe behaviour at a more aggregate level. At a disaggregate level, choice behaviour is defined in terms of commodities differentiated by qualities or attributes. In contrast, aggregate demand behaviour is defined in terms of broadly defined and generically different commodities. In a DC model, the main focus of analysis is not the total quantity of demand, but rather the relative shares or substitution between the choice alternatives, in contrast to a continuous demand model where the focus is on the aggregate substitution between groups of commodities as well as on the income effects. Seen in this way, there is scope for complementary usage of DC and CD models within the framework of a CGE model where DC models are used to describe the preferences for a narrowly defined set of commodities belonging to a particular sector of an economy, and CD models are used to describe the interactions between these sectors. In this paper, we describe how DC and CD models can be used in such an integrated fashion in a spatial computable general equilibrium model to inquire into the wider economic impacts of a transport investment project in the Sydney Metropolitan Area.

How much can holding and/or limiting boarding improve transit performance?

- Transportation Research Part B: Methodological---2012---Felipe Delgado,Juan Carlos Munoz,Ricardo Giesen

Bus bunching affects transit operations by increasing passenger waiting times and its variability. This work proposes a new mathematical programming model to control vehicles operating on a transit corridor minimizing total delays. The model can handle a heterogeneous fleet of vehicles with different capacities without using binary variables, which make solution times compatible with real-time requirements. Two control policies are studied within a rolling horizon framework: (i) vehicle holding (HRT), which can be applied at any stop and (ii) holding combined with boarding limits (HBLRT), in which the number of boarding passengers at any stop can be limited in order to increase operational speed. Both strategies are evaluated in a simulation environment under different operational conditions. The results show that HBLRT and HRT outperform other benchmark control strategies in all scenarios, with savings of excess waiting time of up to 77% and very low variability in performance. HBLRT shows significant benefits in relation to HRT only under short headway operation and high passenger demand. Moreover, our results suggest implementing boarding limits only when the next arriving vehicle is nearby. Interestingly, in these cases HBLRT not only reduces an extra 6.3% the expected waiting time in comparison with HRT, but also outperforms other control schemes in terms of comfort and reliability to both passengers and operators. To passengers HBLRT provide a more balanced load factor across vehicles yielding a more comfortable experience. To operators the use of boarding limits speed up vehicles reducing the average cycle time and its variability, which is key for a smooth operation at terminals.

On the holding-back problem in the cell transmission based dynamic traffic assignment models

- Transportation Research Part B: Methodological---2012---Kien Doan,Satish V. Ukkusuri

Traffic holding-back is considered an undesirable issue in dynamic traffic assignment since the vehicles are artificially held back on links in spite of the availability of downstream capacity. Holding-back occurs naturally in some system optimal dynamic traffic assignment models. In this paper, we focus on the holding back issue in the cell transmission based models and review the current methods of solving holding-back to understand their advantages and drawbacks. Then, we propose improvements to overcome the drawbacks of the current models. Finally, we propose a novel model which completely eliminates holding-back in a system optimal dynamic traffic assignment for traffic networks with multiple O–D pairs. Rigorous numerical results illustrate the benefits of using the proposed models.

Do more US airports need slot controls? A welfare based approach to determine slot levels

- Transportation Research Part B: Methodological---2012---Prem Swaroop,Bo Zou,Michael O. Ball,Mark Hansen

This paper analyzes the welfare effects of slot controls on major US airports. We consider the fundamental tradeoff between benefits from queuing delay reduction and costs due to simultaneous schedule delay increase to passengers while imposing slot limits at airports. A set of quantitative models and simulation procedures are developed to explore the possible airline scheduling responses through reallocating and trimming flights. We find that, of the 35 major US airports, a more widespread use of slot controls would improve travelers’ welfare. The results from our analyses suggest that slot caps at the four airports that currently have slot controls (Washington Reagan, Newark, New York LaGuardia, New York John F. Kennedy) are set too high. Further slot reduction by removing some of the flights at these airports could generate additional benefits to passengers. Slot controls can potentially reduce two thirds of the total system delays caused by congestion. A number of implementation and design issues related to the use of slot controls are also discussed in the paper.

A capacity-increasing mechanism in freeway traffic

- Transportation Research Part B: Methodological---2012---Kwangho Kim,Michael J. Cassidy

A reason is unveiled for the time-varying pattern in discharge flow that is commonly observed at freeway bottlenecks. We hypothesize that four known effects in freeway traffic can interact upstream of a bottleneck in ways that trigger periodic bursts in its discharge flow. Repeated observations of a 3-km freeway stretch support the hypothesis. Controlled experiments show that the capacity-increasing mechanism can be favorably modulated by metering the site’s on-ramps in an unconventional manner. The unconventional strategy repeatedly produced higher average discharge flows and shorter on-ramp queues than did a more traditional metering policy.

Design of more equitable congestion pricing and tradable credit schemes for multimodal transportation networks

- Transportation Research Part B: Methodological---2012---Di Wu,Yafeng Yin,Siriphong Lawphongpanich,Hai Yang

This paper develops a modeling framework that considers the effect of income on travelers’ choices of trip generation, mode and route on multimodal transportation networks and explicitly captures the distributional impacts of congestion–mitigation policies on different income and geographic groups. The modeling framework is applied to design more equitable yet efficient congestion pricing and tradable credit schemes. The design models are formulated as mathematical programs with equilibrium constraints, and solved by derivative-free solution algorithms. Numerical examples are presented to demonstrate the models and offer insight on the mechanisms of achieving better equity under congestion pricing or tradable credit schemes.

On the design of public infrastructure systems with elastic demand

- Transportation Research Part B: Methodological---2012---Carlos F. Daganzo

This paper considers the optimization of public infrastructure systems, recognizing that these systems serve multiple user classes. Example application domains include: public transportation systems, electricity distribution grids, urban water distribution systems, and maintenance of pavement and bridge systems. Under the guidance of a policy-making body, the analyst chooses both the system design, including its layout and control, and the prices to be charged for the service. The goal of the optimization is to maximize society’s welfare recognizing that the system’s performance will in general depend on the system' s demand, and vice versa.

Using prospect theory to investigate the low marginal value of travel time for small time changes

- Transportation Research Part B: Methodological--2012---Katrine Hjorth,Mogens Fosgerau

A common finding in stated preference studies that measure the value of travel time (VTT) is that the measured VTT increases with the size of the time change considered, in conflict with standard neoclassical economic theory. We present a new test of a possible explanation for the phenomenon that builds on the diminishing or constant sensitivity of the value functions in prospect theory.

Managing congestion and emissions in road networks with tolls and rebates

- Transportation Research Part B: Methodological--2012---Linxi Chen,Hai Yang

Traffic congestion and emissions are two main types of social cost, and their minimization sometimes conflicts with each other. In this paper we seek nonnegative link toll schemes and/or link toll cum rebate schemes for Pareto-efficient control and management of both vehicular congestion and emissions on road networks using a bi-objective optimization approach. We provide necessary and sufficient conditions for the existence of such schemes to decentralize a given target link flow pattern. Then, we investigate the possibility of introducing such schemes to obtain specific Pareto system optimum target link flow patterns with two types of link emission function: increasing functions and non-monotonic functions, respectively.

User rationality and optimal park-and-ride location under potential demand maximization

- Transportation Research Part B: Methodological--2012---Holguı´n-Veras, José,Wilfredo F. Yushimito,Felipe Aros-Vera,Reilly, John (Jack)

The paper develops analytical formulations to gain insight into the optimal location, i.e., the one that maximizes the potential market, and to estimate the potential catchment area of Park and Ride (P&R) facilities. The formulations are based on the assumption that a traveler would use a P&R facility if and only if the corresponding generalized cost is lower than the drive only alternative. The paper considers two different scenarios: a linear city (or a travel corridor), and a two-dimensional city with Euclidean travel. Analytical derivations were obtained for both cases using, as starting point, the necessary condition for P&R use.

Is the travel time of private roads too short, too long, or just right?

- Transportation Research Part B: Methodological--2012---Vincent van den Berg,Erik Verhoef

We consider price and service-quality setting in oligopolistic markets for congestible services, applied to the case of private roads. Previous studies show that parallel competitors set a volume/capacity ratio (and thereby a travel time or service quality) that is socially optimal if they take the actions of the others as given. We find that this result does not hold when capacity and toll setting are separate stages—as then firms aim to limit toll competition by setting lower capacities, and thus higher travel times—or when firms set capacities sequentially, as then firms aim to limit the capacities of later entrants by setting higher capacities. In our Stackelberg competition, the last firm to act has no capacity decisions to influence. Hence, it is only concerned with the toll-competition substage, and sets a travel time that is longer than socially optimal. The first firm cares mostly about the competitors' capacities that it can influence: it sets a travel time that is shorter than socially optimal. The average travel time will be too short from a societal point of view.

Optimal team deployment in urban search and rescue

- Transportation Research Part B: Methodological--2012---Lichun Chen,Elise Miller-Hooks

The problem of optimally deploying urban search and rescue (USAR) teams to disaster sites in post-disaster circumstances is formulated as a multistage stochastic program (MSP). A portion of sites requiring assistance arrive dynamically over the decision horizon and key problem characteristics are known only with uncertainty a priori. The problem seeks to identify a set of tours for USAR teams so as to maximize the total expected number of people that can be saved by attending to all or a subset of disaster sites within the disaster region. Decisions are taken dynamically over the decision horizon as situational awareness improves and survival likelihood diminishes with the aim of increasing the expected number of saved lives. To overcome the expensive computational effort associated with solving a MSP, a column generation-based strategy that consists of solving a series of interrelated two-stage stochastic programs with recourse within a shrinking time horizon is developed.

A kinematic wave theory of multi-commodity network traffic flow

- Transportation Research Part B: Methodological---2012---Wen-Long Jin

A systematic understanding of traffic dynamics on road networks is crucial for many transportation studies and can help to develop more efficient ramp metering, evacuation, signal control, and other management and control strategies. In this study, we present a theory of multi-commodity network traffic flow based on the Lighthill–Whitham–Richards (LWR) model. In particular, we attempt to analyze kinematic waves of the Riemann problem for a general junction with multiple upstream and downstream links. In this theory, kinematic waves on a link can be determined by its initial condition and prevailing stationary state. In addition to a stationary state, a flimsy interior state can develop next to the junction on a link. In order to pick out unique, physical solutions, we introduce two types of entropy conditions in supply-demand space such that (i) speeds of kinematic waves should be negative on upstream links and positive on downstream links, and (ii) fair merging and First-In-First-Out diverging rules are used to prescribe fluxes from interior states. We prove that, for given initial upstream demands, turning proportions, and downstream supplies, there exists a unique critical demand level satisfying the entropy conditions. It follows that stationary states and kinematic waves on all links exist and are unique, since they are uniquely determined by the critical demand level. For a simple model of urban or freeway intersections with four upstream and four downstream links, we demonstrate that theoretical solutions are consistent with numerical ones from a multi-commodity Cell Transmission Model. In a sense, the proposed theory can be considered as the continuous version of the multi-commodity Cell Transmission Model with fair merging and First-In-First-Out diverging rules. Finally we discuss future research topics along this line.

Stochastic traffic assignment, Lagrangian dual, and unconstrained convex optimization

- Transportation Research Part B: Methodological---2012---Chi Xie,S. Travis Waller

In this paper, traffic assignment problems with stochastic travel cost perceptions are reformulated and investigated in a new unconstrained nonlinear programming formulation. The objective function of the unconstrained formulation consists of two terms, in which the first term specifies the routing principle of the target problem through a satisfaction function and the sum of the first and second terms denotes the system cost or optimization objective. This formulation proves to be the Lagrangian dual of a generic primal formulation proposed by Maher et al. (2005) for the stochastic system-optimal problem. The primal–dual modeling framework presents such a common functional form that can accommodate a wide range of different traffic assignment problems. Our particular attention is given to the dual formulation in that its unconstrained feature opens the door of applying unconstrained optimization algorithms for its embraced traffic assignment problems. Numerical examples are provided to support the insights and facts derived from applying the primal and dual formulations to model stochastic system-optimal and user-equilibrium problems and justify the conjugate relationship between the primal and dual models.

Parametric search and problem decomposition for approximating Pareto-optimal paths

- Transportation Research Part B: Methodological---2012---Chi Xie,S. Travis Waller

The multiobjective shortest path problem arises in many transportation and logistics applications, either as a stand-alone network routing problem or a subroutine of a more complex multiobjective network optimization problem. It has been addressed by different solution strategies, including labeling methods, ranking methods, constraint methods, and parametric methods. Increasing attention has been paid to parametric methods in recent years, partially because of its simple algorithmic logic and its flexibility of being used in different user-preference decision-making environments. The core idea of a parametric algorithm is scalarization, by which a multiobjective shortest path problem can be tackled by repeatedly solving a single-objective subproblem. However, existing parametric algorithms suffer two notorious deficiencies, which considerably limit its further applications: first, typical subroutines for the single-objective subproblem in general cannot capture nonextreme Pareto-optimal paths; second, parametric algorithms for biobjective problems cannot be directly extended to solving multiobjective problems. This paper provides some algorithmic improvements that can partially overcome these deficiencies. In particular, the contribution of this work is twofold: first, in the biobjective parametric solution framework, we propose an approximate label-setting algorithm for the parameterized, constrained single-objective subproblem, which is capable of identifying all extreme paths and a large percentage (i.e., 85–100%) of nonextreme paths; second, we suggest a general projection scheme that can decompose a multiobjective problem into a number of biobjective problems. The approximate parametric algorithm runs in polynomial time. The algorithmic design and solution performance of the algorithm for multiobjective shortest path problems are illustrated, and numerically evaluated and compared with a benchmark algorithm in terms of solution completeness and efficiency.

Public-transit frequency setting using minimum-cost approach with stochastic demand and travel time

- Transportation Research Part B: Methodological---2012---Yuval Hadas,Matan Shnaiderman

Common practice in public-transit planning is to determine the frequency of service based on accumulated hourly passenger counts, average travel time, given vehicle capacity, and the standard of minimum frequency by time of day. With the increased usage of automatic vehicle location (AVL) and automatic passenger counting (APC) systems, it is possible to construct the statistical distributions of passenger demand and travel time by time of day. This can give rise to improve the accuracy of the frequencies determined. This study presents a new approach of frequency setting by enabling the use of stochastic properties of the collected data and its associated costs within a supply chain optimization model. An optimization framework is constructed based on two main cost elements: (a) empty-seat driven (unproductive cost) and (b) overload and un-served demand (increased user cost). The objective function is to minimize the total cost incurred with decision variables of either frequency or vehicle capacity (vehicle size). That is, from the operator perspective it is desirable to utilize efficiently the fleet of vehicles which is related to the decisions of the vehicle size. From the authority perspective, the concern is to provide an adequate level of service in terms of frequency. The study contains sensitivity analysis of the cost elements involved for economic evaluation.

Route choice in pedestrian evacuation under conditions of good and zero visibility: Experimental and simulation results

- Transportation Research Part B: Methodological---2012---Ren-Yong Guo,Hai-Jun Huang,S.C. Wong

The route choice of pedestrians during evacuation under conditions of both good and zero visibility is investigated using a group of experiments conducted in a classroom, and a microscopic pedestrian model with discrete space representation. Observation of the video recordings made during the experiments reveals several typical forms of behavior related to preference for destination, effect of capacity, interaction between pedestrians, following behavior and evacuation efficiency. Based on these forms of behavior, a microscopic pedestrian model with discrete space representation is developed. In the model, two algorithms are proposed to describe the movement of pedestrians to a destination under conditions of both good and zero visibility, respectively. Through numerical simulations, the ability of the model to reproduce the behavior observed in the experiments is verified. The study is helpful for devising evacuation schemes and in the design of internal layouts and exit arrangements in buildings that are similar to the classroom.

Modeling transport management and land use over time

- Transportation Research Part B: Methodological---2012---Xiaosu Ma,Hong K. Lo

Due to ever increasing travel demand, fiscal and environmental constraints, it is recognized that pure transport supply or pure demand management alone is not effective to mitigate traffic congestion. Developing integrated transport supply and demand management (TS–DM) strategies is crucial for ensuring sustainable urban development. TS–DM strategies will not only affect the transport system performance, but also induce changes in the land use pattern and hence changes in land value. Moreover, the implementation of TS–DM strategies typically involves a progressively phased schedule; one must account for the costs and effects that accrue over time. This paper develops a formulation to study the impact of TS–DM strategies on the overall system performance and activity location costs expressed as land value. Specifically, a nested multinomial logit model combined with the bid-rent process is formulated to model residents' location and travel choices, with the problem of housing supply integrated in this framework. The overall combined network equilibrium problem is expressed as a non-linear complementarity problem. The existence and uniqueness of the equilibrium solutions are investigated through an equivalent mathematical programming formulation. Moreover, analytical results are derived to study the distribution of benefits due to transport infrastructure improvement among different stakeholders for networks with one origin–destination (OD) pair, for scenarios of homogenous and heterogeneous values of time. The analytical results show that transport improvements benefit landowners or developers rather than tenants under the scenario of homogeneous value of time; and benefit people with a higher income more under the scenario of heterogeneous value of time. Finally, a mathematical program is developed to determine the optimal TS–DM strategies over time in order to optimize the overall system performance. For general networks with multiple OD pairs, where analytical results are not available, a numerical example is provided to illustrate the effects of TS–DM strategies, which generally echo the analytical results developed for the case with one OD pair.

Modeling the effects of integrated rail and property development on the design of rail line services in a linear monocentric city

- Transportation Research Part B: Methodological---2012---Zhi-Chun Li,William H.K. Lam,S.C. Wong,Keechoo Choi

This paper proposes a new model for investigating the effects of integrated rail and property development on the design of rail line services in a linear monocentric city, in which the property development rights at railway station areas are conferred to a private rail operator. The proposed model allows an explicit consideration of the interaction between two types of agents in the economy: (1) a private rail operator who seeks to optimize rail service variables—rail line length, number and spacing of stations, headway and fare—to maximize its own net profit, which is the sum of revenues from passenger fare-box and property development; and (2) households who choose the residential locations that maximize their own utilities subject to a budget constraint. The solution properties of the proposed model are analyzed, and a heuristic solution algorithm is presented. An illustrative example is used to show the application of the proposed model. The findings show that integrated rail and property development can change a city' s land-use pattern and housing market (in terms of housing density, space, and price), and its economic viability is closely related to household income level and residential density of the city.

Accommodating multiple constraints in the multiple discrete–continuous extreme value (MDCEV) choice model

- Transportation Research Part B: Methodological---2012---Marisol Castro,Chandra R. Bhat,Ram M. Pendyala,Sergio R. Jara-Díaz

Multiple-discrete continuous choice models formulated and applied in recent years consider a single linear resource constraint, which, when combined with consumer preferences, determines the optimal consumption point. However, in reality, consumers face multiple resource constraints such as those associated with time, money, and capacity. Ignoring such multiple constraints and instead using a single constraint can, and in general will, lead to poor data fit and inconsistent preference estimation, which can then have a serious negative downstream effect on forecasting and welfare/policy analysis.

A behavioral car-following model that captures traffic oscillations

- Transportation Research Part B: Methodological---2012---Danjue Chen,Jorge Laval,Zuduo Zheng,Soyoung Ahn

This paper presents a behavioral car-following model based on empirical trajectory data that is able to reproduce the spontaneous formation and ensuing propagation of stop-and-go waves in congested traffic. By analyzing individual drivers' car-following behavior throughout oscillation cycles it is found that this behavior is consistent across drivers and can be captured by a simple model. The statistical analysis of the model' s parameters reveals that there is a strong correlation between driver behavior before and during the oscillation, and that this correlation should not be ignored if one is interested in microscopic output. If macroscopic outputs are of interest, simulation results indicate that an existing model with fewer parameters can be used instead. This is shown for traffic oscillations caused by rubbernecking as observed in the US 101 NGSIM dataset. The same experiment is used to establish the relationship between rubbernecking behavior and the period of oscillations.

The value of travel time variability with trip chains, flexible scheduling and correlated travel times

- Transportation Research Part B: Methodological---2012---Erik Jenelius

This paper extends the analysis of the value of mean travel time (VMTT) and day-to-day travel time variability (VTTV) from single, isolated trips to daily trip chains, considering the effects of flexibility in activity scheduling and within-day correlation of travel times. Using a multi-stage stochastic programming approach, we show that the VMTT and VTTV on a trip is conditional on the realized travel times on preceding trips, first through the arrival time to the preceding activity and second through the information provided about subsequent travel times. Analytical formulas for the VMTT and VTTV are obtained for two special cases with piecewise constant and linear marginal cost functions, respectively. With flexible scheduling, there is typically a cost associated with a positive correlation of travel times, arising from persistent deviations from typical travel demand or supply on a given day. However, there is also a strict benefit in the dependence since it allows for a more efficient scheduling of later trips.

Synergistic sensor location for link flow inference without path enumeration: A node-based approach

- Transportation Research Part B: Methodological---2012---ManWo Ng

Sensors are becoming increasingly critical elements in contemporary transportation systems, gathering essential (real-time) traffic information for the planning, management and control of these complex systems. In a recent paper, Hu, Peeta and Chu introduced the interesting problem of determining the smallest subset of links in a traffic network for counting sensor installation, in such a way that it becomes possible to infer the flows on all remaining links. The problem is particularly elegant because of its limited number of assumptions. Unfortunately, path enumeration was required, which – as recognized by the authors – is infeasible for large-scale networks without further simplifying assumptions (that would destroy the assumption-free nature of the problem). In this paper, we present a reformulation of this link observability problem, requiring only node enumeration. Using this node-based approach, we prove a conjecture made by Hu, Peeta and Chu by deriving an explicit relationship between the number of nodes and links in a transportation network, and the minimum number of sensors to install in order to be able to infer all link flows. In addition, we demonstrate how the proposed method can be employed for road networks that already have sensors installed on them. Numerical examples are presented throughout.

Latent class model for car following behavior

- Transportation Research Part B: Methodological---2012---Haris N. Koutsopoulos,Haneen Farah

Car-following behavior, which describes the behavior of a vehicle while following the vehicle in front of it, has a significant impact on traffic performance, safety, and air pollution. In addition, car-following is an essential component of micro-simulation models. Over the last decade the use of microscopic simulation models as a tool for investigating traffic systems, ITS applications, and emission impacts, is becoming increasingly popular. The paper presents a flexible framework for modeling car-following behavior that relaxes some limitations and assumptions of the most commonly used car following models. The proposed approach recognizes different regimes in driving such as car-following, free-flow, emergency stopping, and incorporates different decisions in each regime, such as acceleration, deceleration, and do-nothing depending on the situation. A case study using NGSIM vehicle trajectory data is used to illustrate the proposed model structure. Statistical tests suggest that the model performs better than previous models.

Optimal paths in dynamic networks with dependent random link travel times

- Transportation Research Part B: Methodological---2012---He Huang,Song Gao

This paper addresses the problem of finding optimal paths in a network where all link travel times are stochastic and time-dependent, and correlated over time and space. A disutility function of travel time is defined to evaluate the paths, and those with the minimum expected disutility are defined as the optimal paths. Bellman’s Principle (Bellman, 1958) is shown to be invalid if the optimality or non-dominance of a path and its sub-paths is defined with respect to the complete set of departure times and joint realizations of link travel time. An exact label-correcting algorithm is designed to find optimal paths based on a new property for which Bellman’s Principle holds. The algorithm has exponential worst-case computational complexity. Computational tests are conducted on three types of networks. Although the average running time is exponential, the number of the optimal path candidates is polynomial on two networks and grows exponentially in the third one. Computational results in large networks and analytical results in a small network show that stochastic dependencies affect optimal path finding in a stochastic network, and that the impact is closely related to the levels of correlation and risk attitude.

Synchronization of bus timetabling

- Transportation Research Part B: Methodological---2012---Omar J. Ibarra-Rojas,Yasmin A. Rios-Solis

Timetable generation is a subproblem of bus network strategic planning, in which the departure time of each trip is determined. We study the bus network of Monterrey, Mexico, which is similar to those of other cities in Latin America. It is a large bus network where passenger transfers must be favored, almost evenly spaced departures are sought, and bus bunching of different lines must be avoided. We formulate the timetabling problem of this network with the objective of maximizing the number of synchronizations to facilitate passenger transfers and avoid bus bunching along the network. We define these synchronizations as the arrivals of two trips with a separation time within a time window to make a flexible formulation. This flexibility is a critical aspect for the bus network, since travel times vary because of reasons such as driver speed, traffic congestion, and accidents. By proving that our problem is NP-hard we answer a 10-year-old open question about the NP-hardness of similar problems present in literature. Next, we analyze the structural properties of the feasible solution space of our model. This analysis leads to a preprocessing stage that eliminates numerous decision variables and constraints. Moreover, this preprocessing defines feasible synchronization and arrival time windows that are used in a new metaheuristic algorithm. Empirical experimentation shows that our proposed algorithm obtains high-quality solutions for real-size instances in less than one minute.

Liner ship route schedule design with sea contingency time and port time uncertainty

- Transportation Research Part B: Methodological---2012---Shuaian Wang,Qiang Meng

This paper deals with a tactical-level liner ship route schedule design problem which aims to determine the arrival time of a ship at each portcall on a ship route and the sailing speed function on each voyage leg by taking into account time uncertainties at sea and at port. It first derives the optimality condition for the sailing speed function with sea contingency and subsequently demonstrates the convexity of the bunker consumption function. A mixed-integer non-linear stochastic programming model is developed for the proposed liner ship route schedule design problem by minimizing the ship cost and expected bunker cost while maintaining a required transit time service level. In view of the special structure of the model, an exact cutting-plane based solution algorithm is proposed. Numerical experiments on real data provided by a global liner shipping company demonstrate that the proposed algorithm can efficiently solve real-case problems.

Dynamic traffic assignment approximating the kinematic wave model: System optimum, marginal costs, externalities and tolls

- Transportation Research Part B: Methodological---2012---Malachy Carey,David Watling

System marginal costs, externalities and optimal congestion tolls for traffic networks are generally derived from system optimising (SO) traffic assignment models and when they are treated as varying over time they are referred to as dynamic. In dynamic system optimum (DSO) models the link flows and travel times or costs are generally modelled using so-called ‘whole link’ models. Here we instead develop an SO model that more closely reflects traffic flow theory and derive the marginal costs and externalities from that. The most widely accepted traffic flow model appears to be the LWR (Lighthill, Whitham and Richards) model and a tractable discrete implementation or approximation to that is provided by the cell transmission model (CTM) or a finite difference approximation (FDA). These handle spillbacks, traffic controls and moving queues in a way that is consistent with the LWR model and hence with the kinematic wave model and fluid flow model. An SO formulation using the CTM is already available, assuming a single destination and a trapezoidal flow-density function. We extend the formulation to allow more general nonlinear flow density functions and derive and interpret system marginal costs and externalities. We show that if tolls computed from the DSO solution are imposed on users then the DSO solution would also satisfy the criteria for a dynamic user equilibrium (DUE). We extend the analysis to allow for physical or behavioural constraints on the link outflow proportions at merges and inflow proportions at diverges. We also extend the model to elastic demands and establish connections between the present DSO model and earlier DSO models.

Optimizing the freight train connection service network of a large-scale rail system

- Transportation Research Part B: Methodological---2012---Bo-Liang Lin,Zhi-Mei Wang,Li-Jun Ji,Ya-Ming Tian,Guo-Qing Zhou

This paper presents a formulation and solution for the train connection services (TCSs) problem in a large-scale rail network in order to determine the optimal freight train services, the frequency of services, and the distribution of classification workload among yards. TCS problem is modeled as a bi-level programming problem. The upper-level is intended to find an optimal train connection service, and the lower-level is used for assigning each shipment to a sequence of train services and determining the frequency of services.

A self-coördinating bus route to resist bus bunching

- Transportation Research Part B: Methodological---2012---John J. Bartholdi,Donald D. Eisenstein

The primary challenge for an urban bus system is to maintain constant headways between successive buses. Most bus systems try to achieve this by adherence to a schedule; but this is undermined by the tendency of headways to collapse, so that buses travel in bunches. To counter this, we propose a new method of coördinating buses. Our method abandons the idea of a schedule and even any a priori target headway. Under our scheme headways are dynamically self-equalizing and the natural headway of the system tends to emerge spontaneously. Headways also become self-correcting in that after disturbances they reëqualize without intervention by management or even awareness of the drivers.

Information provision by regulated public transport companies

- Transportation Research Part B: Methodological---2012---Bruno De Borger,Mogens Fosgerau

We study the interaction between pricing, frequency of service and information provision by public transport firms offering scheduled services, and we do so under various regulatory regimes. The model assumes that users can come to the bus stop or rail station at random or they can plan their trips; the fraction of users who plan their trips is endogenous and depends on the frequency of service and on the quality of information provided. Four institutional regimes are considered, reflecting various degrees of government regulation. A numerical example illustrates the theoretical results. Findings include the following. First, fare regulation induces the firm to provide less frequency and less information than is socially optimal. Second, if information and frequency did not affect the number of planning users a higher fare always induces the firm to raise both frequency and the quality of information. With endogenous planning, however, this need not be the case, as the effect of higher fares strongly depends on how frequency and information quality affect the number of planners. Third, a profit-maximizing firm offers more information than a fare-regulated firm. Fourth, if the agency regulates both the fare and the quality of information then more stringent information requirements induce the firm to reduce frequency; this strongly limits the welfare improvement of information regulation. Finally, of all institutional structures considered, socially optimal fares, frequency and quality of information stimulate passengers least to plan their trips, because the high frequency offered reduces the benefits of trip planning.

Joint optimization of pavement maintenance and resurfacing planning

- Transportation Research Part B: Methodological---2012---Weihua Gu,Yanfeng Ouyang,Samer Madanat

This paper presents an analytical approach for joint planning of pavement maintenance and resurfacing activities that minimizes pavement lifecycle costs, including user, maintenance and resurfacing costs, for an infinite time horizon. The optimization problem is formulated as a nonlinear mathematical program with continuous pavement state and continuous time, and optimality conditions are derived. Managerial insights and practical implications are drawn from two realistic application scenarios, where the maintenance cost is either independent of or linearly dependent on pavement condition, to address impacts of routine maintenance activities on pavement resurfacing planning decisions. Numerical examples demonstrate clear trade-offs between maintenance and resurfacing activities in terms of both pavement improvement effectiveness and costs. This paper shows that maintenance activities, if applied optimally, have the potential to significantly prolong pavement service life between consecutive rehabilitations and reduce overall pavement lifecycle costs.

A bottom-up optimal pavement resurfacing solution approach for large-scale networks

- Transportation Research Part B: Methodological---2012---Nakul Sathaye,Samer Madanat

Pavement management systems have been implemented across the world by transportation agencies in recent decades. To support these applications, increasingly sophisticated methods have been developed to model pavement deterioration and solve for optimal management strategies. Recently a simpler optimization approach for the system-level resurfacing problem has been developed, which is bottom-up rather than top-down, preserving facility-specific features to develop informative budget allocation results (Sathaye and Madanat, 2011). In this paper we expand upon and enhance this approach for application to large-scale, heterogeneous road networks. The methodological enhancements allow for the approach to be applied to a broader spectrum of real-world problems and efficiently for large-scale networks. These developments are implemented and presented in a case study which uses empirical models. The results are shown to be robust to deterioration model uncertainty, which is consistent with previous findings for small networks and single facilities.

Hub location under uncertainty

- Transportation Research Part B: Methodological---2012---Sibel A. Alumur,Stefan Nickel,Francisco Saldanha-da-Gama

Hub location problems are network design problems which are solved as part of a strategic decision making process. In strategic planning, decisions may have a long lasting effect and the implementation may take considerable time. Moreover, input data is not precisely known in advance. Hence, decisions have to be made anticipating uncertainty. In this paper, we address several aspects concerning hub location problems under uncertainty. Two sources of uncertainty are considered: the set-up costs for the hubs and the demands to be transported between the nodes. Generic models are presented for single and multiple allocation versions of the problems. Firstly, the two sources of uncertainty are analyzed separately and afterwards a more comprehensive model is proposed considering all sources of uncertainty. Using a set of computational tests performed, we analyze the changes in the solutions driven by the different sources of uncertainty considered isolated and combined.

A statistical deterioration forecasting method using hidden Markov model for infrastructure management

- Transportation Research Part B: Methodological---2012---Kiyoshi Kobayashi,Kiyoyuki Kaito,Nam Lethanh

The application of Markov models as deterioration-forecasting tools has been widely documented in the practice of infrastructure management. The Markov chain models employ monitoring data from visual inspection activities over a period of time in order to predict the deterioration progress of infrastructure systems. Monitoring data play a vital part in the managerial framework of infrastructure management. As a matter of course, the accuracy of deterioration prediction and life cycle cost analysis largely depends on the soundness of monitoring data. However, in reality, monitoring data often contain measurement errors and selection biases, which tend to weaken the correctness of estimation results. In this paper, the authors present a hidden Markov model to tackle selection biases in monitoring data. Selection biases are assumed as random variables. Bayesian estimation and Markov Chain Monte Carlo simulation are employed as techniques in tackling the posterior probability distribution, the random generation of condition states, and the model' s parameters. An empirical application to the Japanese national road system is presented to demonstrate the applicability of the model. Estimation results highlight the fact that the properties of the Markov transition matrix have greatly improved in comparison with the properties obtained from applying the conventional multi-stage exponential Markov model.

Non-unique flows in macroscopic first-order intersection models

- Transportation Research Part B: Methodological---2012---Ruben Corthout,Gunnar Flötteröd,Francesco Viti,Chris M.J. Tampère

Currently, most intersection models embedded in macroscopic Dynamic Network Loading (DNL) models are not well suited for urban and regional applications. This is so because so-called internal supply constraints, bounding flows due to crossing and merging conflicts inherent to the intersection itself, are missing. This paper discusses the problems that arise upon introducing such constraints. A general framework for the distribution of (internal) supply is adopted, which is based on the definition of priority parameters that describe the strength of each flow in the competition for a particular supply. Using this representation, it is shown that intersection models – with realistic behavioral assumptions, and in simple configurations – can produce non-unique flow patterns under identical boundary conditions. This solution non-uniqueness is thoroughly discussed and approaches on how it can be dealt with are provided. Also, it is revealed that the undesirable model properties are not solved – but rather enhanced – when diverting from a point-like to a spatial modeling approach.

Continuous-time point-queue models in dynamic network loading

- Transportation Research Part B: Methodological---2012---Ban, Xuegang (Jeff),Jong-Shi Pang,Henry X. Liu,Rui Ma

Extending a recent work (Pang et al., in press) pertaining to a simple single-bottleneck model, this paper is the first of a two-part research wherein we undertake a mathematically rigorous study of the continuous-time dynamic user equilibrium (DUE) problem using the recently introduced mathematical paradigm of differential complementarity systems (DCSs) (Pang and Stewart, 2008). The first step in this comprehensive research is to gain a thorough understanding of some continuous-time point-queue models, which will be used as the building block of a computationally tractable model for the continuous-time DUE problem that we will study in detail in the accompanying paper (Ban et al., in press). Starting with the original point-queue model introduced by Vickrey (1969), we summarize some desirable properties that a continuous-time point-queue model should possess, and show that one of these properties—the nonnegativity of the queue lengths—is violated by Vickrey' s original model. As a remedy to this drawback of Vickrey' s model and with the goal of extending it to a continuous-time setting, we introduce two continuous-time point-queue models and show that they satisfy the properties we propose. Discretizations of the continuous-time models are discussed and construction of numerical trajectories is presented; convergence of such trajectories as the time step approaches zero is established; regularity of a solution to the continuous-time problem is clarified, and numerical results are presented.

Airport complementarity: Private vs. government ownership and welfare gravitation

- Transportation Research Part B: Methodological---2012---Benny Mantin

We study the effects of airport ownership (private vs. government) on welfare in the presence of airport complementarity, where each airport is located in a different country. Considering Cournot competition in the airline market, the unique Nash equilibrium is such that the two countries privatize their airports, even though both countries are better off, from a welfare perspective, with public (government-owned) airports. Considering a differentiated Bertrand competition in the airline market, the same result prevails if the cross price elasticities are sufficiently high, otherwise the symmetric government-ownership of airports may also be a Nash equilibrium.

Modeling and solving continuous-time instantaneous dynamic user equilibria: A differential complementarity systems approach

- Transportation Research Part B: Methodological---2012---Ban, Xuegang (Jeff),Jong-Shi Pang,Henry X. Liu,Rui Ma

This paper is the second of a two-part research wherein we undertake a mathematically rigorous investigation of the continuous-time dynamic user equilibrium (DUE) problem using the recently introduced mathematical paradigm of differential complementarity systems (DCSs). Based on the thorough study of continuous-time single-destination point-queue models in the previous part, we first extend this special case to multiple destinations respecting the First-In–First-Out property of travel flows. A DCS with constant time delay is then introduced to formulate the continuous-time model of instantaneous dynamic traffic equilibria (IDUE) with a fixed demand profile. We develop a time decomposition scheme based on link free flow travel times to convert the delay DCS to a series of DCSs without time delays that are solved by a numerical time-stepping method. We provide rigorous numerical treatment of the time-decomposed IDUE model, including solvability of the discrete-time complementarity problems and convergence of the numerical trajectories to a continuous-time solution. We present numerical results to validate the IDUE on a small network and also on the Sioux Falls network.

Prediction and field validation of traffic oscillation propagation under nonlinear car-following laws

- Transportation Research Part B: Methodological---2012---Xiaopeng Li,Xin Wang,Yanfeng Ouyang

A recent study (Li and Ouyang, 2011) proposed a describing-function approach (DFA) to analytically predict oscillation propagation properties (i.e., dominating frequency and amplitude growth) for a general class of nonlinear car-following laws. This paper presents a new graphic solution approach to DFA and proposes a systematic framework to validate DFA using observed vehicle trajectory data. A set of new empirical measures are defined to extract steady-state traffic properties and oscillation characteristics from vehicle trajectory data. A frequency-domain calibration approach based on DFA is developed to construct a proper nonlinear car-following model that fits these empirical measurements. The analytical DFA predictions of oscillation propagation patterns of the calibrated car-following law are then compared with (i) the observed oscillation properties, and (ii) the simulated oscillation characteristics from the same car-following law. Empirical experiments with real-world trajectory data show that the prediction, the simulation, and the field observation typically match very nicely. This not only validates the analytical prediction approach in the previous study, but also shows that the framework proposed in this paper is capable of calibrating a realistic nonlinear car-following law that reproduces the observed oscillation propagation phenomenon. Our proposed modeling method also brings theoretical analyses and empirical observations into one integrated framework that potentially lays the foundation to understand how nonlinearities in a car-following law affect traffic oscillation evolution, and develop possible counteracting strategies.

Developing Responsive Rail Services through collaboration

- Transportation Research Part B: Methodological---2012---April Kuo,Elise Miller-Hooks

In this paper, the problem of optimally serving one off-loads arriving on spot markets through rail services is addressed. To facilitate rail' s responsiveness, collaboration among competing rail carriers positioned to handle the newly arising demand is considered. Through such collaboration, carriers can, by agreement, provide transport on existing trains for one-off loads belonging to their competitors. Additionally, carriers can pool shipments with synergistic origins, destinations and desired delivery dates to form new train lines operated by one of the carriers in the collaboration. This problem of serving spot markets through collaboration among competing rail carriers operating within an alliance in co-transporting one-off loads arriving on the spot market is mathematically formulated and an efficient solution methodology employing concepts of collaborative decision-making incorporated within a combinatorial auction (CA)-based framework is proposed for its solution. The proposed technique aids in forming profitable trains that might otherwise have been underutilized and permits rail carriers to capture a greater share of the freight market.

User-equilibrium route flows and the condition of proportionality

- Transportation Research Part B: Methodological---2012---Hillel Bar-Gera,David Boyce,Nie, Yu (Marco)

User-equilibrium (UE) static deterministic traffic assignment is a widely accepted model among researchers, and is extensively applied in travel forecasting practice. UE route flows are also quite commonly used in methodological research as well as in practical applications, even though it is well known that route flows are not uniquely determined by the UE conditions. One way to resolve this dilemma is by imposing an additional condition, such as the condition of proportionality.

Inverse optimization with endogenous arrival time constraints to calibrate the household activity pattern problem

- Transportation Research Part B: Methodological---2012---Joseph Y.J. Chow,Will W. Recker

A parameter estimation method is proposed for calibrating the household activity pattern problem so that it can be used as a disaggregate, activity-based analog of the traffic assignment problem for activity-based travel forecasting. Inverse optimization is proposed for estimating parameters of the household activity pattern problem such that the observed behavior is optimal, the patterns can be replicated, and the distribution of the parameters is consistent. In order to fit the model to both the sequencing of activities and the arrival times to those activities, an inverse problem is formulated as a mixed integer linear programming problem such that coefficients of the objectives are jointly estimated along with the goal arrival times to the activities. The formulation is designed to be structurally similar to the equivalent problems defined by Ahuja and Orlin and can be solved exactly with a cutting plane algorithm. The concept of a unique invariant common prior is used to regularize the estimation method, and proven to converge using the Method of Successive Averages. The inverse model is tested on sample households from the 2001 California Household Travel Survey and results indicate a significant improvement over the standard inverse problem in the literature as well as baseline prescriptive models that do not make use of sample data for calibration. Although, not unexpectedly, the estimated optimization model by itself is a relatively poor forecasting model, it may be used in determining responses of a population to spatio-temporal scenarios where revealed preference data is absent.

Recent developments in discrete choice model formulation, estimation, and inference

- Transportation Research Part B: Methodological---2012---Chandra R. Bhat

The developments in discrete choice formulation, estimation and inference techniques have been fast and furious over the past few years. This special issue of Transportation Research Part B is a compilation of some of the cutting-edge research in the field.

Modeling social interactions between individuals for joint activity scheduling

- Transportation Research Part B: Methodological---2012---Nicole Ronald,Theo Arentze,Harry Timmermans

Joint social activities, in particular those outside households, are currently ignored or modeled very simply in transport models, despite these sorts of activities contributing to a significant amount of travel. We describe an experimental model of social activities, in which individuals negotiate about the type, purpose, location, and days of activities. After participating in activities, individuals learn about new locations and acquaintances. Using concepts from the activity-based modeling and social networks fields, a prototype model was created using Python incorporating utility-based agents who used a protocol to communicate with each other about potential activities in order to negotiate a suitable day and location. It can be shown that agents with a large number of acquaintances participated in more activities. Pairs of agents with high similarity values, based on age and gender, also socialized with each other more often. Future work involves further development and validation and eventual incorporation into activity-based models.

Development and estimation of a semi-compensatory model with a flexible error structure

- Transportation Research Part B: Methodological---2012---Sigal Kaplan,Yoram Shiftan,Shlomo Bekhor

In decisions involving many alternatives, such as residential choice, individuals conduct a two-stage decision process, consisting of eliminating non-viable alternatives and choice from the retained choice set. In light of the potential of semi-compensatory discrete choice models to mathematically represent such decisions, research is inching ahead with the aim of alleviating their high computational complexity and their severe restrictive assumptions. To date, still a major barrier for the implementation of semi-compensatory models is their underlying assumption of independently and identically distributed error terms across alternatives at the choice stage. This study relaxes the assumption by introducing nested substitution patterns and alternatively random taste heterogeneity at the choice stage, thus equating the structural flexibility of semi-compensatory models to their compensatory counterparts. The proposed model is applied to off-campus rental apartment choice by students. Results show the feasibility and importance of introducing a flexible error structure into semi-compensatory models.

Estimation of the mixed logit likelihood function by randomized quasi-Monte Carlo

- Transportation Research Part B: Methodological---2012---D. Munger,L’Ecuyer, P.,F. Bastin,C. Cirillo,B. Tuffin

We examine the effectiveness of randomized quasi-Monte Carlo (RQMC) techniques to estimate the integrals that express the discrete choice probabilities in a mixed logit model, for which no closed form formula is available. These models are used extensively in travel behavior research. We consider popular RQMC constructions such as randomized Sobol’, Faure, and Halton points, but our main emphasis is on randomly-shifted lattice rules, for which we study how to select the parameters as a function of the considered class of integrands. We compare the effectiveness of all these methods and of standard Monte Carlo (MC) to reduce both the variance and the bias when estimating the log-likelihood function at a given parameter value. In our numerical experiments, randomized lattice rules (with carefully selected parameters) and digital nets are the best performers and they reduce the bias as much as the variance. With panel data, in our examples, the performance of all RQMC methods degrades rapidly when we simultaneously increase the dimension and the number of observations per individual.

A Monte Carlo experiment to analyze the curse of dimensionality in estimating random coefficients models with a full variance–covariance matrix

- Transportation Research Part B: Methodological--2012---Elisabetta Cherchi,Cristian Guevara

When the dimension of the vector of estimated parameters increases, simulation based methods become impractical, because the number of draws required for estimation grows exponentially with the number of parameters. In simulation methods, the lack of empirical identification when the number of parameters increases is usually known as the “curse of dimensionality” in the simulation methods. We investigate this problem in the case of the random coefficients Logit model. We compare the traditional Maximum Simulated Likelihood (MSL) method with two alternative estimation methods: the Expectation–Maximization (EM) and the Laplace Approximation (HH) methods that do not require simulation. We use Monte Carlo experimentation to investigate systematically the performance of the methods under different circumstances, including different numbers of variables, sample sizes and structures of the variance–covariance matrix. Results show that indeed MSL suffers from lack of empirical identification as the dimensionality grows while EM deals much better with this estimation problem. On the other hand, the HH method, although not being simulation-based, showed poor performance with large dimensions, principally because of the necessity of inverting large matrices. The results also show that when MSL is empirically identified this method seems superior to EM and HH in terms of ability to recover the true parameters and estimation time.

Calculating errors for measures derived from choice modelling estimates

- Transportation Research Part B: Methodological--2012---Andrew Daly,Stephane Hess,Gerard de Jong

The calibration of choice models produces a set of parameter estimates and an associated covariance matrix, usually based on maximum likelihood estimation. However, in many cases, the values of interest to analysts are in fact functions of these parameters rather than the parameters themselves. It is thus also crucial to have a measure of variance for these derived quantities and it is preferable that this can be guaranteed to have the maximum likelihood properties, such as minimum variance. While the calculation of standard errors using the Delta method has been described for a number of such measures in the literature, including the ratio of two parameters, these results are often seen to be approximate calculations and do not claim maximum likelihood properties. In this paper, we show that many measures commonly used in transport studies and elsewhere are themselves maximum likelihood estimates and that the standard errors are thus exact, a point we illustrate for a substantial number of commonly used functions. We also discuss less appropriate methods, notably highlighting the issues with using simulation for obtaining the variance of a function of estimates.

State-dependent congestion pricing with reference-dependent preferences

- Transportation Research Part B: Methodological--2011---Charles Lindsey

Demand and capacity fluctuations are common for roads and other congestible facilities. With ongoing advances in pricing technology and ways of communicating information to prospective users, state-dependent congestion pricing is becoming practical. But it is still rare or nonexistent in many potential applications. One explanation is that people dislike uncertainty about how much they will pay. To explore this idea, a model of reference-dependent preferences is developed based on Köszegi and Rabin (2006). Using a facility yields an “intrinsic” utility and a “gain–loss” utility measured relative to the probability distribution over states of utility outcomes. Two types of preferences are analyzed: bundled preferences in which gains and losses are perceived for overall utility, and unbundled preferences in which gains and losses are perceived separately for the toll and other determinants of utility.

The tax treatment of company cars, commuting and optimal congestion taxes

- Transportation Research Part B: Methodological---2011---Bruno De Borger,Bart Wuyts

In Europe, the preferential tax treatment of company cars implies that many employees receive a company car as part of their compensation package. In this paper, we consider a model in which wages and the decision whether or not to provide a company car are the result of direct negotiation between employer and employee. Using this framework, we theoretically and numerically study first- and second-best optimal tax policies on labour and transport markets, focusing on the role of the tax treatment of company cars. We obtain the following results. First, higher labour taxes and a more favourable tax treatment of company cars raise the fraction employees that receives a company car; congestion and congestion tolls reduce it. Second, in countries that provide large implicit subsidies to company cars, eliminating the preferential tax treatment of company cars may be an imperfect but quite effective substitute for currently unavailable congestion tolls. The numerical illustration, calibrated using Belgian data, suggests that it yields about half the welfare gain attainable through optimal congestion taxes. Third, the favourable tax treatment of company cars justifies large public transport subsidies; the numerical results are consistent with zero public transport fares. Finally, we find that earlier models that ignored the preferential tax treatment of company cars may have substantially underestimated optimal congestion tolls in Europe. The numerical illustration suggests that about one third of the optimal congestion toll we obtain can be attributed to the current tax treatment of company cars.

Travel time variability and airport accessibility

- Transportation Research Part B: Methodological---2011---Paul Koster,Eric Kroes,Erik Verhoef

We analyze the cost of access travel time variability for air travelers. Reliable access to airports is important since the cost of missing a flight is likely to be high. First, the determinants of the preferred arrival times at airports are analyzed. Second, the willingness to pay (WTP) for reductions in access travel time, early and late arrival time at the airport, and the probability to miss a flight are estimated, using a stated choice experiment. The results indicate that the WTPs are relatively high. Third, a model is developed to calculate the cost of variable travel times for representative air travelers going by car, taking into account travel time cost, scheduling cost and the cost of missing a flight using empirical travel time data. In this model, the value of reliability for air travelers is derived taking “anticipating departure time choice” into account, meaning that travelers determine their departure time from home optimally. Results of the numerical exercise show that the cost of access travel time variability for business travelers are between 0% and 30% of total access travel cost, and for non-business travelers between 0% and 25%. These numbers depend strongly on the time of the day.

Additive measures of travel time variability

- Transportation Research Part B: Methodological---2011---Leonid Engelson,Mogens Fosgerau

This paper derives a measure of travel time variability for travellers equipped with scheduling preferences defined in terms of time-varying utility rates, and who choose departure time optimally. The corresponding value of travel time variability is a constant that depends only on preference parameters. The measure is unique in being additive with respect to independent parts of a trip. It has the variance of travel time as a special case. Extension is provided to the case of travellers who use a scheduled service with fixed headway.

On a mean field game approach modeling congestion and aversion in pedestrian crowds

- Transportation Research Part B: Methodological---2011---Aimé Lachapelle,Marie-Therese Wolfram

In this paper we present a new class of pedestrian crowd models based on the mean field games theory introduced by Lasry and Lions in 2006. This macroscopic approach is based on a microscopic model, that considers smart pedestrians who rationally interact and anticipate the future. This leads to a forward-backward structure in time. We focus on two-population interactions and validate the modeling with simple examples. Two complementary classes of problems are addressed, namely the case of crowd aversion and the one of congestion. In both cases we describe the model and present numerical solvers (based on the optimization formulation and the partial differential equations respectively). Finally we present numerical tests involving anticipation phenomena and complex group behaviors such as lane formation.

A threshold model of social contagion process for evacuation decision making

- Transportation Research Part B: Methodological---2011---Samiul Hasan,Satish V. Ukkusuri

Individual evacuation decisions are often characterized by the influence of one's social network. In this paper a threshold model of social contagion, originally proposed in the network science literature, is presented to characterize this social influence in the evacuation decision making process. Initiated by a single agent, the condition of a cascade when a portion of the population decides to evacuate has been derived from the model. Simulation models are also developed to investigate the effects of community mixing patterns and the initial seed on cascade propagation and the effect of previous time-steps considered by the agents and the strength of ties on average cascade size. Insights related to social influence include the significant role of mixing patterns among communities in the network and the role of the initial seed on cascade propagation. Specifically, faster propagation of warning is observed in community networks with greater inter-community connections.

Bounded rationality and irreversible network change

- Transportation Research Part B: Methodological---2011---Xiaolei Guo,Henry X. Liu

A network change is said to be irreversible if the initial network equilibrium cannot be restored by revoking the change. The phenomenon of irreversible network change has been observed in reality. To model this phenomenon, we develop a day-to-day dynamic model whose fixed point is a boundedly rational user equilibrium (BRUE) flow. Our BRUE based approach to modeling irreversible network change has two advantages over other methods based on Wardrop user equilibrium (UE) or stochastic user equilibrium (SUE). First, the existence of multiple network equilibria is necessary for modeling irreversible network change. Unlike UE or SUE, the BRUE multiple equilibria do not rely on non-separable link cost functions, which makes our model applicable to real-world large-scale networks, where well-calibrated non-separable link cost functions are generally not available. Second, travelers' boundedly rational behavior in route choice is explicitly considered in our model. The proposed model is applied to the Twin Cities network to model the flow evolution during the collapse and reopening of the I-35W Bridge. The results show that our model can to a reasonable level reproduce the observed phenomenon of irreversible network change.

Modeling stochastic perception error in the mean-excess traffic equilibrium model

- Transportation Research Part B: Methodological---2011---Anthony Chen,Zhong Zhou,William H.K. Lam

In this paper, we extend the α-reliable mean-excess traffic equilibrium (METE) model of Chen and Zhou (Transportation Research Part B 44(4), 2010, 493–513) by explicitly modeling the stochastic perception errors within the travelers' route choice decision processes. In the METE model, each traveler not only considers a travel time budget for ensuring on-time arrival at a confidence level α, but also accounts for the impact of encountering worse travel times in the (1 α) quantile of the distribution tail. Furthermore, due to the imperfect knowledge of the travel time variability particularly in congested networks without advanced traveler information systems, the travelers' route choice decisions are based on the perceived travel time distribution rather than the actual travel time distribution. In order to compute the perceived mean-excess travel time, an approximation method based on moment analysis is developed. It involves using the conditional moment generation function to derive the perceived link travel time, the Cornish–Fisher Asymptotic Expansion to estimate the perceived travel time budget, and the Acerbi and Tasche Approximation to estimate the perceived mean-excess travel time. The proposed stochastic mean-excess traffic equilibrium (SMETE) model is formulated as a variational inequality (VI) problem, and solved by a route-based solution algorithm with the use of the modified alternating direction method. Numerical examples are also provided to illustrate the application of the proposed SMETE model and solution method.

Multi-class percentile user equilibrium with flow-dependent stochasticity

- Transportation Research Part B: Methodological---2011---Nie, Yu (Marco)

Travelers often reserve a buffer time for trips sensitive to arrival time in order to hedge against the uncertainties in a transportation system. To model the effects of such behavior, travelers are assumed to choose routes to minimize the percentile travel time, i.e. the travel time budget that ensures their preferred probability of on-time arrival; in doing so, they drive the system to a percentile user equilibrium (UE), which can be viewed as an extension of the classic Wardrop equilibrium. The stochasticity in the supply of transportation are incorporated by modeling the service flow rate of each road segment as a random variable. Such stochasticity is flow-dependent in the sense that the probability density functions of these random variables, from which the distribution of link travel time are constructed, are specified endogenously with flow-dependent parameters. The percentile route travel time, obtained by directly convolving the link travel time distributions in this paper, is not available in closed form in general and has to be numerically evaluated. To reveal their structural properties, percentile UE solutions are examined in special cases and verified with numerical results. For the general multi-class percentile UE traffic assignment problem, a variational inequality formulation is given and solved using a route-based algorithm. The algorithm makes use of the diagonal elements in the Jacobian of percentile route travel time, which is approximated through recursive convolution. Preliminary numerical experiments indicate that the algorithm is able to achieve highly precise equilibrium solutions.

Finding the most reliable path with and without link travel time correlation: A Lagrangian substitution based approach

- Transportation Research Part B: Methodological---2011---Tao Xing,Xuesong Zhou

Path travel time reliability is an essential measure of the quality of service for transportation systems and an important attribute in travelers' route and departure time scheduling. This paper investigates a fundamental problem of finding the most reliable path under different spatial correlation assumptions, where the path travel time variability is represented by its standard deviation. To handle the non-linear and non-additive cost functions introduced by the quadratic forms of the standard deviation term, a Lagrangian substitution approach is adopted to estimate the lower bound of the most reliable path solution through solving a sequence of standard shortest path problems. A subgradient algorithm is used to iteratively improve the solution quality by reducing the optimality gap. To characterize the link travel time correlation structure associated with the end-to-end trip time reliability measure, this research develops a sampling-based method to dynamically construct a proxy objective function in terms of travel time observations from multiple days. The proposed algorithms are evaluated under a large-scale Bay Area, California network with real-world measurements.

Confidence interval estimation for path flow estimator

- Transportation Research Part B: Methodological---2011---Piya Chootinan,Anthony Chen

The uncertainty of an origin–destination (O–D) trip table estimate is affected by two factors: (i) the multiplicity of solutions due to the underspecified nature of the problem, and (ii) the errors of traffic counts. In this paper, a confidence interval estimation procedure for path flow estimator (PFE) is developed for assessing the quality of O–D trip tables estimated from traffic counts. The confidence interval estimation consists of two parts: (i) a generalized demand scale (GDS) measure for quantifying the intrinsic underspecified nature of the O–D estimation problem at various spatial levels, and (ii) an error bound to quantify the contribution of input errors (traffic counts) to the estimation results. Numerical results using PFE as the O–D estimator show that the proposed confidence interval estimation procedure is able to separate the two sources of uncertainty in constructing the confidence intervals at various spatial levels. Simulation results also confirm that the proposed quality measure indeed contain the true estimates within the defined confidence intervals.

Optimal selection of build–operate-transfer projects on transportation networks

- Transportation Research Part B: Methodological---2011---Di Wu,Yafeng Yin,Siriphong Lawphongpanich

This paper considers the problem of how to select highway projects for the build–operate-transfer (BOT) 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. Without solving the associated problem, we show that optimal tolls and travel times on selected BOT highways can be determined from their attributes under mild assumptions. This leads to an efficient heuristic algorithm for solving the project selection problem.

Designing a home-to-work bus service in a metropolitan area

- Transportation Research Part B: Methodological---2011---Alessandro Perugia,Luigi Moccia,Jean-François Cordeau,Gilbert Laporte

This paper presents a model and an algorithm for the design of a home-to-work bus service in a metropolitan area. This type of service must display an equilibrium between conflicting criteria such as efficiency, effectiveness, and equity. To this end, we introduce a multi-objective model in which, among other aspects, equity is considered by time windows on the arrival time of a bus at a stop. Time windows can have other uses such as, for example, guaranteeing synchronization of the service with other transportation modes. This is one of the guiding principles of the proposed model which is based on concepts that simultaneously tackle several issues at once. Along this line, we propose a cluster routing approach to model both bus stop location and routing in urban road networks where turn restrictions exist. The resulting multi-objective location-routing model is solved by a tabu search algorithm. As an application, we analyze a home-to-work bus service for a large research center located in Rome, Italy. This case study provides a benchmark for the algorithmic results, and shows the practical relevance of the proposed methodology.

Analytical and grid-free solutions to the Lighthill–Whitham–Richards traffic flow model

- Transportation Research Part B: Methodological---2011---Pierre-Emmanuel Mazaré,Ahmad H. Dehwah,Christian G. Claudel,Alexandre M. Bayen

In this article, we propose a computational method for solving the Lighthill–Whitham–Richards (LWR) partial differential equation (PDE) semi-analytically for arbitrary piecewise-constant initial and boundary conditions, and for arbitrary concave fundamental diagrams. With these assumptions, we show that the solution to the LWR PDE at any location and time can be computed exactly and semi-analytically for a very low computational cost using the cumulative number of vehicles formulation of the problem. We implement the proposed computational method on a representative traffic flow scenario to illustrate the exactness of the analytical solution. We also show that the proposed scheme can handle more complex scenarios including traffic lights or moving bottlenecks. The computational cost of the method is very favorable, and is compared with existing algorithms. A toolbox implementation available for public download is briefly described, and posted at http://traffic.berkeley.edu/project/downloads/lwrsolver.

Complementarity formulations for the cell transmission model based dynamic user equilibrium with departure time choice, elastic demand and user heterogeneity

- Transportation Research Part B: Methodological---2011---Lanshan Han,Satish Ukkusuri,Kien Doan

In this paper we formulate the dynamic user equilibrium problem with an embedded cell transmission model on a network with a single OD pair, multiple parallel paths, multiple user classes with elastic demand. The formulation is based on ideas from complementarity theory. The travel time is estimated based on two methods which have different transportation applications: (1) maximum travel time and (2) average travel time. These travel time functions result in linear and non-linear complementarity formulations respectively. Solution existence and the properties of the formulations are rigorously analyzed. Extensive computational experiments are conducted to demonstrate the benefits of the proposed formulations on various test networks.

A shockwave profile model for traffic flow on congested urban arterials

- Transportation Research Part B: Methodological---2011---Xinkai Wu,Henry X. Liu

In this paper a new traffic flow model for congested arterial networks, named shockwave profile model (SPM), is presented. Taking advantage of the fact that traffic states within a congested link can be simplified as free-flow, saturated, and jammed conditions, SPM simulates traffic dynamics by analytically deriving the trajectories of four major shockwaves: queuing, discharge, departure, and compression waves. Unlike conventional macroscopic models, in which space is often discretized into small cells for numerical solutions, SPM treats each homogeneous road segment with constant capacity as a section; and the queuing dynamics within each section are described by tracing the shockwave fronts. SPM is particularly suitable for simulating traffic flow on congested signalized arterials especially with queue spillover problems, where the steady-state periodic pattern of queue build-up and dissipation process may break down. Depending on when and where spillover occurs along a signalized arterial, a large number of queuing patterns may be possible. Therefore it becomes difficult to apply the conventional approach directly to track shockwave fronts. To overcome this difficulty, a novel approach is proposed as part of the SPM, in which queue spillover is treated as either extending a red phase or creating new smaller cycles, so that the analytical solutions for tracing the shockwave fronts can be easily applied. Since only the essential features of arterial traffic flow, i.e., queue build-up and dissipation, are considered, SPM significantly reduces the computational load and improves the numerical efficiency. We further validated SPM using real-world traffic signal data collected from a major arterial in the Twin Cities. The results clearly demonstrate the effectiveness and accuracy of the model. We expect that in the future this model can be applied in a number of real-time applications such as arterial performance prediction and signal optimization.

Transit-network design methodology for actual-size road networks

- Transportation Research Part B: Methodological---2011---Saeed Asadi Bagloee,Ceder, Avishai (Avi)

The main purpose of this study is to design a transit network of routes for handling actual-size road networks. This transit-network design problem is known to be complex and cumbersome. Thus, a heuristic methodology is proposed, taking into account the major concerns of transit authorities such as budget constraints, level-of-service standards and the attractiveness of the transit routes. In addition, this approach considers other important aspects of the problem including categorization of stops, multiclass of transit vehicles, hierarchy planning, system capacity (which has been largely ignored in past studies) and the integration between route-design and frequency-setting analyses. The process developed starts with the construction of a set of potential stops using a clustering concept. Then, by the use of Newton gravity theory and a special shortest-path procedure, a set of candidate routes is formed, categorized by hierarchy (mass, feeder, local routes). In the last step of the process a metaheuristic search engine is launched over the candidate routes, incorporating budgetary constraints, until a good solution is found. The algorithm was tested on the actual-size transit network of the city of Winnipeg; the results show that under the same conditions (budget and constraints) the proposed set of routes resulted in a reduction of 14% of total travel time compared to the existing transit network. In addition the methodology developed is compared favorably with other studies using the transit network of Mandl benchmark. The generality of the methodology was tested on the recent real dataset (pertaining to the year 2010) of the larger city of Chicago, in which a more efficient and optimized scheme was proposed for the existing rail system.

Schedule-based transit assignment model with vehicle capacity and seat availability

- Transportation Research Part B: Methodological---2011---Younes Hamdouch,H.W. Ho,Agachai Sumalee,Guodong Wang

In this paper, we propose a new schedule-based equilibrium transit assignment model that differentiates the discomfort level experienced by sitting and standing passengers. The notion of seat allocation has not been considered explicitly and analytically in previous schedule-based frameworks. The model assumes that passengers use strategies when traveling from their origin to their destination. When loading a vehicle, standing on-board passengers continuing to the next station have priority to get available seats and waiting passengers are loaded on a First-Come-First-Serve (FCFS) principle. The stimulus of a standing passenger to sit increases with his/her remaining journey length and time already spent on-board. When a vehicle is full, passengers unable to board must wait for the next vehicle to arrive. The equilibrium conditions can be stated as a variational inequality involving a vector-valued function of expected strategy costs. To find a solution, we adopt the method of successive averages (MSA) that generates strategies during each iteration by solving a dynamic program. Numerical results are also reported to show the effects of our model on the travel strategies and departure time choices of passengers.

Dynamic bus holding strategies for schedule reliability: Optimal linear control and performance analysis

- Transportation Research Part B: Methodological---2011---Yiguang Xuan,Juan Argote,Carlos F. Daganzo

As is well known, bus systems are naturally unstable. Without control, buses on a single line tend to bunch, reducing their punctuality in meeting a schedule. Although conventional schedule-based strategies that hold buses at control points can alleviate this problem these methods require too much slack, which slows buses. This delays on-board passengers and increases operating costs.

Bicycle commuting in Melbourne during the 2000s energy crisis: A semiparametric analysis of intraday volumes

- Transportation Research Part B: Methodological---2011---Michael Smith,Göran Kauermann

Cycling is attracting renewed attention as a mode of transport in western urban environments, yet the determinants of usage are poorly understood. In this paper we investigate some of these using intraday bicycle volumes collected via induction loops located at ten bike paths in the city of Melbourne, Australia, between December 2005 and June 2008. The data are hourly counts at each location, with temporal and spatial disaggregation allowing for the impact of meteorology to be measured accurately for the first time. Moreover, during this period petrol prices varied dramatically and the data also provide a unique opportunity to assess the cross-price elasticity of demand for cycling. Over-dispersed Poisson regression models are used to model volumes at each location and at each hour of the day. Seasonality and the impact of weather conditions are modelled as semiparametric and estimated using recently developed multivariate penalized spline methodology. Unlike previous studies that use aggregate data, the empirical results show a substantial meteorological and seasonal component to usage. They also suggest there was substitution into cycling as a mode of transport in response to increases in petrol prices, particularly during peak commuting periods and by commuters originating in wealthy and inner city neighbourhoods. Last, we extend the approach to a multivariate longitudinal count data model using a Gaussian copula estimated by Bayesian data augmentation. We find first order serial dependence in the hourly volumes and a ‘return trip’ effect in daily bicycle commutes.

Capacity drops at merges: An endogenous model

- Transportation Research Part B: Methodological---2011---Ludovic Leclercq,Jorge A. Laval,Nicolas Chiabaut

The Newell–Daganzo merge model is not only very simple but also accurately reproduces experimental findings. However, the capacity downstream of the merge is an exogenous variable in the model. This is a serious limitation for merges that behave as active bottlenecks because their downstream capacity is a direct consequence of the merging behavior. This paper proposes an analytical model that extends the Newell–Daganzo model by incorporating, endogenously, the capacity drop related to the merging process. Two cases are investigated depending on the traffic states on the on-ramp. The model properties are analyzed and a sensitivity analysis is performed to quantify the relative contribution of the each parameter in the capacity drop. Finally, the extended Newell–Daganzo model is validated with experimental data coming from an active merge bottleneck on the M6 freeway in UK.

Platoon-based traffic flow model for estimating breakdown probability at single-lane expressway bottlenecks

- Transportation Research Part B: Methodological---2011---Yasuhiro Shiomi,Toshio Yoshii,Ryuichi Kitamura

This study investigates the mechanism of traffic breakdown and establishes a traffic flow model that precisely simulates the stochastic and dynamic processes of traffic flow at a bottleneck. The proposed model contains two models of stochastic processes associated with traffic flow dynamics: a model of platoon formation behind a bottleneck and a model of speed transitions within a platoon. After these proposed models are validated, they are applied to a simple one-way, one-lane expressway section containing a bottleneck, and the stochastic nature of traffic breakdown is demonstrated through theoretical exercises.

A porous flow approach to modeling heterogeneous traffic in disordered systems

- Transportation Research Part B: Methodological---2011---Rahul Nair,Hani S. Mahmassani,Elise Miller-Hooks

A continuum model that describes a disordered, heterogeneous traffic stream is presented. Such systems are widely prevalent in developing countries where classical traffic models cannot be readily applied. The characteristics of such systems are unique since drivers of smaller vehicles exploit their maneuverability to move ahead through lateral gaps at lower speeds. At higher speeds, larger vehicles press their advantage of greater motive power. The traffic stream at the microscopic level is disordered and defines a porous medium. Each vehicle is considered to move through a series of pores defined by other vehicles. A speed-density relationship that explicitly considers the pore space distribution is presented. This captures the considerable dynamics between vehicle classes that are overlooked when all classes are converted to a reference class (usually Passenger Car Equivalents) as is traditionally done. Using a finite difference approximation scheme, traffic evolution for a two-class traffic stream is shown.

Characterization of traffic oscillation propagation under nonlinear car-following laws

- Transportation Research Part B: Methodological---2011---Xiaopeng Li,Yanfeng Ouyang

Unlike linear car-following models, nonlinear models generally can generate more realistic traffic oscillation phenomenon, but nonlinearity makes analytical quantification of oscillation characteristics (e.g, periodicity and amplitude) significantly more difficult. This paper proposes a novel mathematical framework that accurately quantifies oscillation characteristics for a general class of nonlinear car-following laws. This framework builds on the describing function technique from nonlinear control theory and is comprised of three modules: expression of car-following models in terms of oscillation components, analyses of local and asymptotic stabilities, and quantification of oscillation propagation characteristics. Numerical experiments with a range of well-known nonlinear car-following laws show that the proposed approach is capable of accurately predicting oscillation characteristics under realistic physical constraints and complex driving behaviors. This framework not only helps further understand the root causes of the traffic oscillation phenomenon but also paves a solid foundation for the design and calibration of realistic nonlinear car-following models that can reproduce empirical oscillation characteristics.

Evidence of convective instability in congested traffic flow: A systematic empirical and theoretical investigation

- Transportation Research Part B: Methodological---2011---Martin Treiber,Arne Kesting

An extended open system such as traffic flow is said to be convectively unstable if perturbations of the stationary state grow but propagate in only one direction, so they eventually leave the system. By means of data analysis, simulations, and analytical calculations, we give evidence that this concept is relevant for instabilities of congested traffic flow. We analyze detector data from several hundred traffic jams and propose estimates for the linear growth rate, the wavelength, the propagation velocity, and the severity of the associated bottleneck that can be evaluated semi-automatically. Scatter plots of these quantities reveal systematic dependencies. On the theoretical side, we derive, for a wide class of microscopic and macroscopic traffic models, analytical criteria for convective and absolute linear instabilities. Based on the relative positions of the stability limits in the fundamental diagram, we divide these models into five stability classes which uniquely determine the set of possible elementary spatiotemporal patterns in open systems with a bottleneck. Only two classes, both dominated by convective instabilities, are compatible with observations. By means of approximate solutions of convectively unstable systems with sustained localized noise, we show that the observed spatiotemporal phenomena can also be described analytically. The parameters of the analytical expressions can be inferred from observations, and also (analytically) derived from the model equations.

Freeway traffic oscillations: Microscopic analysis of formations and propagations using Wavelet Transform

- Transportation Research Part B: Methodological---2011---Zuduo Zheng,Soyoung Ahn,Danjue Chen,Jorge Laval

In this paper we identify the origins of stop-and-go (or slow-and-go) driving and measure microscopic features of their propagations by analyzing vehicle trajectories via Wavelet Transform. Based on 53 oscillation cases analyzed, we find that oscillations can be originated by either lane-changing maneuvers (LCMs) or car-following (CF) behavior. LCMs were predominantly responsible for oscillation formations in the absence of considerable horizontal or vertical curves, whereas oscillations formed spontaneously near roadside work on an uphill segment. Regardless of the trigger, the features of oscillation propagations were similar in terms of propagation speed, oscillation duration, and amplitude. All observed cases initially exhibited a precursor phase, in which slow-and-go motions were localized. Some of them eventually transitioned into a well-developed phase, in which oscillations propagated upstream in queue. LCMs were primarily responsible for the transition, although some transitions occurred without LCMs. Our findings also suggest that an oscillation has a regressive effect on car-following behavior: a deceleration wave of an oscillation affects a timid driver (characterized by larger response time and/or minimum spacing) to become less timid and an aggressive driver less aggressive, although this change may be short-lived. An extended framework of Newell’s CF model is able to describe the regressive effect with two additional parameters with reasonable accuracy, as verified using vehicle trajectory data.

A splitting rate model of traffic re-routeing and traffic control

- Transportation Research Part B: Methodological---2011---Mike Smith,Richard Mounce

The paper presents an idealised dynamical model of day-to-day or within-day re-routeing using splitting rates at nodes, or node-exit flows, rather than route-flows. It is shown that under certain conditions the dynamical model gives rise to a sequence of link flow vectors which converges to a set of approximate Wardrop equilibria. A special dynamical signal green-time reallocation model is added; the combination is also shown (in outline) to converge to the set of approximate consistent equilibria under certain conditions. Finally the paper uses model network results to illustrate a method of designing fixed time signal timings to meet different scenarios.

Dynamic network loading: A stochastic differentiable model that derives link state distributions

- Transportation Research Part B: Methodological---2011---Carolina Osorio,Gunnar Flötteröd,Michel Bierlaire

We present a dynamic network loading model that yields queue length distributions, accounts for spillbacks, and maintains a differentiable mapping from the dynamic demand on the dynamic queue lengths. The model also captures the spatial correlation of all queues adjacent to a node, and derives their joint distribution. The approach builds upon an existing stationary queueing network model that is based on finite capacity queueing theory. The original model is specified in terms of a set of differentiable equations, which in the new model are carried over to a set of equally smooth difference equations. The physical correctness of the new model is experimentally confirmed in several congestion regimes. A comparison with results predicted by the kinematic wave model (KWM) shows that the new model correctly represents the dynamic build-up, spillback and dissipation of queues. It goes beyond the KWM in that it captures queue lengths and spillbacks probabilistically, which allows for a richer analysis than the deterministic predictions of the KWM. The new model also generates a plausible fundamental diagram, which demonstrates that it captures well the stationary flow/density relationships in both congested and uncongested conditions.

Managing evacuation networks

- Transportation Research Part B: Methodological---2011---Carlos F. Daganzo,Stella K. So

This paper proposes a non-anticipative, adaptive, decentralized strategy for managing evacuation networks. The strategy is non-anticipative because it does not rely on demand forecasts, adaptive because it uses real-time traffic information, and decentralized because all the information is available locally. It can be used with a failed communication network.

Animal dynamics based approach for modeling pedestrian crowd egress under panic conditions

- Transportation Research Part B: Methodological---2011---Nirajan Shiwakoti,Majid Sarvi,Geoff Rose,Martin Burd

Collective movement is important during emergencies such as natural disasters or terrorist attacks, when rapid egress is essential for escape. The development of quantitative theories and models to explain and predict the collective dynamics of pedestrians has been hindered by the lack of complementary data under emergency conditions. Collective patterns are not restricted to humans, but have been observed in other non-human biological systems. In this study, a mathematical model for crowd panic is derived from collective animal dynamics. The development and validation of the model is supported by data from experiments with panicking Argentine ants (Linepithema humile). A first attempt is also made to scale the model parameters for collective pedestrian traffic from those for ant traffic, by employing a scaling concept approach commonly used in biology.

Dynamic ride-sharing: A simulation study in metro Atlanta

- Transportation Research Part B: Methodological---2011---Niels A.H. Agatz,Alan L. Erera,Martin W.P. Savelsbergh,Xing Wang

Smartphone technology enables dynamic ride-sharing systems that bring together people with similar itineraries and time schedules to share rides on short-notice. This paper considers the problem of matching drivers and riders in this dynamic setting. We develop optimization-based approaches that aim at minimizing the total system-wide vehicle miles incurred by system users, and their individual travel costs. To assess the merits of our methods we present a simulation study based on 2008 travel demand data from metropolitan Atlanta. The simulation results indicate that the use of sophisticated optimization methods instead of simple greedy matching rules substantially improve the performance of ride-sharing systems. Furthermore, even with relatively low participation rates, it appears that sustainable populations of dynamic ride-sharing participants may be possible even in relatively sprawling urban areas with many employment centers.

A maximum entropy-least squares estimator for elastic origin–destination trip matrix estimation

- Transportation Research Part B: Methodological---2011---Chi Xie,Kara M. Kockelman,S. Travis Waller

In transportation subnetwork–supernetwork analysis, it is well known that the origin–destination (O–D) flow table of a subnetwork is not only determined by trip generation and distribution, but also a result from traffic routing and diversion, due to the existence of internal–external, external–internal and external–external flows. This result indicates the variable nature of subnetwork O–D flows. This paper discusses an elastic O–D flow table estimation problem for subnetwork analysis. The underlying assumption is that each cell of the subnetwork O–D flow table contains an elastic demand function rather than a fixed demand rate and the demand function can capture all traffic diversion effect under various network changes. We propose a combined maximum entropy-least squares estimator, by which O–D flows are distributed over the subnetwork in terms of the maximum entropy principle, while demand function parameters are estimated for achieving the least sum of squared estimation errors. While the estimator is powered by the classic convex combination algorithm, computational difficulties emerge within the algorithm implementation until we incorporate partial optimality conditions and a column generation procedure into the algorithmic framework. Numerical results from applying the combined estimator to a couple of subnetwork examples show that an elastic O–D flow table, when used as input for subnetwork flow evaluations, reflects network flow changes significantly better than its fixed counterpart.

On the existence of pricing strategies in the discrete time heterogeneous single bottleneck model

- Transportation Research Part B: Methodological---2011---Kien Doan,Satish Ukkusuri,Lanshan Han

In this paper, we study the pricing strategies in the discrete time single bottleneck model with general heterogeneous commuters. We first prove that in the system optimal assignment, the queue time must be zero for all the departures. Based on this result, the system optimal problem is formulated as a linear program. The solution existence and uniqueness are discussed. Applying linear programming duality, we then prove that the optimal dual variable values provide an optimal toll with which the system optimal solution is also an equilibrium solution. Extensive computational results are reported to demonstrate the insights gained from the formulations in this paper. These results confirm that a system optimal equilibrium can be found using the proposed approach.

Supply chain disruption and risk management

- Transportation Research Part B: Methodological---2011---Terry L. Friesz

2011

A single-period analysis of a two-echelon inventory system with dependent supply uncertainty

- Transportation Research Part B: Methodological---2011---Behdad Masih-Tehrani,Susan H. Xu,Soundar Kumara,Haijun Li

Disruptions and random supplies have been important sources of uncertainty that should be considered in the design and control of supply chains. There have been many real world examples in which a single catastrophic event has simultaneously degraded the capabilities of several suppliers leading to considerable erosion of profits and goodwill for a company. However, the literature on analytical models that account for the dependence nature of disruptions and its impact on supply chain performance is sparse. In this paper, we consider an m-manufacturer, 1-retailer, newsvendor inventory system with stochastically dependent manufacturing capacities, caused by random disruptions that may simultaneously inflict damages to the capacities of the manufacturers. We develop the structural/analytical properties of key performance measures and optimal inventory policies for the multi-source and assembly inventory systems. We show that stochastic dependence in disruptions can have opposite effects on system performance in the multi-source and assembly systems. While risk diversification is preferred in the multi-source system, risk concentration is preferred in the assembly system. Our results also suggest that, if the retailer ignores the effect of dependent disruptions, then in the multi-source structure, it would underestimate the cost, overestimate the fill rate, and order more units than the optimum; however, in the assembly structure, the opposite would happen. We perform a comprehensive numerical study to validate our analytical results and generate useful managerial and operational insights for effective risk management of supply chains in the presence of dependent supply uncertainty.

A frequency-based maritime container assignment model

- Transportation Research Part B: Methodological---2011---Michael G.H. Bell,Xin Liu,Panagiotis Angeloudis,Achille Fonzone,Solmaz Haji Hosseinloo

This paper transfers the classic frequency-based transit assignment method of Spiess and Florian to containers demonstrating its promise as the basis for a global maritime container assignment model. In this model, containers are carried by shipping lines operating strings (or port rotations) with given service frequencies. An origin-destination matrix of full containers is assigned to these strings to minimize sailing time plus container dwell time at the origin port and any intermediate transhipment ports. This necessitated two significant model extensions. The first involves the repositioning of empty containers so that a net outflow of full containers from any port is balanced by a net inflow of empty containers, and vice versa. As with full containers, empty containers are repositioned to minimize the sum of sailing and dwell time, with a facility to discount the dwell time of empty containers in recognition of the absence of inventory. The second involves the inclusion of an upper limit to the maximum number of container moves per unit time at any port. The dual variable for this constraint provides a shadow price, or surcharge, for loading or unloading a container at a congested port. Insight into the interpretation of the dual variables is given by proposition and proof. Model behaviour is illustrated by a simple numerical example. The paper concludes by considering the next steps toward realising a container assignment model that can, amongst other things, support the assessment of supply chain vulnerability to maritime disruptions.

Build-to-order supply chain network design under supply and demand uncertainties

- Transportation Research Part B: Methodological---2011---Cheng-Chang Lin,Tsai-Hsin Wang

Supply chain disruptions are unintended, unwanted situations resulting in a negative supply chain performance. We study the supply chain network design under supply and demand uncertainty with embedded supply chain disruption mitigation strategies, postponement with downward substitution, centralized stocking and supplier sourcing base. We designed an integrated supply-side, manufacturing and demand-side operations network in such that the total expected operating cost is minimized. We modeled it in a deterministic equivalent formulation. An L-shaped decomposition with an additional decomposition step in the master problem is proposed. The computational results showed that parallel sourcing has a cost advantage against single sourcing under supply disruptions. In addition, the build-to-order (BTO) manufacturing mitigation process has its greatest impact with high variations on demands and is integrated with the component downward substitution. Lastly, the manufacturer needs to order differentiated components to cover its requirement for maximal product demand to prevent the loss of sale, even with fewer modules in stock.

Robust optimization for emergency logistics planning: Risk mitigation in humanitarian relief supply chains

- Transportation Research Part B: Methodological---2011---Aharon Ben-Tal,Byung Do Chung,Supreet Reddy Mandala,Tao Yao

This paper proposes a methodology to generate a robust logistics plan that can mitigate demand uncertainty in humanitarian relief supply chains. More specifically, we apply robust optimization (RO) for dynamically assigning emergency response and evacuation traffic flow problems with time dependent demand uncertainty. This paper studies a Cell Transmission Model (CTM) based system optimum dynamic traffic assignment model. We adopt a min-max criterion and apply an extension of the RO method adjusted to dynamic optimization problems, an affinely adjustable robust counterpart (AARC) approach. Simulation experiments show that the AARC solution provides excellent results when compared to deterministic solution and sampling based stochastic programming solution. General insights of RO and transportation that may have wider applicability in humanitarian relief supply chains are provided.

Reliable logistics networks design with facility disruptions

- Transportation Research Part B: Methodological---2011---Peng Peng,Lawrence V. Snyder,Andrew Lim,Zuli Liu

This paper studies a strategic supply chain management problem to design reliable networks that perform as well as possible under normal conditions, while also performing relatively well when disruptions strike. We present a mixed-integer programming model whose objective is to minimize the nominal cost (the cost when no disruptions occur) while reducing the disruption risk using the p-robustness criterion (which bounds the cost in disruption scenarios). We propose a hybrid metaheuristic algorithm that is based on genetic algorithms, local improvement, and the shortest augmenting path method. Numerical tests show that the heuristic greatly outperforms CPLEX in terms of solution speed, while still delivering excellent solution quality. We demonstrate the tradeoff between the nominal cost and system reliability, showing that substantial improvements in reliability are often possible with minimal increases in cost. We also show that our model produces solutions that are less conservative than those generated by common robustness measures.

Competition and disruption in a dynamic urban supply chain

- Transportation Research Part B: Methodological---2011---Terry L. Friesz,Ilsoo Lee,Cheng-Chang Lin

Rapid changes and complexities in business environments have stressed the importance of interactions between partners and competitors, leading supply chains to become the most important element of contemporary business environments. There is a concomitant need for foresight in describing supply chain performance in all operating environments, including those involving punctuated disruptions. Furthermore, the urban metropolis is now widely recognized to be an environment which is especially vulnerable to supply chain disruptions and for which integrated supply chain decisions can produce very substantial net benefits. Accordingly, this paper presents a dynamic supply chain network model formulated as a differential variational inequality; the model is fashioned to allow consideration of supply chain disruption threats to producers, freight carriers, and retail enterprises. The DVI is solved using a fixed-point algorithm, and a simple numerical example, introduced to illustrate how the impacts of supply chain disruptions may be quantified, is presented.

The Pollution-Routing Problem

- Transportation Research Part B: Methodological---2011---Tolga Bektas,Gilbert Laporte

The amount of pollution emitted by a vehicle depends on its load and speed, among other factors. This paper presents the Pollution-Routing Problem (PRP), an extension of the classical Vehicle Routing Problem (VRP) with a broader and more comprehensive objective function that accounts not just for the travel distance, but also for the amount of greenhouse emissions, fuel, travel times and their costs. Mathematical models are described for the PRP with or without time windows and computational experiments are performed on realistic instances. The paper sheds light on the tradeoffs between various parameters such as vehicle load, speed and total cost, and offers insight on economies of 'environmental-friendly' vehicle routing. The results suggest that, contrary to the VRP, the PRP is significantly more difficult to solve to optimality but has the potential of yielding savings in total cost.

Product substitution and dual sourcing under random supply failures

- Transportation Research Part B: Methodological---2011---Mengshi Lu,Simin Huang,Zuo-Jun Max Shen

Product substitution can mitigate supply chain disruptions. However, it may not be very effective without multiple sourcing. In this paper, we consider a supply chain with two downward substitutable products. The products can be ordered from an unreliable supplier or a reliable but more expensive supplier. It is found that in an optimal sourcing policy the higher-grade product should be preferred over the lower-grade product. A sufficient condition is given for an optimal policy where only the higher-grade product is dual-sourced. The effect of substitution is contrasted with the non-substitution case. Numerical study shows the impact of demand variability and correlation on the effect of product substitution and the corresponding optimal sourcing policy.

Strategies for customer service level protection under multi-echelon supply chain disruption risk

- Transportation Research Part B: Methodological---2011---Amanda J. Schmitt

We model a multi-echelon system where disruptions can occur at any stage and evaluate multiple strategies for protecting customer service if a disruption should occur. The strategies considered take advantage of the network itself and include satisfying demand from an alternate location in the network, procuring material or transportation from an alternate source or route, and holding strategic inventory reserves throughout the network. Unmet demand is modeled using a mix of backordering and lost sales. We conduct numerical analysis and provide recommendations on selecting strategic mitigation methods to diminish the impact of disruptions on customer service. We demonstrate that the greatest service level improvements can be made by providing both proactive inventory placement to cover short disruptions or the start of long disruptions, and reactive back-up methods to help the supply chain recover after long or permanent disruptions.

A multiobjective chance constrained programming model for supplier selection under uncertainty

- Transportation Research Part B: Methodological---2011---R. Ufuk Bilsel,A. Ravindran

Risk management is an inherent part of supplier selection. While companies are enjoying the benefits of outsourcing, risks brought by this practice should be taken into account in the process of decision making. This paper presents a multiobjective stochastic sequential supplier allocation model to help in supplier selection under uncertainty. Demand for products, capacities at suppliers as well as transportation and other variable costs are the main sources of uncertainty and are modeled using probability distributions. Disruptions are exogenous events and the model provides proactive mitigation strategies against disruptions by assigning backup suppliers who can be used in case of a default at a primary supplier. When there is no disruption, the model's solution is an optimal supplier order assignment, considering operational risks.

The maximum approximate composite marginal likelihood (MACML) estimation of multinomial probit-based unordered response choice models

- Transportation Research Part B: Methodological---2011---Chandra R. Bhat

The likelihood functions of multinomial probit (MNP)-based choice models entail the evaluation of analytically-intractable integrals. As a result, such models are usually estimated using maximum simulated likelihood (MSL) techniques. Unfortunately, for many practical situations, the computational cost to ensure good asymptotic MSL estimator properties can be prohibitive and practically infeasible as the number of dimensions of integration rises. In this paper, we introduce a maximum approximate composite marginal likelihood (MACML) estimation approach for MNP models that can be applied using simple optimization software for likelihood estimation. It also represents a conceptually and pedagogically simpler procedure relative to simulation techniques, and has the advantage of substantial computational time efficiency relative to the MSL approach. The paper provides a "blueprint" for the MACML estimation for a wide variety of MNP models.

A simulation evaluation of the maximum approximate composite marginal likelihood (MACML) estimator for mixed multinomial probit models

- Transportation Research Part B: Methodological---2011---Chandra R. Bhat,Raghuprasad Sidharthan

This paper evaluates the ability of the maximum approximate composite marginal likelihood (MACML) estimation approach to recover parameters from finite samples in mixed cross-sectional and panel multinomial probit models. Comparisons with the maximum simulated likelihood (MSL) estimation approach are also undertaken. The results indicate that the MACML approach recovers parameters much more accurately than the MSL approach in all model structures and covariance specifications. The MACML inference approach also estimates the parameters efficiently, with the asymptotic standard errors being, in general, only a small proportion of the true values. As importantly, the MACML inference approach takes only a very small fraction of the time needed for MSL estimation. In particular, the results suggest that, for the case of five random coefficients, the MACML approach is about 50 times faster than the MSL for the cross-sectional random coefficients case, about 15 times faster than the MSL for the panel inter-individual random coefficients case, and about 350 times or more faster than the MSL for the panel intra- and inter-individual random coefficients case. As the number of alternatives in the unordered-response model increases, one can expect even higher computational efficiency factors for the MACML over the MSL approach. Further, as should be evident in the panel intra- and inter-individual random coefficients case, the MSL is all but practically infeasible when the mixing structure leads to an explosion in the dimensionality of integration in the likelihood function, but these situations are handled with ease in the MACML approach. It is hoped that the MACML procedure will spawn empirical research into rich model specifications within the context of unordered multinomial choice modeling, including autoregressive random coefficients, dynamics in coefficients, space-time effects, and spatial/social interactions.

Embedding risk attitude and decision weights in non-linear logit to accommodate time variability in the value of expected travel time savings

- Transportation Research Part B: Methodological---2011---David Hensher,William Greene,Zheng Li

In recent years we have seen important extensions of logit models in behavioural research such as incorporation of preference and scale heterogeneity, attribute processing heuristics, and estimation of willingness to pay (WTP) in WTP space. With rare exception, however, a non-linear treatment of the parameter set to allow for behavioural reality, such as embedded risk attitude and perceptual conditioning of occurrence probabilities attached to specific attributes, is absent. This is especially relevant to the recent focus in travel behaviour research on identifying the willingness to pay for reduced travel time variability, which is the source of estimates of the value of trip reliability that has been shown to take on an increasingly important role in project appraisal. This paper incorporates, in a generalised non-linear (in parameters) logit model, alternative functional forms for perceptual conditioning (known as probability weighting) and risk attitude in the utility function to account for travel time variability, and then derives an empirical estimate of the willingness to pay for trip time variability-embedded travel time savings as an alternative to separate estimates of time savings and trip time reliability. We illustrate the richness of the approach using a stated choice data set for commuter choice between unlabelled attribute packages. Statistically significant risk attitude parameters and parameters underlying decision weights are estimated for multinomial logit and mixed multinomial logit models, along with values of expected travel time savings.

Recovery of inter- and intra-personal heterogeneity using mixed logit models

- Transportation Research Part B: Methodological---2011---Stephane Hess,Kenneth Train

Most applications of discrete choice models in transportation now utilise a random coefficient specification, such as mixed logit, to represent taste heterogeneity. However, little is known about the ability of these models to capture the heterogeneity in finite samples (as opposed to asymptotically). Also, due to the computational intensity of the standard estimation procedures, several alternative, less demanding methods have been proposed, and yet the relative accuracy of these methods has not been investigated. This is especially true in the context of work looking at joint inter-respondent and intra-respondent variation. This paper presents an overview of the various different estimators, gives insights into some of the theoretical properties, and analyses their performance in a large scale study on simulated data. In particular, we specify 31 different forms of heterogeneity, with multiple versions of each dataset, and with results from over 16,000 mixed logit estimation runs. The findings suggest that variation in tastes over consumers is captured by all the methods, including the simpler versions, at least when sample size is sufficiently large. When tastes vary over choice situations for each consumer, as well as over consumers, the ability of the methods to capture and differentiate the two sources of heterogeneity becomes more tenuous. Only the most computationally intensive approach is able to capture adequately the two sources of variation, but at the cost of very high run times. Our results highlight the difficulty of retrieving taste heterogeneity with only cross-sectional data, providing further evidence of the benefits of repeated choice data. Our findings also suggest that the data requirements of random coefficients models may be more substantial than is commonly assumed, further reinforcing concerns about small sample issues.

Joint inventory-location problem under the risk of probabilistic facility disruptions

- Transportation Research Part B: Methodological---2011---Qi Chen,Xiaopeng Li,Yanfeng Ouyang

This paper studies a reliable joint inventory-location problem that optimizes facility locations, customer allocations, and inventory management decisions when facilities are subject to disruption risks (e.g., due to natural or man-made hazards). When a facility fails, its customers may be reassigned to other operational facilities in order to avoid the high penalty costs associated with losing service. We propose an integer programming model that minimizes the sum of facility construction costs, expected inventory holding costs and expected customer costs under normal and failure scenarios. We develop a Lagrangian relaxation solution framework for this problem, including a polynomial-time exact algorithm for the relaxed nonlinear subproblems. Numerical experiment results show that this proposed model is capable of providing a near-optimum solution within a short computation time. Managerial insights on the optimal facility deployment, inventory control strategies, and the corresponding cost constitutions are drawn.

A bottom-up solution for the multi-facility optimal pavement resurfacing problem

- Transportation Research Part B: Methodological---2011---Nakul Sathaye,Samer Madanat

Transportation infrastructure management has been a subject of growing economic importance in recent years due to the magnitude of agency expenditures. Increasingly sophisticated methods have been developed to model pavement deterioration and solve for optimal management strategies. However, it is unclear whether these more complex methods are providing more useful results. This paper presents a simple approach for optimizing the frequency and intensity of resurfacing for multiple highway facilities. It builds upon existing optimization methods for the single-facility, continuous-state, continuous-time problem and corresponding results, which include a threshold structure for optimal solutions. This threshold structure allows for mathematical simplifications and for a straightforward optimization approach to be applied to the multi-facility case. The approach is bottom-up rather than top-down, preserving facility-specific features to develop informative budget allocation results. Application of the approach in a case study indicates that solutions are likely to be robust to deterioration model uncertainty, which is consistent with previous facility-level findings. In addition, the methodology is shown to be robust to the form of the deterioration model.

Improving travel efficiency by parking permits distribution and trading

- Transportation Research Part B: Methodological---2011---Xiaoning Zhang,Hai Yang,Hai-Jun Huang

In this paper, we study various parking management schemes in a many-to-one network, where each origin is connected to the destination by a highway with a bottleneck and a parallel transit line. First, we derive a model to compute the morning commuting pattern when the destination has inadequate parking space to accommodate potential private cars. Second, we propose and compare the following three schemes of distributing parking permits to commuters residing in different origins: uniform, Pareto improving, and system optimum distribution of parking permits. Third, free trading of parking permits among commuters in a free market is introduced to better cater for commuters' parking needs. Numerical examples show that parking permits distribution and trading are very efficient in traffic management.

Dynamic user equilibrium with side constraints for a traffic network: Theoretical development and numerical solution algorithm

- Transportation Research Part B: Methodological---2011---R.X. Zhong,A. Sumalee,T.L. Friesz,William H.K. Lam

This paper investigates a traffic volume control scheme for a dynamic traffic network model which aims to ensure that traffic volumes on specified links do not exceed preferred levels. The problem is formulated as a dynamic user equilibrium problem with side constraints (DUE-SC) in which the side constraints represent the restrictions on the traffic volumes. Travelers choose their departure times and routes to minimize their generalized travel costs, which include early/late arrival penalties. An infinite-dimensional variational inequality (VI) is formulated to model the DUE-SC. Based on this VI formulation, we establish an existence result for the DUE-SC by showing that the VI admits at least one solution. To analyze the necessary condition for the DUE-SC, we restate the VI as an equivalent optimal control problem. The Lagrange multipliers associated with the side constraints as derived from the optimality condition of the DUE-SC provide the traffic volume control scheme. The control scheme can be interpreted as additional travel delays (either tolls or access delays) imposed upon drivers for using the controlled links. This additional delay term derived from the Lagrange multiplier is compared with its counterpart in a static user equilibrium assignment model. If the side constraint is chosen as the storage capacity of a link, the additional delay can be viewed as the effort needed to prevent the link from spillback. Under this circumstance, it is found that the flow is incompressible when the link traffic volume is equal to its storage capacity. An algorithm based on Euler's discretization scheme and nonlinear programming is proposed to solve the DUE-SC. Numerical examples are presented to illustrate the mechanism of the proposed traffic volume control scheme.

Real-time traffic estimation using data expansion

- Transportation Research Part B: Methodological---2011---Roger Lederman,Laura Wynter

This paper presents a method for estimating missing real-time traffic volumes on a road network using both historical and real-time traffic data. The method was developed to address urban transportation networks where a non-negligible subset of the network links do not have real-time link volumes, and where that data is needed to populate other real-time traffic analytics. Computation is split between an offline calibration and a real-time estimation phase. The offline phase determines link-to-link splitting probabilities for traffic flow propagation that are subsequently used in real-time estimation. The real-time procedure uses current traffic data and is efficient enough to scale to full city-wide deployments. Simulation results on a medium-sized test network demonstrate the accuracy of the method and its robustness to missing data and variability in the data that is available. For traffic demands with a coefficient of variation as high as 40%, and a real-time feed in which as much as 60% of links lack data, we find the percentage root mean square error of link volume estimates ranges from 3.9% to 18.6%. We observe that the use of real-time data can reduce this error by as much as 20%.

Robust single-track train dispatching model under a dynamic and stochastic environment: A scenario-based rolling horizon solution approach

- Transportation Research Part B: Methodological---2011---Lingyun Meng,Xuesong Zhou

After a major service disruption on a single-track rail line, dispatchers need to generate a series of train meet-pass plans at different decision times of the rescheduling stage. The task is to recover the impacted train schedule from the current and future disturbances and minimize the expected additional delay under different forecasted operational conditions. Based on a stochastic programming with recourse framework, this paper incorporates different probabilistic scenarios in the rolling horizon decision process to recognize (1) the input data uncertainty associated with predicted segment running times and segment recovery times and (2) the possibilities of rescheduling decisions after receiving status updates. The proposed model periodically optimizes schedules for a relatively long rolling horizon, while selecting and disseminating a robust meet-pass plan for every roll period. A multi-layer branching solution procedure is developed to systematically generate and select meet-pass plans under different stochastic scenarios. Illustrative examples and numerical experiments are used to demonstrate the importance of robust disruption handling under a dynamic and stochastic environment. In terms of expected total train delay time, our experimental results show that the robust solutions are better than the expected value-based solutions by a range of 10-30%.

Scheduling freight trains traveling on complex networks

- Transportation Research Part B: Methodological---2011---Shi Mu,Maged Dessouky

In the US, freight railways are one of the major means to transport goods from ports to inland destinations. According to the Association of American Railroad's study, rail companies move more than 40% of the nation's total freight. Given the fact that the freight railway industry is already running without much excess capacity, better planning and scheduling tools are needed to effectively manage the scarce resources, in order to cope with the rapidly increasing demand for railway transportation. This research develops optimization-based approaches for scheduling of freight trains. Two mathematical formulations of the scheduling problem are first introduced. One assumes the path of each train, which is the track segments each train uses, is given and the other one relaxes this assumption. Several heuristics based on mixtures of the two formulations are proposed. The proposed algorithms are able to outperform two existing heuristics, namely a simple look-ahead greedy heuristic and a global neighborhood search algorithm, in terms of railway total train delay. For large networks, two algorithms based on the idea of decomposition are developed and are shown to significantly outperform two existing algorithms.

How a fast lane may replace a congestion toll

- Transportation Research Part B: Methodological---2011---Mogens Fosgerau

This paper considers a congested bottleneck. A fast lane reserves a more than proportional share of capacity to a designated group of travelers. Travelers are otherwise identical and other travelers can use the reserved capacity when it would otherwise be idle. The paper shows that such a fast lane is always Pareto improving under Nash equilibrium in arrival times at the bottleneck and inelastic demand. It can replicate the arrival schedule and queueing outcomes of a toll that optimally charges a constant toll during part of the demand peak. Within some bounds, the fast lane scheme is still welfare improving when demand is elastic.

Distribution-free travel time reliability assessment with probability inequalities

- Transportation Research Part B: Methodological---2011---ManWo Ng,W.Y. Szeto,S. Travis Waller

An assumption that pervades the current transportation system reliability assessment literature is that probability distributions of the sources of uncertainty are known explicitly. However, this distribution may be unavailable (inaccurate) in reality as we may have no (insufficient) data to calibrate the distribution. In this paper we relax this assumption and present a new method to assess travel time reliability that is distribution-free in the sense that the methodology only requires that the first N moments (where N is a user-specified positive integer) of the travel time to be known and that the travel times reside in a set of bounded and known intervals. Because of our modeling approach, all sources of uncertainty are automatically accounted for, as long as they are statistically independent. Instead of deriving exact probabilities on travel times exceeding certain thresholds via computationally intensive methods, we develop semi-analytical probability inequalities to quickly (i.e. within a fraction of a second) obtain upper bounds on the desired probability. Numerical experiments suggest that the inclusion of higher order moments can potentially significantly improve the bounds. The case study also demonstrates that the derived bounds are nontrivial for a large range of travel time values.

Multiple equilibria in a dynamic traffic network

- Transportation Research Part B: Methodological--2011---Takamasa Iryo

This study provides an example in which the dynamic user equilibrium (DUE) assignment of a congested road network with bottlenecks is non-unique. In previous studies, the uniqueness of DUE assignments with the bottleneck model has been shown in limited cases such as single-origin and single-destination networks. Consequently, it is still an important issue whether or not uniqueness is a general property of DUE assignments. The present study describes a network in which multiple patterns of link travel time are found, thus providing a negative answer to this question. The network has a loopy structure with multiple bottlenecks and multiple origin-destination (OD) pairs. Given a certain demand pattern of departure times for vehicles leaving their origins, a non-convex set of equilibria with a non-unique pattern of link travel times is shown to exist.

A dual decomposition method for sector capacity constrained traffic flow optimization

- Transportation Research Part B: Methodological--2011---D. Sun,A. Clinet,A.M. Bayen

An aggregate air traffic flow model based on a multicommodity network is used for traffic flow management in the National Airspace System. The problem of minimizing the total travel time of flights in the National Airspace System of the United States, subject to sector capacity constraints, is formulated as an Integer Program. The resulting solution achieves optimal delay control. The Integer Program implemented for the scenarios investigated has billions of variables and constraints. It is relaxed to a Linear Program for computational efficiency. A dual decomposition method is applied to solve the large scale Linear Program in a computationally tractable manner. A rounding algorithm is developed to map the Linear Program solution to a physically acceptable result, and is implemented for the entire continental United States. A 2-h traffic flow management problem is solved with the method.

Operational macroscopic modeling of complex urban road intersections

- Transportation Research Part B: Methodological--2011---Gunnar Flötteröd,Jannis Rohde

This article describes a new approach to the macroscopic first order modeling and simulation of traffic flow in complex urban road intersections. The framework is theoretically sound, operational, and comprises a large body of models presented so far in the literature. Working within the generic node model class of Tampere et al. (2011), the approach is developed in two steps. First, building on the incremental transfer principle of Daganzo et al. (1997), an incremental node model for general road intersections is developed. A limitation of this model (as of the original incremental transfer principle) is that it does not capture situations where the increase of one flow decreases another flow, e.g., due to conflicts. In a second step, the new model is therefore supplemented with the capability to describe such situations. A fixed-point formulation of the enhanced model is given, solution existence and uniqueness are investigated, and two solution algorithms are developed. The feasibility and realism of the new approach is demonstrated through a synthetic and a real case study.

The corridor problem: Preliminary results on the no-toll equilibrium

- Transportation Research Part B: Methodological--2011---Richard Arnott,Elijah DePalma

Consider a traffic corridor that connects a continuum of residential locations to a point central business district, and that is subject to flow congestion. The population density function along the corridor is exogenous, and except for location vehicles are identical. All vehicles travel along the corridor from home to work in the morning rush hour, and have the same work start-time but may arrive early. The two components of costs are travel time costs and schedule delay (time early) costs. Determining equilibrium and optimum traffic flow patterns for this continuous model, and possible extensions, is termed "The Corridor Problem". Equilibria must satisfy the trip-timing condition, that at each location no vehicle can experience a lower trip price by departing at a different time. This paper investigates the no-toll equilibrium of the basic Corridor Problem.

Increasing the capacity of signalized intersections with separate left turn phases

- Transportation Research Part B: Methodological---2011---Yiguang Xuan,Carlos F. Daganzo,Michael J. Cassidy

A separate turn phase is often used on the approach leg to an intersections with heavy left turns. This wastes capacity on the approach because some of its lanes cannot discharge during its green phases. The paper shows that the problem can be eliminated by reorganizing traffic on all the lanes upstream of an intersection using a mid-block pre-signal. If drivers behave deterministically, the capacity that can be achieved is the same as if there were no left turns. However, if the reorganization is too drastic, it may be counterintuitive to drivers. This can be remedied by reorganizing traffic on just some of the available lanes. It is shown that such partial reorganization still increases capacity significantly, even if drivers behave randomly and only one lane is reorganized. The paper shows how to optimize the design of a pre-signal system for a generic intersection. It also identifies both, the potential benefits of the proposed system for a broad class of intersections, and the domain of application where the benefits are most significant.

On the macroscopic stability of freeway traffic

- Transportation Research Part B: Methodological---2011---Carlos F. Daganzo

A simple model of traffic flow is used to analyze the spatio-temporal distribution of flow and density on closed-loop homogeneous freeways with many ramps, which produce inflows and allow outflows. As we would expect, if the on-ramp demand is space-independent then this distribution tends toward uniformity in space if the freeway is either: (i) uncongested; or (ii) congested with queues on its on-ramps and enough inflow to cause the average freeway density to increase with time. In all other cases, however, including any recovery phase of a rush hour where the freeway's average density declines, the distribution of flow and density quickly becomes uneven. This happens even under conditions of perfect symmetry, where the percentage of vehicles exiting at every off ramp is the same. The flow-density deviations from the average are shown to grow exponentially in time and propagate backwards in space with a fixed wave speed. A consequence of this type of instability is that, during recovery, gaps of uncongested traffic will quickly appear in the unevenly congested stream, reducing average flow. This extends the duration of recovery and invariably creates clockwise hysteresis loops on scatter-plots of average system flow vs. density during any rush hour that oversaturates the freeway. All these effects are quantified with formulas and verified with simulations. Some have been observed in real networks. In a more practical vein, it is also shown that the negative effects of instability diminish (i.e., freeway flows increase) if (a) some drivers choose to exit the freeway prematurely when it is too congested and/or (b) freeway access is regulated in a certain traffic-responsive way. These two findings could be used to improve the algorithms behind VMS displays for driver guidance (finding a), and on-ramp metering rates (finding b).

Traveler delay costs and value of time with trip chains, flexible activity scheduling and information

- Transportation Research Part B: Methodological---2011---Erik Jenelius,Lars-Göran Mattsson,David Levinson

The delay costs of traffic disruptions and congestion and the value of travel time reliability are typically evaluated using single trip scheduling models, which treat the trip in isolation of previous and subsequent trips and activities. In practice, however, when activity scheduling to some extent is flexible, the impact of delay on one trip will depend on the actual and predicted travel time on itself as well as other trips, which is important to consider for long-lasting disturbances and when assessing the value of travel information. In this paper we extend the single trip approach into a two trips chain and activity scheduling model. Preferences are represented as marginal activity utility functions that take scheduling flexibility into account. We analytically derive trip timing optimality conditions, the value of travel time and schedule adjustments in response to travel time increases. We show how the single trip models are special cases of the present model and can be generalized to a setting with trip chains and flexible scheduling. We investigate numerically how the delay cost depends on the delay duration and its distribution on different trips during the day, the accuracy of delay prediction and travel information, and the scheduling flexibility of work hours. The extension of the model framework to more complex schedules is discussed.

Global optimization method for mixed transportation network design problem: A mixed-integer linear programming approach

- Transportation Research Part B: Methodological---2011---Paramet Luathep,Agachai Sumalee,William H.K. Lam,Zhi-Chun Li,Hong K. Lo

This paper proposes a global optimization algorithm for solving a mixed (continuous/discrete) transportation network design problem (MNDP), which is generally expressed as a mathematical programming with equilibrium constraint (MPEC). The upper level of the MNDP aims to optimize the network performance via both expansion of existing links and addition of new candidate links, whereas the lower level is a traditional Wardrop user equilibrium (UE) problem. In this paper, we first formulate the UE condition as a variational inequality (VI) problem, which is defined from a finite number of extreme points of a link-flow feasible region. The MNDP is approximated as a piecewise-linear programming (P-LP) problem, which is then transformed into a mixed-integer linear programming (MILP) problem. A global optimization algorithm based on a cutting constraint method is developed for solving the MILP problem. Numerical examples are given to demonstrate the efficiency of the proposed method and to compare the results with alternative algorithms reported in the literature.

Bus congestion, optimal infrastructure investment and the choice of a fare collection system in dedicated bus corridors

- Transportation Research Part B: Methodological---2011---Alejandro Tirachini,David Hensher

Microeconomic optimisation of scheduled public transport operations has traditionally focused on finding optimal values for the frequency of service, capacity of vehicles, number of lines and distance between stops. In addition, however, there exist other elements in the system that present a trade-off between the interests of users and operators that have not received attention in the literature, such as the optimal selection of a fare payment system and a designed running speed (i.e., the cruising speed that buses maintain in between two consecutive stops). Alternative fare payment methods (e.g., on-board and off-board, payment by cash, magnetic strip or smart card) have different boarding times and capital costs, with the more efficient systems such as a contactless smart card imposing higher amounts of capital investment. Based on empirical data from several Bus Rapid Transit systems around the world, we also find that there is a positive relationship between infrastructure cost per kilometre and commercial speed (including stops), achieved by the buses, which we further postulate as a linear relationship between infrastructure investment and running speed. Given this context, we develop a microeconomic model for the operation of a bus corridor that minimises total cost (users and operator) and has five decision variables: frequency, capacity of vehicles, station spacing, fare payment system and running speed, thus extending the traditional framework. Congestion, induced by bus frequency, plays an important role in the design of the system, as queues develop behind high demand bus stops when the frequency is high. We show that (i) an off-board fare payment system is the most cost effective in the majority of circumstances; (ii) bus congestion results in decreased frequency while fare and bus capacity increase, and (iii) the optimal running speed grows with the logarithm of demand.

Morning commute problem considering route choice, user heterogeneity and alternative system optima

- Transportation Research Part B: Methodological---2011---Yang Liu,Nie, Yu (Marco)

This paper extends the bottleneck model to study congestion behavior of morning commute and its implications to transportation economics. The proposed model considers simultaneous route and departure time choices of heterogenous users who are distinguished by their valuation of travel time and punctual arrival. Moreover, two dynamic system optima are considered: one minimizes system cost in the unit of monetary value (i.e., the conventional system optimum, or SO) and the other minimizes system cost in the unit of travel time (i.e., the time-based SO, or TSO). Analytical solutions of no-toll equilibrium, SO and TSO are provided and the welfare effects of the corresponding dynamic congestion pricing options are examined, with and without route choice. The analyses suggest that TSO provides a Pareto-improving solution to the social inequity issue associated with SO. Although a TSO toll is generally discriminatory, anonymous TSO tolls do exist under certain circumstances. Unlike in the case with homogenous users, an SO toll generally alters users' route choices by tolling the poorer users off the more desirable road, which worsens social inequity. Numerical examples are presented to verify analytical results.

Clockwise hysteresis loops in the Macroscopic Fundamental Diagram: An effect of network instability

- Transportation Research Part B: Methodological---2011---Vikash V. Gayah,Carlos F. Daganzo

A recent study reported that the Macroscopic Fundamental Diagram of a medium size city exhibited a clockwise hysteresis loop on a day in which a major disturbance caused many drivers to use unfamiliar routes. It is shown below that, even in a perfectly symmetric network with uniform demand, clockwise loops are to be expected when there are disturbances, especially if the disturbances cause a significant fraction of the drivers to not change routes adaptively. It is also shown that when drivers are not adaptive networks are inherently more unstable as they recover from congestion than as they are loaded. In other words, during recovery congestion tends more strongly toward unevenness because very congested areas clear more slowly than less congested areas. Since it is known that uneven congestion distributions reduce network flows, it follows that lower network flows should arise during recovery, resulting in clockwise loops. Fortunately, the presence of a sufficient number of drivers that choose routes adaptively to avoid congested areas helps to even out congestion during recovery, increasing flow. Thus, clockwise loops are less likely to occur when driver adaptivity is high.

Lane changing patterns of bane and benefit: Observations of an uphill expressway

- Transportation Research Part B: Methodological---2011---Anthony D. Patire,Michael J. Cassidy

A mechanism is unveiled by which congestion forms on a 3-lane, uphill expressway segment, and causes reductions in output flow. Vehicular lane-changing (LC) is key to the mechanism, particularly LC induced by speed disturbances (SDs) that periodically arise in the expressway's median and center lanes. Early in the rush, when flow was relatively low in the shoulder lane, drivers readily migrated toward that lane to escape the oncoming SDs. The shoulder lane thus acted as a 'release valve' for the high vehicular accumulations created by the SDs, such that forced vehicular decelerations were short-lived. The release valve failed only later in the rush, when flow increased in the shoulder lane in response to rising demand. LC induced by the SDs thereafter became disruptive: the decelerations they imposed spread laterally, and a persistent queue formed in all lanes. Long-run output flow dropped each day by 4-11% once the queue engulfed the base of the incline, and impeded vehicle ascent. Subtle details of this mechanism became visible by examining thousands of vehicle trajectories that were extracted from a series of eleven roadside video cameras. Though these trajectories were collected from only a single day, we suspect that the findings can be generalized to other days at the present site, and to other sites. This is because: (i) conspicuous features of the mechanism were repeatedly observed in loop detector data that were measured over many days at the site; (ii) these macroscopic features are consistent with observations previously made at other sites; and (iii) the more subtle details unveiled by the trajectories are compatible with a general theory of multi-lane traffic.

Optimal allocation of turns to lanes at an isolated signal-controlled junction

- Transportation Research Part B: Methodological--2011---C.K. Wong,B.G. Heydecker

Conventional design methods require the lane marking patterns, which are painted on ground showing road users the permissible turning directions on different approach lanes, as exogenous inputs to define the traffic stream grouping for analysis. This predefined grouping of traffic movements may restrict the design of signal timings in the optimisation procedures. More recently, a lane-based design method has been developed to relax the lane markings as binary-type control variables in a mathematical programming approach. The lane marking patterns and the signal timings can then be optimised simultaneously in a unified framework. This paper presents an extension work to further relax the numbers of approach lane in traffic arms as new integer variables which can then be optimised to give optimal lane arrangement in various arms of a junction to manage the given traffic demands more efficiently. All well-defined signal timings variables in the phase-based approach as well as the lane marking and lane flow variables in the lane-based approach together with their governing constraints are all preserved in the new formulation for the reserve capacity optimisation of isolated signal-controlled junctions.

Network-based real option models

- Transportation Research Part B: Methodological--2011---Joseph Y.J. Chow,Amelia C. Regan

Building on earlier work to incorporate real option methodologies into network modeling, two models are proposed. The first is the network option design problem, which maximizes the expanded net present value of a network investment as a function of network design variables with the option to defer the committed design investment. The problem is shown to be a generalized version of the network design problem and the multi-period network design problem. A heuristic based on radial basis functions is used to solve the problem for continuous link expansion with congestion effects. The second model is a link investment deferral option set, which decomposes the network investment deferral option into individual, interacting link or project investments. This model is a project selection problem under uncertainty, where each link or project can be deferred such that the expanded net present value is maximized. The option is defined in such a way that a lower bound can be solved using an exact method based on multi-option least squares Monte Carlo simulation. Numerical tests are conducted with the classical Sioux Falls network and compared to earlier published results.

Equilibrium properties of taxi markets with search frictions

- Transportation Research Part B: Methodological--2011---Hai Yang,Teng Yang

The equilibrium properties of an aggregate taxi market are investigated using a general bilateral searching and meeting function which characterizes the search frictions between vacant taxis and unserved customers. Three specific issues are analyzed for meeting functions that exhibit increasing, constant and decreasing returns to scale. Firstly, service quality in terms of customer wait/search time and average profit per taxi are examined jointly in relation to taxi fleet size, and a Pareto-improving win-win situation is identified, where an increase in taxi fleet size leads to improvements in both service quality and market profitability. Such a Pareto-improving situation is found to emerge if and only if the meeting functions show increasing returns to scale. Secondly, the properties of the socially optimal solution are examined. It is found that the taxi fleet size should be chosen such that the total cost of operating vacant taxis equals the total cost of customer waiting time multiplied by an asymmetric factor of the meeting function, and that taxi services should be subsidized at social optimum only when the meeting functions show increasing returns to scale. Thirdly, the Pareto-efficient services are examined for trade-offs between social welfare and profits in the light of partially conflicting objectives of the public sector and the private taxi firms using a bi-objective maximization approach. The taxi utilization rate and the customer wait/search time or service quality are proved to be constant along the Pareto frontier and equal to those at social optimum if the meeting functions show constant returns to scale. Extensions are made to the cases with increasing and decreasing returns to scale.

On the capacity of isolated, curbside bus stops

- Transportation Research Part B: Methodological---2011---Weihua Gu,Yuwei Li,Michael J. Cassidy,Julia B. Griswold

The maximal rates that buses can discharge from bus stops are examined. Models were developed to estimate these capacities for curbside stops that are isolated from the effects of traffic signals. The models account for key features of the stops, including their target service levels assigned to them by a transit agency. Among other things, the models predict that adding bus berths to a stop can sometimes return disproportionally high gains in capacity. This and other of our findings are at odds with information furnished in professional handbooks.

Intermodal hub-and-spoke network design: Incorporating multiple stakeholders and multi-type containers

- Transportation Research Part B: Methodological---2011---Qiang Meng,Xinchang Wang

This paper develops a mathematical program with equilibrium constraints (MPEC) model for the intermodal hub-and-spoke network design (IHSND) problem with multiple stakeholders and multi-type containers. The model incorporates a parametric variational inequality (VI) that formulates the user equilibrium (UE) behavior of intermodal operators in route choice for any given network design decision of the network planner. The model also uses a cost function that is capable of reflecting the transition from scale economies to scale diseconomies in distinct flow regimes for carriers or hub operators, and a disutility function integrating actual transportation charges and congestion impacts for intermodal operators. To solve the MPEC model, a hybrid genetic algorithm (HGA) embedded with a diagonalization method for solving the parametric VI is proposed. Finally, the comparative analysis of the HGA and an exhaustive enumeration algorithm indicates a good performance of the HGA in terms of computational time and solution quality. The HGA is also applied to solve a large-scale problem to show the applicability of the proposed model and algorithm.

The multinomial logit model revisited: A semi-parametric approach in discrete choice analysis

- Transportation Research Part B: Methodological---2011---Baibing Li

The multinomial logit model in discrete choice analysis is widely used in transport research. It has long been known that the Gumbel distribution forms the basis of the multinomial logit model. Although the Gumbel distribution is a good approximation in some applications such as route choice problems, it is chosen mainly for mathematical convenience. This can be restrictive in many other scenarios in practice. In this paper we show that the assumption of the Gumbel distribution can be substantially relaxed to include a large class of distributions that is stable with respect to the minimum operation. The distributions in the class allow heteroscedastic variances. We then seek a transformation that stabilizes the heteroscedastic variances. We show that this leads to a semi-parametric choice model which links the linear combination of travel-related attributes to the choice probabilities via an unknown sensitivity function. This sensitivity function reflects the degree of travelers' sensitivity to the changes in the combined travel cost. The estimation of the semi-parametric choice model is also investigated and empirical studies are used to illustrate the developed method.

Generalized extreme value (GEV)-based error structures for multiple discrete-continuous choice models

- Transportation Research Part B: Methodological---2011---Abdul Rawoof Pinjari

This paper formally derives the class of multiple discrete-continuous generalized extreme value (MDCGEV) models, a general class of multiple discrete-continuous choice models based on generalized extreme value (GEV) error specifications. Specifically, the paper proves the existence of, and derives the general form of, closed-form consumption probability expressions for multiple discrete-continuous choice models with GEV-based error structures. In addition to deriving the general form, the paper derives a compact and readily usable form of consumption probability expressions that can be used to estimate multiple discrete-continuous choice models with general cross-nested error structures. The cross-nested version of the MDCGEV model is applied to analyze household annual expenditure patterns in various transportation-related expenses using data from a Consumer Expenditure Survey in the United States. Model estimation results and predictive log-likelihood based validation tests indicate the superiority of the cross-nested model over the mutually exclusively nested and non-nested model specifications. Further, the cross-nested model was amenable to the accommodation of socio-demographic heterogeneity in inter-alternative covariance across decision-makers through a parameterization of the allocation parameters.

Collection, spillback, and dissipation in pedestrian evacuation: A network-based method

- Transportation Research Part B: Methodological---2011---Ren-Yong Guo,Hai-Jun Huang,S.C. Wong

We present a method of predicting pedestrian route choice behavior and physical congestion during the evacuation of indoor areas with internal obstacles. Under the proposed method, a network is first constructed by discretizing the space into regular hexagonal cells and giving these cells potentials before a modified cell transmission model is employed to predict the evolution of pedestrian flow in the network over time and space. Several properties of this cell transmission model are explored. The method can be used to predict the evolution of pedestrian flow over time and space in indoor areas with internal obstacles and to investigate the collection, spillback, and dissipation behavior of pedestrians passing through a bottleneck. The cell transmission model is further extended to imitate the movements of multiple flows of pedestrians with different destinations. An algorithm based on generalized cell potential is also developed to assign the pedestrian flow.

Stochastic cell transmission model (SCTM): A stochastic dynamic traffic model for traffic state surveillance and assignment

- Transportation Research Part B: Methodological---2011---A. Sumalee,R.X. Zhong,T.L. Pan,W.Y. Szeto

The paper proposes a first-order macroscopic stochastic dynamic traffic model, namely the stochastic cell transmission model (SCTM), to model traffic flow density on freeway segments with stochastic demand and supply. The SCTM consists of five operational modes corresponding to different congestion levels of the freeway segment. Each mode is formulated as a discrete time bilinear stochastic system. A set of probabilistic conditions is proposed to characterize the probability of occurrence of each mode. The overall effect of the five modes is estimated by the joint traffic density which is derived from the theory of finite mixture distribution. The SCTM captures not only the mean and standard deviation (SD) of density of the traffic flow, but also the propagation of SD over time and space. The SCTM is tested with a hypothetical freeway corridor simulation and an empirical study. The simulation results are compared against the means and SDs of traffic densities obtained from the Monte Carlo Simulation (MCS) of the modified cell transmission model (MCTM). An approximately two-miles freeway segment of Interstate 210 West (I-210W) in Los Ageles, Southern California, is chosen for the empirical study. Traffic data is obtained from the Performance Measurement System (PeMS). The stochastic parameters of the SCTM are calibrated against the flow-density empirical data of I-210W. Both the SCTM and the MCS of the MCTM are tested. A discussion of the computational efficiency and the accuracy issues of the two methods is provided based on the empirical results. Both the numerical simulation results and the empirical results confirm that the SCTM is capable of accurately estimating the means and SDs of the freeway densities as compared to the MCS.

Robust Wardrop's user equilibrium assignment under stochastic demand and supply: Expected residual minimization approach

- Transportation Research Part B: Methodological---2011---Chao Zhang,Xiaojun Chen,Agachai Sumalee

Various models of traffic assignment under stochastic environment have been proposed recently, mainly by assuming different travelers' behavior against uncertainties. This paper focuses on the expected residual minimization (ERM) model to provide a robust traffic assignment with an emphasis on the planner's perspective. The model is further extended to obtain a stochastic prediction of the traffic volumes by the technique of path choice approach. We show theoretically the existence and the robustness of the ERM solution. In addition, we employ an improved solution algorithm for solving the ERM model. Numerical experiments are carried out to illustrate the characteristics of the proposed model, by comparing with other existing models.

A generalized modeling framework to analyze interdependencies among infrastructure systems

- Transportation Research Part B: Methodological---2011---Pengcheng Zhang,Srinivas Peeta

Extreme events over the past decade in the USA, ranging from the 9/11 terror attacks to the 2003 Northeast power blackout to the 2005 hurricanes, have highlighted the urgent need to understand the interdependencies among civil infrastructure systems for more effective and efficient planning, design and operations. The need is further highlighted by the challenges arising from the capacity needs of rapid urbanization and the need to renew aging infrastructure. This paper proposes a generalized modeling framework that combines a multilayer network concept with a market-based economic approach to capture the interdependencies among various infrastructure systems with disparate physical and operational characteristics. Thereby, the various infrastructure systems are modeled as individual networks connected through links representing market interactions. The market interactions capture the various types of interdependencies through supply-demand mechanisms. The modeling framework uses a multilayer infrastructure network (MIN) concept, the computable general equilibrium (CGE) theory, and its spatial extension (SCGE), to formulate an equilibrium problem. The mapping between the modeling framework and the real-world context is discussed, followed by a description of the various model components. Numerical experiments are conducted to illustrate the capability of the model to capture various types of interdependencies and to provide insights on the importance of these interdependencies for real-world problems.

Managing network mobility with tradable credits

- Transportation Research Part B: Methodological---2011---Hai Yang,Xiaolei Wang

A system of tradable travel credits is explored in a general network with homogeneous travelers. A social planner is assumed to initially distribute a certain number of travel credits to all eligible travelers, and then there are link-specific charges to travelers using that link. Free trading of credits among travelers is assumed. For a given credit distribution and credit charging scheme, the existence of a unique equilibrium link flow pattern is demonstrated with either fixed or elastic demand. It can be obtained by solving a standard traffic equilibrium model subject to a total credit consumption constraint. The credit price at equilibrium in the trading market is also conditionally unique. The appropriate distribution of credits among travelers and correct selection of link-specific rates is shown to lead to the most desirable network flow patterns in a revenue-neutral manner. Social optimum, Pareto-improving and revenue-neutral, and side-constrained traffic flow patterns are investigated.

Airport congestion pricing and passenger types

- Transportation Research Part B: Methodological---2011---Achim I. Czerny,Anming Zhang

We consider a public and congested airport served by airlines that may have market power, and two types of travelers with different relative values of time. We find that in the absence of passenger-type-based price discrimination by airlines, it can be useful to increase the airport charge so as to protect passengers with a great relative time value from excessive congestion caused by passengers with a low relative time value. As a result, the socially efficient airport charge can be substantially higher than what we learned from the recent literature on congestion pricing with non-atomistic airlines.

Properties of a well-defined macroscopic fundamental diagram for urban traffic

- Transportation Research Part B: Methodological---2011---Nikolas Geroliminis,Jie Sun

A field experiment in Yokohama (Japan) revealed that a macroscopic fundamental diagram (MFD) linking space-mean flow, density and speed exists on a large urban area. It was observed that when the highly scattered plots of flow vs. density from individual fixed detectors were aggregated the scatter nearly disappeared and points grouped along a well defined curve. Despite these and other recent findings for the existence of well-defined MFDs for urban areas, these MFDs should not be universally expected. In this paper we investigate what are the properties that a network should satisfy, so that an MFD with low scatter exists. We show that the spatial distribution of vehicle density in the network is one of the key components that affect the scatter of an MFD and its shape. We also propose an analytical derivation of the spatial distribution of congestion that considers correlation between adjacent links. We investigate the scatter of an MFD in terms of errors in the probability density function of spatial link occupancy and errors of individual links' fundamental diagram (FD). Later, using real data from detectors for an urban arterial and a freeway network we validate the proposed derivations and we show that an MFD is not well defined in freeway networks as hysteresis effects are present. The datasets in this paper consist of flow and occupancy measures from 500 fixed sensors in the Yokohama downtown area in Japan and 600 loop detectors in the Twin Cities Metropolitan Area Freeway network in Minnesota, USA.

A prospect-based user equilibrium model with endogenous reference points and its application in congestion pricing

- Transportation Research Part B: Methodological---2011---Hongli Xu,Yingyan Lou,Yafeng Yin,Jing Zhou

A cell-based Merchant-Nemhauser model for the system optimum dynamic traffic assignment problem

- Transportation Research Part B: Methodological---2011---Nie, Yu (Marco)

A cell-based variant of the Merchant-Nemhauser (M-N) model is proposed for the system optimum (SO) dynamic traffic assignment (DTA) problem. Once linearized and augmented with additional constraints to capture cross-cell interactions, the model becomes a linear program that embeds a relaxed cell transmission model (CTM) to propagate traffic. As a result, we show that CTM-type traffic dynamics can be derived from the original M-N model, when the exit-flow function is properly selected and discretized. The proposed cell-based M-N model has a simple constraint structure and cell network representation because all intersections and cells are treated uniformly. Path marginal costs are defined using a recursive formula that involves a subset of multipliers from the linear program. This definition is then employed to interpret the necessary condition, which is a dynamic extension of the Wardrop's second principle. An algorithm is presented to solve the flow holding back problem that is known to exist in many discrete SO-DTA models. A numerical experiment is conducted to verify the proposed model and algorithm.

A dynamic traffic assignment model for a continuum transportation system

- Transportation Research Part B: Methodological---2011---Yanqun Jiang,S.C. Wong,H.W. Ho,Peng Zhang,Ruxun Liu,Agachai Sumalee

A predictive continuum dynamic user-optimal (PDUO-C) model is formulated in this study to investigate the dynamic characteristics of traffic flow and the corresponding route-choice behavior of travelers within a region with a dense urban road network. The modeled region is arbitrary in shape with a single central business district (CBD) and travelers continuously distributed over the region. Within this region, the road network is represented as a continuum and travelers patronize a two-dimensional continuum transportation system to travel to the CBD. The PDUO-C model is solved by a promising solution algorithm that includes elements of the finite volume method (FVM), the finite element method (FEM), and the explicit total variation diminishing Runge-Kutta (TVD-RK) time-stepping method. A numerical example is given to demonstrate the utility of the proposed model and the effectiveness of the solution algorithm in solving this PDUO-C problem.

On the degradation of performance for traffic networks with oblivious users

- Transportation Research Part B: Methodological---2011---George Karakostas,Taeyon Kim,Anastasios Viglas,Hao Xia

We consider the problem of characterizing user equilibria and optimal solutions for routing in a given network. We extend the known models by considering users oblivious to congestion in the following sense: While in the typical user equilibrium setting the users follow a strategy that minimizes their individual cost by taking into account the (dynamic) congestion due to the current routing pattern, an oblivious user ignores congestion altogether; instead, he or she decides his routing on the basis of cheapest routes on a network without any flow whatsoever. These cheapest routes can be, for example, the shortest paths in the network without any flow. This model tries to capture the fact that a certain percentage of travelers base their route simply on the distances they observe on a map, without thinking (or knowing, or caring) about the delays experienced on this route due to their fellow travelers. In this work we study the effect of such users using as the measure of network performance its price of anarchy, i.e., the ratio of the total latency experienced by the users (oblivious or not) at equilibrium over the social optimum.

Applications of wavelet transform for analysis of freeway traffic: Bottlenecks, transient traffic, and traffic oscillations

- Transportation Research Part B: Methodological---2011---Zuduo Zheng,Soyoung Ahn,Danjue Chen,Jorge Laval

This paper demonstrates the capabilities of wavelet transform (WT) for analyzing important features related to bottleneck activations and traffic oscillations in congested traffic in a systematic manner. In particular, the analysis of loop detector data from a freeway shows that the use of wavelet-based energy can effectively identify the location of an active bottleneck, the arrival time of the resulting queue at each upstream sensor location, and the start and end of a transition during the onset of a queue. Vehicle trajectories were also analyzed using WT and our analysis shows that the wavelet-based energies of individual vehicles can effectively detect the origins of deceleration waves and shed light on possible triggers (e.g., lane-changing). The spatiotemporal propagations of oscillations identified by tracing wavelet-based energy peaks from vehicle to vehicle enable analysis of oscillation amplitude, duration and intensity.

Hysteresis in traffic flow revisited: An improved measurement method

- Transportation Research Part B: Methodological---2011---Jorge A. Laval

This paper presents new insights on the hysteresis phenomenon in congested freeway traffic. It is found that existing theories based on different driver behavior for acceleration and deceleration are incomplete. The data suggests that one needs to consider aggressive and timid driver behavior as well. These findings are based on an improved method for measuring traffic flow variables from trajectory data consistently with kinematic wave theory.

Frequency-based transit assignment considering seat capacities

- Transportation Research Part B: Methodological---2011---Jan-Dirk Schmöcker,Achille Fonzone,Hiroshi Shimamoto,Fumitaka Kurauchi,Michael G.H. Bell

This paper proposes a frequency-based assignment model that considers travellers probability of finding a seat in their perception of route cost and hence also their route choice. The model introduces a "fail-to-sit" probability at boarding points with travel costs based on the likelihood of travelling seated or standing. Priority rules are considered; in particular it is assumed that standing on-board passengers will occupy any available seats of alighting passengers before newly boarding passengers can fill any remaining seats. At the boarding point passengers are assumed to mingle, meaning that FIFO is not observed, as is the case for many crowded bus and metro stops, particularly in European countries. The route choice considers the common lines problem and an user equilibrium solution is sought through a Markov type network loading process and the method of successive averages. The model is first illustrated with a small example network before being applied to the inner zone of London's underground network. The effect of different values passengers might attach to finding a seat are illustrated. Applications of the model for transit planning as well as for information provision at the journey planner stage are discussed.

An appraisal of a column-generation-based algorithm for centralized train-conflict resolution on a metropolitan railway network

- Transportation Research Part B: Methodological---2011---Yun-Hong Min,Myoung-Ju Park,Sung-Pil Hong,Soon-Heum Hong

In practice, a train-conflict resolution is decentralized around dispatchers each of whom controls a few segments in a global railway network with her rule-of-thumb to operational data. Conceptually, the global sub-optimality or infeasibility of the decentralized system is resolved by a network controller who coordinates the dispatchers and train operators at the lower layers on a real-time basis. However, such notion of a multi-layer system cannot be effectual unless the top layer is able to provide a global solution soon enough for the dynamic lower layers to adapt in a seamless manner. Unfortunately, a train-conflict resolution problem is NP-hard as formally established in this paper and an effective solution method traded off between computation time and solution quality has been lacking in literature.

Thus, we propose a column-generation-based algorithm that exploits the separability of the problem. A key ingredient of the algorithm is an efficient heuristic for the pricing subproblem for column generation. Tested on the real data from the Seoul metropolitan railway network, the algorithm provides near-optimal conflict-free timetables in a few seconds for most cases. The performance of the proposed algorithm is compared to the ones of the previous MIP-based heuristic by Törnquist and Persson (2007) and the priority-based heuristic by Sahin (1999).

Optimizing the demand captured by a railway system with a regular timetable

- Transportation Research Part B: Methodological--2011---Roberto Cordone,Francesco Redaelli

The railway systems in various European countries adopt regular timetables, in which the trains arrive and depart at constant intervals. In fact, their simple structure provides several advantages both to the passengers and to the management of the service. The design of such timetables has recently received a certain attention in the literature, but the standard model aims to optimize the service for a fixed demand. We relax this unrealistic assumption, taking into account the reciprocal influence between the quality of the timetable and the amount of transport demand captured by the railway. This results into a mixed-integer non linear model with a non-convex continuous relaxation. We solve it by a branch-and-bound algorithm based on a piecewise-linear overestimate of the objective function and a heuristic algorithm which iteratively applies the standard fixed-demand model and a demand-estimation model, feeding each one with data based on the solution obtained from the other one at the previous iteration. The computational results presented concern both random instances and a real-world regional network located in Northwestern Italy.

Estimating a model of dynamic activity generation based on one-day observations: Method and results

- Transportation Research Part B: Methodological--2011---Theo A. Arentze,Dick Ettema,Harry J.P. Timmermans

In this paper we develop and explore an approach to estimate dynamic models of activity generation on one-day travel-diary data. Dynamic models predict multi-day activity patterns of individuals taking into account dynamic needs as well as day-varying preferences and time-budgets. We formulate an ordered-logit model of dynamic activity-agenda-formation decisions and show how one-day observation probabilities can be derived from the model as a function of the model's parameters and, with that, how parameters can be estimated using standard loglikelihood estimation. A scale parameter cannot be identified because information on within-person variability is lacking in one-day data. An application of the method to data from a national travel survey illustrates the method. A test on simulated data indicates that, given a pre-set scale, the parameters can be identified and that estimates are robust for a source of heterogeneity not captured in the model. This result indicates that dynamic activity-based models of the kind considered here can be estimated from data that are less costly to collect and that support the large sample sizes typically required for travel-demand modeling. We conclude therefore that the proposed approach opens up a way to develop large-scale dynamic activity-based models of travel demand.

The value of travel time variance

- Transportation Research Part B: Methodological--2011---Mogens Fosgerau,Leonid Engelson

This paper considers the value of travel time variability under scheduling preferences that are defined in terms of linearly time varying utility rates associated with being at the origin and at the destination. The main result is a simple expression for the value of travel time variability that does not depend on the shape of the travel time distribution. The related measure of travel time variability is the variance of travel time. These conclusions apply equally to travellers who can freely choose departure time and to travellers who use a scheduled service with fixed headway. Depending on parameters, travellers may be risk averse or risk seeking and the value of travel time may increase or decrease in the mean travel time.

Nonlinear pricing on private roads with congestion and toll collection costs

- Transportation Research Part B: Methodological---2011---Judith Y.T. Wang,Charles Lindsey,Hai Yang

Nonlinear pricing (a form of second-degree price discrimination) is widely used in transportation and other industries but it has been largely overlooked in the road-pricing literature. This paper explores the incentives for a profit-maximizing toll-road operator to adopt some simple nonlinear pricing schemes when there is congestion and collecting tolls is costly. Users are assumed to differ in their demands to use the road. Regardless of the severity of congestion, an access fee is always profitable to implement either as part of a two-part tariff or as an alternative to paying a toll. Use of access fees for profit maximization can increase or decrease welfare relative to usage-only pricing for profit maximization. Hence a ban on access fees could reduce welfare.

First-best marginal cost toll for a traffic network with stochastic demand

- Transportation Research Part B: Methodological---2011---Agachai Sumalee,Wei Xu

First-best marginal cost pricing (MCP) in traffic networks has been extensively studied with the assumption of deterministic travel demand. However, this assumption may not be realistic as a transportation network is exposed to various uncertainties. This paper investigates MCP in a traffic network under stochastic travel demand. Cases of both fixed and elastic demand are considered. In the fixed demand case, travel demand is represented as a random variable, whereas in the elastic demand case, a pre-specified random variable is introduced into the demand function. The paper also considers a set of assumptions of traveler behavior. In the first case, it is assumed that the traveler considers only the mean travel time in the route choice decision (risk-neutral behavior), and in the second, both the mean and the variance of travel time are introduced into the route choice model (risk-averse behavior). A closed-form formulation of the true marginal cost toll for the stochastic network (SN-MCP) is derived from the variational inequality conditions of the system optimum and user equilibrium assignments. The key finding is that the calculation of the SN-MCP model cannot be made by simply substituting related terms in the original MCP model by their expected values. The paper provides a general function of SN-MCP and derives the closed-form SN-MCP formulation for specific cases with lognormal and normal stochastic travel demand. Four numerical examples are explored to compare network performance under the SN-MCP and other toll regimes.

Congestion tolling in the bottleneck model with heterogeneous values of time

- Transportation Research Part B: Methodological---2011---Vincent van den Berg,Erik Verhoef

When analysing the effects of transport policies it is important to adequately control for heterogeneity: previous studies note that ignoring heterogeneity biases the estimated welfare effects of tolling. This paper examines the effects of tolling, in a bottleneck model, with a continuously distributed value of time. With homogeneous users, first-best public tolling has no effect on prices. With heterogeneity it does: low values of time lose, and high values of time gain. The average congestion externality decreases with the heterogeneity in the value of time. Consequently, the welfare gain of first-best tolling also decreases. The more heterogeneous the value of time is, the lower the relative efficiency of a public pay-lane. This finding contrasts with the previous literature. Earlier studies, using static flow congestion, conclude that the relative efficiency increases with this type of heterogeneity. With more heterogeneity in the value of time, the relative efficiency of a private pay-lane is also lower, while that of a public time-invariant toll is higher. Our results suggest that the welfare gains of different tolling schemes are affected differently by heterogeneity. Further, the impact of heterogeneity on the effects of a policy also depends on the type of congestion considered.

Optimal congestion taxes in a time allocation model

- Transportation Research Part B: Methodological--2011---Bruno De Borger

The purpose of this paper is to study optimal congestion taxes in a time-allocation framework. This makes it possible to distinguish taxes on inputs in the production of car trips and taxes on transport as an activity. Moreover, the model allows us to consider the implications of treating transport as a demand, derived from other activities. We extend several well known tax rules from the public finance literature and carefully interpret the implications for the optimal tax treatment of passenger transport services. The main findings of the paper are the following. First, if governments are limited to taxing market inputs into transport trip production, the time-allocation framework: (i) provides an argument for taxing congestion below marginal external cost, (ii) implies a favourable tax treatment for time-saving devices such as GPS, and (iii) provides a previously unnoticed argument for public transport subsidies. Second, if the government has access to perfect road pricing that directly taxes transport as an activity, all previous results disappear. Third, in the absence of perfect road pricing, the activity-specific congestion attracted by employment centres, by shopping centres or by large sports and cultural events should be corrected via higher taxes on market inputs in these activities (e.g., entry tickets, parking fees, etc.).

The independence of volume-capacity ratio of private toll roads in general networks

- Transportation Research Part B: Methodological--2011---Di Wu,Yafeng Yin,Hai Yang

In a general traffic network under some widely used assumptions, this paper proves that the level of service, represented by the volume-capacity (v/c) ratio, offered by a profit-maximizing private firm on a private toll road is independent of another competitor's choice of capacity and toll rate for another private toll road. The v/c ratio will be the same as the one provided by a centralized welfare-maximizing traffic authority. Moreover, the ratio remains the same even in a regulated market where the authority imposes a cap for the generalized travel cost on the private toll road.

Route swapping in dynamic traffic networks

- Transportation Research Part B: Methodological--2011---Richard Mounce,Malachy Carey

A dynamic traffic assignment (DTA) model typically consists of a traffic performance model and a route choice model. The traffic performance model describes how traffic propagates (over time) along routes connecting origin-destination (OD) pairs, examples being the cell transmission model, the vertical queueing model and the travel time model. This is implemented in a dynamic network loading (DNL) algorithm, which uses the given route inflows to compute the link inflows (and hence link costs), which are then used to compute the route travel times (and hence route costs). A route swap process specifies the route inflows for tomorrow (at the next iteration) based on the route inflows today (at the current iteration). A dynamic user equilibrium (DUE), where each traveller on the network cannot reduce his or her cost of travel by switching to another route, can be sought by iterating between the DNL algorithm and the route swap process. The route swap process itself takes up very little computational time (although route set generation can be very computationally intensive for large networks). However, the choice of route swap process dramatically affects convergence and the speed of convergence. The paper details several route swap processes and considers whether they lead to a convergent system, assuming that the route cost vector is a monotone function of the route inflow vector.

The econometric estimation of airports' cost function

- Transportation Research Part B: Methodological---2011---Juan Carlos Martín,Augusto Voltes-Dorta

The econometric estimation of cost functions has been proposed in the literature as a suitable approach in order to obtain estimations of marginal costs, efficiency levels and scale elasticities for transport industries. However, regarding the airport industry, no significant attention has been paid in developing an airport-specific estimation methodology rather than adapting the procedures applied to other industries. The lack of comparable airport data is one of the causes which could explain the scarcity of this literature in the past, as well as the use of very limited approaches to explain airport technology. This paper tries to overcome these limitations by developing an airport-specific methodology to estimate a multi-output long-run cost function using an unbalanced pooled database on 161 airports worldwide. The specification of hedonically-adjusted aircraft operations, domestic and international passengers, cargo and commercial revenues in the output vector, as well as the calculation of input prices are discussed. Both technical and allocative inefficiencies are specified in the model using a Stochastic Frontier method that has been estimated through Bayesian Inference and Markov Chain Monte Carlo methods.

A competitive, charter air-service planning model for student athlete travel

- Transportation Research Part B: Methodological---2011---Gautam Gupta,Anne Goodchild,Mark Hansen

This paper presents a model for planning an air charter service for pre-scheduled group travel. This model is used to investigate the competitiveness of such an enterprise for student athlete travel in conference sports. The relevant demand subset to be served by a limited charter fleet is identified through a comparison with existing scheduled travel options. Further, the routing and scheduling of the charter aircraft is performed within the same framework. Through this modeling a method for formulating and accommodating continuous time windows and competitive market dynamics in strategic planning for a charter service is developed. Computational improvements to the basic model are also presented and tested. The model is applied to the Big Sky Conference for the 2006-2007 season, quantifying the benefits to the students from such a service and the change in expenditure associated with such a benefit for various assumptions about operations and value of time. The findings indicate the lack of spatial or sport based patterns for maximizing benefit, indicating the absence of simplistic "rules of thumb" for operating such a service, and validating the need for the model.

CO2 emissions: Are land-use changes enough for California to reduce VMT? Specification of a two-part model with instrumental variables

- Transportation Research Part B: Methodological---2011---David Heres,Deb Niemeier

With vehicle miles of travel increasing at a faster pace than population, one strategy being actively pursued by both state and local governments is compact development. California recently passed legislation that aggressively promotes sustainability by endorsing and rewarding compact development. Likewise, the California Air Resources Board has set a statewide reduction target of 5MMT of greenhouse gas reductions from land use, based largely on achieving compact development patterns. In this paper, we use a multivariate two-part model with instrumental variables, which corrects for residential location self-selection bias. We use a much larger and more geographically representative travel survey on household travel patterns and socioeconomic characteristics than represented in previous California studies; this allows us to robustly consider other influences on travel. Our results indicate that, all else equal, a 10% in residential density would reduce VMT by 1.9%. This elasticity is larger than the reported in previous econometric studies for the US, and specifically for California. However, as we show, the magnitude of this impact is still low considering reasonable ranges for policies aimed to increase residential density.

Biofuel refinery location and supply chain planning under traffic congestion

- Transportation Research Part B: Methodological---2011---Yun Bai,Taesung Hwang,Seungmo Kang,Yanfeng Ouyang

This research focuses on planning biofuel refinery locations where the total system cost for refinery investment, feedstock and product transportation and public travel is minimized. Shipment routing of both feedstock and product in the biofuel supply chain and the resulting traffic congestion impact are incorporated into the model to decide optimal locations of biofuel refineries. A Lagrangian relaxation based heuristic algorithm is introduced to obtain near-optimum feasible solutions efficiently. To further improve optimality, a branch-and-bound framework (with linear programming relaxation and Lagrangian relaxation bounding procedures) is developed. Numerical experiments with several testing examples demonstrate that the proposed algorithms solve the problem effectively. An empirical Illinois case study and a series of sensitivity analyses are conducted to show the effects of highway congestion on refinery location design and total system costs.

Approximate network loading and dual-time-scale dynamic user equilibrium

- Transportation Research Part B: Methodological---2011---Terry L. Friesz,Taeil Kim,Changhyun Kwon,Matthew A. Rigdon

In this paper we present a dual-time-scale formulation of dynamic user equilibrium (DUE) with demand evolution. Our formulation belongs to the problem class that Pang and Stewart (2008) refer to as differential variational inequalities. It combines the within-day time scale for which route and departure time choices fluctuate in continuous time with the day-to-day time scale for which demand evolves in discrete time steps. Our formulation is consistent with the often told story that drivers adjust their travel demands at the end of every day based on their congestion experience during one or more previous days. We show that analysis of the within-day assignment model is tremendously simplified by expressing dynamic user equilibrium as a differential variational inequality. We also show there is a class of day-to-day demand growth models that allow the dual-time-scale formulation to be decomposed by time-stepping to yield a sequence of continuous time, single-day, dynamic user equilibrium problems. To solve the single-day DUE problems arising during time-stepping, it is necessary to repeatedly solve a dynamic network loading problem. We observe that the network loading phase of DUE computation generally constitutes a differential algebraic equation (DAE) system, and we show that the DAE system for network loading based on the link delay model (LDM) of Friesz et al. (1993) may be approximated by a system of ordinary differential equations (ODEs). That system of ODEs, as we demonstrate, may be efficiently solved using traditional numerical methods for such problems. To compute an actual dynamic user equilibrium, we introduce a continuous time fixed-point algorithm and prove its convergence for effective path delay operators that allow a limited type of nonmonotone path delay. We show that our DUE algorithm is compatible with network loading based on the LDM and the cell transmission model (CTM) due to Daganzo (1995). We provide a numerical example based on the much studied Sioux Falls network.

A mixed-integer linear program for optimizing sensor locations along freeway corridors

- Transportation Research Part B: Methodological---2011---Adam Danczyk,Henry X. Liu

How to optimally allocate limited freeway sensor resources is of great interest to transportation engineers. In this paper, we focus on the optimal allocation of point sensors, such as loop detectors, to minimize performance measurement errors. Although it has been shown that the minimization problem can be intuitively formulated as a nonlinear program, the formulation is so complex that only heuristic approaches can be used to solve the problem. In this paper, we transform the nonlinear program into an equivalent mixed-integer linear model. The linearized model is shown to have a graphical interpretation and can be solved using resource constrained shortest path algorithms. A customized Branch-and-Bound technique is then proposed to solve the resource constrained shortest path problem. Numerical experiments along an urban freeway corridor demonstrate that this sensor location model is successful in allocating loop detectors to improve the accuracy of travel time estimation.

Reliable sensor deployment for network traffic surveillance

- Transportation Research Part B: Methodological---2011---Xiaopeng Li,Yanfeng Ouyang

New sensor technologies enable synthesis of disaggregated vehicle information from multiple locations. This paper proposes a reliable facility location model to optimize traffic surveillance benefit from synthesized sensor pairs (e.g., for travel time estimation) in addition to individual sensor flow coverage (e.g., for traffic volume statistics), while considering probabilistic sensor failures. Customized greedy and Lagrangian relaxation algorithms are proposed to solve this problem, and their performance is discussed. Numerical results show that the proposed algorithms solve the problem efficiently. We also discuss managerial insights on how optimal sensor deployment and surveillance benefits vary with surveillance objective and system parameters (such as sensor failure probabilities).

Discretised link travel time models based on cumulative flows: Formulations and properties

- Transportation Research Part B: Methodological---2011---Jiancheng Long,Ziyou Gao,W.Y. Szeto

In the research area of dynamic traffic assignment, link travel times can be derived from link cumulative inflow and outflow curves which are generated by dynamic network loading. In this paper, the profiles of cumulative flows are piecewise linearized. Both the step function (SF) and linear interpolation (LI) are used to approximate cumulative flows over time. New formulations of the SF-type and LI-type link travel time models are developed. We prove that these two types of link travel time models ensure first-in-first-out (FIFO) and continuity of travel times with respect to flows, and have other desirable properties. Since the LI-type link travel time model does not satisfy the causality property, a modified LI-type (MLI-type) link travel time model is proposed in this paper. We prove that the MLI-type link travel time model ensures causality, strong FIFO and travel time continuity, and that the MLI-type link travel time function is strictly monotone under the condition that the travel time of each vehicle on a link is greater than the free flow travel time on that link. Numerical examples are set up to illustrate the properties and accuracy of the three models.

An empirical analysis on the arterial fundamental diagram

- Transportation Research Part B: Methodological---2011---Xinkai Wu,Henry X. Liu,Nikolas Geroliminis

For uninterrupted traffic flow, it is well-known that the fundamental diagram (FD) describes the relationship between traffic flow and density under steady state. For interrupted traffic flow on a signalized road, it has been recognized that the arterial fundamental diagram (AFD) is significantly affected by signal operations. But little research up to date has discussed in detail how signal operations impact the AFD. In this paper, based upon empirical observations from high-resolution event-based traffic signal data collected from a major arterial in the Twin Cities area, we study the impacts of g/C ratio, signal coordination, and turning movements on the cycle-based AFD, which describes the relationship between traffic flow and occupancy in a signal cycle. By microscopically investigating individual vehicle trajectories from event-based data, we demonstrate that not only g/C ratio constrains the capacity of a signalized approach, poor signal coordination and turning movements from upstream intersections also have significant impact on the capacity. We show that an arterial link may not be congested even with high occupancy values. Such high values could result from queue build-up during red light that occupies the detector, i.e. the

Queue-Over-Detector (QOD) phenomenon discussed in this paper. More importantly, by removing the impact of QOD, a stable form of AFD is revealed, and one can use that to identify three different regimes including under-saturation, saturation, and over-saturation with queue spillovers. We believe the stable form of AFD is of great importance for traffic signal control because of its ability to identify traffic states on a signal link.

Reducing bunching with bus-to-bus cooperation

- Transportation Research Part B: Methodological---2011---Carlos F. Daganzo,Josh Pilachowski

Schedule-based or headway-based control schemes to reduce bus bunching are not resilient because they cannot prevent buses from losing ground to the buses they follow when disruptions increase the gaps separating them beyond a critical value. (Following buses are then overwhelmed with passengers and cannot process their work quick enough to catch up.) This critical gap problem can be avoided, however, if buses at the leading end of such gaps are given information to cooperate with the ones behind by slowing down. This paper builds on this idea. It proposes an adaptive control scheme that adjusts a bus cruising speed in real-time based on both, its front and rear spacings much as if successive bus pairs were connected by springs. The scheme is shown to yield regular headways with faster bus travel than existing control methods. Its simple and decentralized logic automatically compensates for traffic disruptions and inaccurate bus driver actions. Its hardware and data requirements are minimal.

Macroscopic relations of urban traffic variables: Bifurcations, multivaluedness and instability

- Transportation Research Part B: Methodological---2011---Carlos F. Daganzo,Vikash V. Gayah,Eric J. Gonzales

Recent experimental work has shown that the average flow and average density within certain urban networks are related by a unique, reproducible curve known as the Macroscopic Fundamental Diagram (MFD). For networks consisting of a single route this MFD can be predicted analytically; but when the networks consist of multiple overlapping routes experience shows that the flows observed in congestion for a given density are less than those one would predict if the routes were homogeneously congested and did not overlap. These types of networks also tend to jam at densities that are only a fraction of their routes' average jam density. This paper provides an explanation for these phenomena. It shows that, even for perfectly homogeneous networks with spatially uniform travel patterns, symmetric equilibrium patterns with equal flows and densities across all links are unstable if the average network density is sufficiently high. Instead, the stable equilibrium patterns are asymmetric. For this reason the networks jam at lower densities and exhibit lower flows than one would predict if traffic was evenly distributed. Analysis of small idealized networks that can be treated as simple dynamical systems shows that these networks undergo a bifurcation at a network-specific critical density such that for lower densities the MFDs have predictably high flows and are univalued, and for higher densities the order breaks down. Microsimulations show that this bifurcation also manifests itself in large symmetric networks. In this case though, the bifurcation is more pernicious: once the network density exceeds the critical value, the stable state is one of complete gridlock with zero flow. It is therefore important to ensure in real-world applications that a network's density never be allowed to approach this critical value. Fortunately, analysis shows that the bifurcation's critical density increases considerably if some of the drivers choose their routes adaptively in response to traffic conditions. So far, for networks with adaptive drivers, bifurcations have only been observed in simulations, but not (yet) in real life. This could be because real drivers are more adaptive than simulated drivers and/or because the observed real networks were not sufficiently congested.

A generic class of first order node models for dynamic macroscopic simulation of traffic flows

- Transportation Research Part B: Methodological---2011---Chris M.J. Tampère,Ruben Corthout,Dirk

Cattrysse,Lambertus H. Immers

Node models for macroscopic simulation have attracted relatively little attention in the literature. Nevertheless, in dynamic network loading (DNL) models for congested road networks, node models are as important as the extensively studied link models. This paper provides an overview of macroscopic node models found in the literature, explaining both their contributions and shortcomings. A formulation defining a generic class of first order macroscopic node models is presented, satisfying a list of requirements necessary to produce node models with realistic, consistent results. Defining a specific node model instance of this class requires the specification of a supply constraint interaction rule and (optionally) node supply constraints. Following this theoretical discussion, specific macroscopic node model instances for unsignalized and signalized intersections are proposed. These models apply an oriented capacity proportional distribution of the available supply over the incoming links of a node. A computationally efficient algorithm to solve the node models exactly is included.

Congestion derivatives for a traffic bottleneck

- Transportation Research Part B: Methodological---2010---Tao Yao,Terry L. Friesz,Mike Mingcheng Wei,Yafeng Yin

Historically, congestion pricing is considered to be an efficient mechanism used to decrease total social cost by charging users' true costs including congestion externalities. Congestion pricing under uncertainty has been relatively little studied. In this paper, we review the literature on deterministic congestion pricing and introduce possible sources of uncertainty for a simple bottleneck. We show that, when prices involve exogenous uncertainty that is independent of the central authority and of individual drivers, total social cost may be expressed in closed form as a function of departure time and uncertainty. We also show that there is a class of financial derivatives based on congestion that have the potential to reduce total social cost. In particular, such derivatives are shown to have the potential to alter drivers' departure behavior and reduce drivers' risks of high variance in trip costs, including congestion tolls. Finally, numerical formulations and examples are given to justify the robustness of our results with respect to more general congestion uncertainty.

Endogenous arrivals in batch queues with constant or variable capacity

- Transportation Research Part B: Methodological---2010---Amnon Rapoport,William E. Stein,Vincent Mak,Rami Zwick,Darryl A. Seale

We study batch queueing systems with continuous time, finite commuter populations, single server, and endogenously determined arrival times. Symmetric equilibrium solutions in mixed strategies are constructed and subsequently tested in two experiments that examine two different batch queueing models, one with a fixed server capacity, and the other with a variable server capacity. With experience in playing the stage queueing game repeatedly, experimental results from groups of 20 subjects support equilibrium play on the aggregate level when the server capacity is fixed and commonly known. When it is known to be variable, randomly changing from round to round, subjects diverge from equilibrium play and increase their individual payoffs substantially by significantly shortening their waiting time.

Design of limited-stop services for an urban bus corridor with capacity constraints

- Transportation Research Part B: Methodological---2010---Carola Leiva,Juan Carlos Muñoz,Ricardo Giesen,Homero Larrain

In high-demand bus networks, limited-stop services promise benefits for both users and operators, and have proven their attractiveness in systems such as Transmilenio (Bogota, Colombia) and Transantiago (Santiago, Chile). The design of these services involves defining their itinerary, frequency and vehicle size, yet despite the importance of these factors for the network's efficiency, no published works appear to provide the tools for designing high-frequency unscheduled services on an urban bus corridor, minimizing social costs. This paper presents an optimization approach that minimizes these costs in terms of wait time, in-vehicle travel time and operator cost. Various optimization models are formulated that can accommodate the operating characteristics of a bus corridor, given an origin-destination trip matrix and a set of services that are a priori attractive. The models then determine which of these services should be offered at what frequencies and with which type of vehicles. A case study in which the model is applied to a real-world case of a bus corridor in the city of Santiago, Chile, is presented and the results are analyzed. Finally, the model is used on two different demand scenarios establishing which type of services tend to be good candidates on each case and providing preliminary insights on the impact of some key parameters.

A computationally efficient methodology to characterize travel time reliability using the fast Fourier transform

- Transportation Research Part B: Methodological--2010---ManWo Ng,S. Travis Waller

In this paper we present a novel methodology to assess travel time reliability in a transportation network, when the source of uncertainty is given by random road capacities. Specifically, we present a method based on the theory of Fourier transforms to numerically approximate the probability density function of the system-wide travel time. Except for noted pathological cases, any common continuous or discrete probability distribution can be used to model capacity uncertainty. Theoretical bounds on the approximation errors are formally derived, both for general distributions as well as for the specific instance of normally distributed capacities. These bounds provide valuable insights into the structure of the approximation errors and suggest ways to reduce them. From a practical point of view, we propose a procedure based on successively refining the computational grid in order to guarantee accurate approximations. The proposed methodology takes advantage of the established computational efficiency of the fast Fourier transform. In a numerical case study, we demonstrate that the results of the methodology are consistent with intuition.

Induced demand and rebound effects in road transport

- Transportation Research Part B: Methodological--2010---Kent M. Hymel,Kenneth Small,Kurt Van Dender

This paper analyzes aggregate personal motor-vehicle travel within a simultaneous model of aggregate vehicle travel, fleet size, fuel efficiency, and congestion formation. We measure the impacts of driving costs on congestion, and two other well-known feedback effects affecting motor-vehicle travel: its responses to aggregate road capacity ("induced demand") and to driving costs including those caused by fuel-economy improvements ("rebound effect"). We measure these effects using cross-sectional time series data at the level of US states for 1966 through 2004. Results show that congestion affects the demand for driving negatively, as expected, and more strongly when incomes are higher. We decompose induced demand into effects from increasing overall accessibility of destinations and those from increasing urban capacity, finding the two elasticities close in magnitude and totaling about 0.16, somewhat smaller than most previous estimates. We confirm previous findings that the magnitude of the rebound effect decreases with income and increases with fuel cost, and find also that it increases with the level of congestion.

Travel time measurement in closed toll highways

- Transportation Research Part B: Methodological--2010---F. Soriguera,D. Rosas,F. Robusté

Travel time for a road trip is a drivers' most appreciated traffic information. Measuring travel times on a real time basis is also a perfect indicator of the level of service in a road link, and therefore is a useful measurement for traffic managers in order to improve traffic operations on the network. In conclusion, accurate travel time measurement is one of the key factors in traffic management systems. This paper presents a new approach for measuring travel times on closed toll highways using the existing surveillance infrastructure. In a closed toll system, where toll plazas are located on the on/off-ramps and each vehicle is charged a particular fee depending on its origin and destination, the data used for toll collection can also be valuable for measuring mainline travel times on the highway. The proposed method allows estimating mainline travel times on single sections of highway (defined as a section between two neighboring ramps) using itineraries covering different origin-destinations. The method provides trip time estimations without investing in any kind of infrastructure or technology. This overcomes some of the limitations of other methods, like the information delay and the excess in the travel time estimation due to the accumulation of exit times (i.e. the time required to travel along the exit link plus the time required to pay the fee at the toll gate). The results obtained in a pilot test on the AP-7 toll highway, near Barcelona in Spain, show that the developed methodology is sound.

Comparing different sampling schemes for approximating the integrals involved in the efficient design of stated choice experiments

- Transportation Research Part B: Methodological---2010---Jie Yu,Peter Goos,Martina Vandebroek

The semi-Bayesian approach for constructing efficient stated choice designs requires the evaluation of the design selection criterion value over numerous draws taken from the prior parameter distribution assumed when generating the design. The semi-Bayesian D-criterion value of a design is then calculated as the average value of the D-errors over all the draws taken. The traditional way to take draws from a distribution is to use the Pseudo-Monte Carlo approach. However, other sampling approaches are available as well. Examples are Quasi-Monte Carlo approaches using Halton sequences, Faure sequences, modified Latin hypercube sampling and extensible shifted lattice points, a Gauss-Hermite quadrature approach and a method using spherical-radial transformations. Not much is known in general about which sampling scheme is most efficient for calculating semi-Bayesian D-errors when constructing efficient stated choice designs. In this study, we compare the performance of these approaches under various scenarios and identify the most efficient sampling scheme for each situation. The method based on a spherical-radial transformation is shown to outperform the other methods when small numbers of draws are used.

A flexible spatially dependent discrete choice model: Formulation and application to teenagers' weekday recreational activity participation

- Transportation Research Part B: Methodological---2010---Chandra R. Bhat,Ipek N. Sener,Naveen Eluru

This study proposes a simple and practical Composite Marginal Likelihood (CML) inference approach to estimate ordered-response discrete choice models with flexible copula-based spatial dependence structures across observational units. The approach is applicable to data sets of any size, provides standard error estimates for all parameters, and does not require any simulation machinery. The combined copula-CML approach proposed here should be appealing for general multivariate modeling contexts because it is simple and flexible, and is easy to implement The ability of the CML approach to recover the parameters of a spatially ordered process is evaluated using a simulation study, which clearly points to the effectiveness of the approach. In addition, the combined copula-CML approach is applied to study the daily episode frequency of teenagers' physically active and physically inactive recreational activity participation, a subject of considerable interest in the transportation, sociology, and adolescence development fields. The data for the analysis are drawn from the 2000 San Francisco Bay Area Survey. The results highlight the value of the copula approach that separates the univariate marginal distribution form from the multivariate dependence structure, as well as underscore the need to consider spatial effects in recreational activity participation. The variable effects indicate that parents' physical activity participation constitutes the most important factor influencing teenagers' physical activity participation levels. Thus, an effective way to increase active recreation among teenagers may be to direct physical activity benefit-related information and education campaigns toward parents, perhaps at special physical education sessions at the schools of teenagers.

A multivariate ordered-response model system for adults' weekday activity episode generation by activity purpose and social context

- Transportation Research Part B: Methodological---2010---Nazneen Ferdous,Naveen Eluru,Chandra R. Bhat,Italo Meloni

This paper proposes a multivariate ordered-response system framework to model the interactions in non-work activity episode decisions across household and non-household members at the level of activity generation. Such interactions in activity decisions across household and non-household members are important to consider for accurate activity-travel pattern modeling and policy evaluation. The econometric challenge in estimating a multivariate ordered-response system with a large number of categories is that traditional classical and Bayesian simulation techniques become saddled with convergence problems and imprecision in estimates, and they are also extremely cumbersome if not impractical to implement. We address this estimation problem by resorting to the technique of composite marginal likelihood (CML), an emerging inference approach in the statistics field that is based on the classical frequentist approach, is very simple to estimate, is easy to implement regardless of the number of count outcomes to be modeled jointly, and requires no simulation machinery whatsoever. The empirical analysis in the paper uses data drawn from the 2007 American Time Use Survey (ATUS) and provides important insights into the determinants of adults' weekday activity episode generation behavior. The results underscore the substantial linkages in the activity episode generation of adults based on activity purpose and accompaniment type. The extent of this linkage varies by individual demographics, household demographics, day of the week, and season of the year. The results also highlight the flexibility of the CML approach to specify and estimate behaviorally rich structures to analyze inter-individual interactions in activity episode generation.

Revenue sharing with multiple airlines and airports

- Transportation Research Part B: Methodological---2010---Anming Zhang,Xiaowen Fu,Yang, Hangjun (Gavin)

This paper investigates the effects of concession revenue sharing between an airport and its airlines. It is found that the degree of revenue sharing will be affected by how airlines' services are related to each other (complements, independent, or substitutes). In particular, when carriers provide strongly substitutable services to each other, the airport has incentive to charge airlines, rather than to pay airlines, a share of concession revenue. In these situations, while revenue sharing improves profit, it reduces social welfare. It is further found that airport competition results in a higher degree of revenue sharing than would be had in the case of single airports. The airport-airline chains may nevertheless derive lower profits through the revenue-sharing rivalry, and the situation is similar to a Prisoners' Dilemma. As the chains move further away from their joint profit maximum, welfare rises beyond the level achievable by single airports. The (equilibrium) revenue-sharing proportion at an airport is also shown to decrease in the number of its carriers, and to increase in the number of carriers at competing airports. Finally, the effects of a 'pure' sharing contract are compared to those of the two-part sharing contract. It is found that whether an airport is subject to competition is critical to the welfare consequences of alternative revenue sharing arrangements.

Airline emission charges: Effects on airfares, service quality, and aircraft design

- Transportation Research Part B: Methodological---2010---Jan Brueckner,Anming Zhang

This paper explores the effect of airline emissions charges on airfares, airline service quality, aircraft design features, and network structure, using a detailed and realistic theoretical model of competing duopoly airlines. These impacts are derived by analyzing the effects of an increase in the effective price of fuel, which is the path by which emissions charges will alter airline choices. The results show that emission charges will raise fares, reduce flight frequency, increase load factors, and raise aircraft fuel efficiency, while having no effect on aircraft size. Given that these adjustments occur in response to the treatment of an emissions externality that is currently unaddressed, they represent efficient changes that move society closer to a social optimum.

Pareto-improving congestion pricing and revenue refunding with multiple user classes

- Transportation Research Part B: Methodological---2010---Xiaolei Guo,Hai Yang

This study investigates Pareto-improving congestion pricing and revenue refunding schemes in general transportation networks, which make every road user better off as compared with the situation without congestion pricing. We consider user heterogeneity in value of time (VOT) by adopting a multiclass user model with fixed origin-destination (OD) demands. We first prove that an OD and class-based Pareto-improving refunding scheme exists if and only if the total system monetary travel disutility is reduced. In view of the practical difficulty in identifying individual user's VOT, we further investigate class-anonymous refunding schemes that give the same amount of refund to all user classes traveling between the same OD pair regardless of their VOTs. We establish a sufficient condition for the existence of such OD-specific but class-anonymous Pareto-improving refunding schemes, which needs information only on the average toll paid and average travel time for trips between each OD pair.

Three-phase traffic theory and two-phase models with a fundamental diagram in the light of empirical stylized facts

- Transportation Research Part B: Methodological---2010---Martin Treiber,Arne Kesting,Dirk Helbing

Despite the availability of large empirical data sets and the long history of traffic modeling, the theory of traffic congestion on freeways is still highly controversial. In this contribution, we compare Kerner's three-phase traffic theory with the phase diagram approach for traffic models with a fundamental diagram. We discuss the inconsistent use of the term "traffic phase" and show that patterns demanded by three-phase traffic theory can be reproduced with simple two-phase models, if the model parameters are suitably specified and factors characteristic for real traffic flows are considered, such as effects of noise or heterogeneity or the actual freeway design (e.g. combinations of off- and on-ramps). Conversely, we demonstrate that models created to reproduce three-phase traffic theory create similar spatiotemporal traffic states and associated phase diagrams, no matter whether the parameters imply a fundamental diagram in equilibrium or non-unique flow-density relationships. In conclusion, there are different ways of reproducing the empirical stylized facts of spatiotemporal congestion patterns summarized in this contribution, and it appears possible to overcome the controversy by a more precise definition of the scientific terms and a more careful comparison of models and data, considering effects of the measurement process and the right level of detail in the traffic model used.

A kinematic wave theory of lane-changing traffic flow

- Transportation Research Part B: Methodological---2010---Wen-Long Jin

Frequent lane-changes in highway merging, diverging, and weaving areas could disrupt traffic flow and, even worse, lead to accidents. In this paper, we propose a simple model for studying bottleneck effects of lane-changing traffic and aggregate traffic dynamics of a roadway with lane-changing areas. Based on the observation that, when changing its lane, a vehicle affects traffic on both its current and target lanes, we propose to capture such lateral interactions by introducing a new lane-changing intensity variable. With a modified fundamental diagram, we are able to study the impacts of lane-changing traffic on overall traffic flow. In addition, the corresponding traffic dynamics can be described with a simple kinematic wave model. For a location-dependent lane-changing intensity variable, we discuss kinematic wave solutions of the Riemann problem of the new model and introduce a supply-demand method for its numerical solutions. With both theoretical and empirical analysis, we demonstrate that lane-changes could have significant bottleneck effects on overall traffic flow. In the future, we will be interested in studying lane-changing intensities for different road geometries, locations, on-ramp/off-ramp flows, as well as traffic conditions. The new modeling framework could be helpful for developing ramp-metering and other lane management strategies to mitigate the bottleneck effects of lane-changes.

Traffic assignment by paired alternative segments

- Transportation Research Part B: Methodological---2010---Hillel Bar-Gera

The static user-equilibrium (UE) traffic assignment model is widely used in practice. One main computational challenge in this model is to obtain sufficiently precise solutions suitable for scenario comparisons, as quickly as possible. An additional computational challenge stems from the need in practice to perform analyses based on route flows, which are not uniquely determined by the UE condition. Past research focused mainly on the first aspect. The purpose of this paper is to describe an algorithm that addresses both issues. The traffic assignment by paired alternative segments (TAPAS) algorithm, focuses on pairs of alternative segments as the key building block to the UE solution. A condition of proportionality, which is practically equivalent to entropy maximization, is used to choose one stable route flow solution. Numerical results for five publicly available networks, including two large-scale realistic networks, show that the algorithm can identify highly precise solutions that maintain proportionality in relatively short computation times.

Single-assignment hub location problems with multiple capacity levels

- Transportation Research Part B: Methodological---2010---Isabel Correia,Stefan Nickel,Francisco Saldanha-da-Gama

In this paper, an extension of the classical capacitated single-allocation hub location problem is studied in which the size of the hubs is part of the decision making process. For each potential hub a set of capacities is assumed to be available among which one can be chosen. Several formulations are proposed for the problem, which are compared in terms of the bound provided by the linear programming relaxation. Different sets of inequalities are proposed to enhance the models. Several preprocessing tests are also presented with the goal of reducing the size of the models for each particular instance. The results of the computational experiments performed using the proposed models are reported.

Equilibria of bilateral taxi-customer searching and meeting on networks

- Transportation Research Part B: Methodological---2010---Hai Yang,Cowina W.Y. Leung,S.C. Wong,Michael G.H. Bell

This paper proposes an equilibrium model to characterize the bilateral searching and meeting between customers and taxis on road networks. A taxi driver searches or waits for a customer by considering both the expected searching or waiting time cost and ride revenue, and a customer seeks a taxi ride to minimize full trip price. We suppose that the bilateral taxi-customer searching and meeting occurs anywhere in residential and commercial zones or at prescribed taxi stands, such as an airport or a railway station. We propose a meeting function to spell out the search and meeting frictions that arise endogenously as a result of the distinct spatial feature of the area and the taxi-customer moving decisions. With the proposed meeting function and the assumptions underlying taxi-customer search behaviors, the stationary competitive equilibrium achieved at fixed fare prices is determined when the demand of the customers matches the supply of taxis or there is market clearing at the prevailing searching and waiting times in every meeting location. We establish the existence of such an equilibrium by virtue of Brouwer's fixed-point theorem and demonstrate its principal operational characteristics with a numerical example.

Continuous kinematic wave models of merging traffic flow

- Transportation Research Part B: Methodological---2010---Wen-Long Jin

Merging junctions are important network bottlenecks, and a better understanding of merging traffic dynamics has both theoretical and practical implications. In this paper, we present continuous kinematic wave models of merging traffic flow which are consistent with discrete Cell Transmission Models with various distribution schemes. In particular, we develop a systematic approach to constructing kinematic wave solutions to the Riemann problem of merging traffic flow in supply-demand space. In the new framework, Riemann solutions on a link consist of an interior state and a stationary state, subject to admissible conditions such that there are no positive and negative kinematic waves on the upstream and downstream links, respectively. In addition, various distribution schemes in Cell Transmission Models are considered entropy conditions. In the proposed analytical framework, we prove that the stationary states and boundary fluxes exist and are unique for the Riemann problem for both fair and constant distribution schemes. We also discuss two types of invariant merge models, in which local and discrete boundary fluxes are the same as global and continuous ones. With numerical examples, we demonstrate the validity of the analytical solutions of interior states, stationary states, and corresponding kinematic waves. Discussions and future studies are presented in the conclusion section.

Optimal fueling strategies for locomotive fleets in railroad networks

- Transportation Research Part B: Methodological---2010---Seyed Mohammad Nourbakhsh,Yanfeng Ouyang

Railroad companies spend billions of dollars each year to purchase fuel for thousands of locomotives across the railroad network. Each fuel station charges a site-dependent fuel price, and the railroad companies must pay an additional flat contracting fee in order to use it. This paper presents a linear mixed-integer mathematical model that integrates not only fuel station location decisions but also locomotive fueling schedule decisions. The proposed model helps railroads decide which fuel stations to contract, and how each locomotive should purchase fuel along its predetermined shipment path, such that no locomotive runs out of fuel while the summation of fuel purchasing costs, shipment delay costs (due to fueling), and contracting charges is minimized. A Lagrangian relaxation framework is proposed to decompose the problem into fueling schedule and facility location selection sub-problems. A network shortest path formulation of the fueling schedule sub-problem is developed to obtain an exact optimal solution to the fueling schedule sub-problem. The proposed framework is applied to a large-scale empirical case and is shown to effectively reduce system costs.

An adaptive time gap car-following model

- Transportation Research Part B: Methodological---2010---Antoine Tordeux,Sylvain Lassarre,Michel Roussignol

We intend to define a continuous car-following model exclusively based on the time gap. A model of the interaction between a vehicle and its predecessor is produced by adjusting the time gap to a targeted safety time that is a function of speed. The model is defined by a differential system, to which a consistent numerical scheme is associated. The parameters of the model are statistically estimated by maximum likelihood. In order to reproduce a heterogeneous traffic flow, vehicles are differentiated by type, and to recreate asymmetric longitudinal behavior, acceleration phases are distinguished from deceleration phases. Introducing a reaction time, inducing a delay in the perception and processing of information about vehicles in interaction, can alter the stability of the flux through appearance of kinematic waves. By simulation, the types and domains of parameters which are asymptotically unstable are identified. The results reveal that, in the model, the statistically estimated parameters form is strongly factor of instability.

Access control policies without inside queues: Their properties and public policy implications

- Transportation Research Part B: Methodological---2010---H.M. Zhang,Wei Shen

An access control policy that eliminates all queues beyond the entry points to a network has obvious benefits, which include smooth travel and predictable travel times inside the network. Yet it has never been proven, to the best of our knowledge, whether excluding inside queues yields sub-optimal network performance or, in other words, allowing inside queues can actually further reduce the system travel cost. Moreover, it is not clear whether an optimal control policy derived from efficiency considerations can also be a fair policy to all road users. This paper provide answers to these questions in the context of a monocentric network. By analyzing the structure of the access control problem considering all feasible policies (with/without inside queues), we show that the minimal system cost realizable by access control can be obtained without directly solving a non-convex optimization program, and can indeed always be achieved by a control policy excluding all of the inside queues. These optimal policies are defined by a polyhedral set and a Finite Generation Algorithm can be applied to derive the analytical form of this set. The optimal policies are not unique in general, thus making it possible to achieve both minimal system cost and fairness simultaneously.

Introduction to special issue of Transportation Research Part B Modelling non-urban transport investment and pricing

- Transportation Research Part B: Methodological---2010---Nicole Adler,Stef Proost

This special issue of Transportation Research Part B is concerned with the state of the art modelling approaches applied to transport infrastructure issues. Six papers have been included, utilizing either partial or general equilibrium models in order to develop economic assessments of large, inter-urban transport modes. The papers as a group highlight the importance of accounting for the market environment and competition among infrastructure providers, assessing economic and regional equity issues in a wider context, acknowledging the risks of misrepresentation of project benefits and reducing network dimensionality in order to assist the development of second opinions in cost-benefit analyses.

Assessing spatial equity and efficiency impacts of transport infrastructure projects

- Transportation Research Part B: Methodological---2010---Johannes Bröcker,Artem Korzhenevych,Carsten Schürmann

Policy decisions on transport infrastructure investments often require knowledge of welfare effects generated from using these infrastructures on a detailed regional level. This is in particular true for the EU initiative promoting the development of the trans-European transport (TEN-T) networks. As projects within this initiative affect regions in different countries, incentive compatible financing schemes cannot be designed without knowing where the benefits accrue. Furthermore, this initiative is also intended to contribute to the cohesion objective on a community scale, and only with regional impact studies one can assess to which extent these objectives are attained. As standard cost-benefit analysis is unable to assign benefits to eventual beneficiaries in the economy, we develop and apply a spatial computable general equilibrium (SCGE) model as a suitable alternative. The model has a household sector and a production sector with two industries, one producing local goods, the other producing tradables. Regions interact through costly trade, with trade costs depending, among others, on the state of the infrastructure. New links reduce trade costs, which changes trade flows, production, goods prices and factor prices and thus eventually the welfare of households in different regions. We present the formal structure of the model, the calibration procedure and the data sources for calibrating the model and estimating the trade cost reductions stemming from new transport links. As the model is only able to quantify effects related to trade in goods we also suggest a simplified approach to add effects stemming from passenger transport. We apply the methods to a policy experiment related to the TEN-T priority list of projects. We quantify project by project the social return, check whether significant benefit spillovers to countries not involved in financing might prevent realization of projects in spite of their respective profitability from European wide point of view, and finally we evaluate the contribution of each project to the spatial cohesion objective. Our results confirm sceptical views on EU involvement in infrastructure policy that have been expressed in the literature.

High-speed rail and air transport competition: Game engineering as tool for cost-benefit analysis

- Transportation Research Part B: Methodological---2010---Nicole Adler,Eric Pels,Chris Nash

This research develops a methodology to assess infrastructure investments and their effects on transport equilibria taking into account competition between multiple privatized transport operator types. The operators, including high-speed rail, hub-and-spoke legacy airlines and regional low-cost carriers, maximize best response functions via prices, frequency and train/plane sizes, given infrastructure provision, cost functions and environmental charges. The methodology is subsequently applied to all 27 European Union countries, specifically analyzing four of the prioritized Trans-European networks. The general conclusions suggest that the European Union, if interested in maximizing overall social welfare, should encourage the development of the high-speed rail network across Europe.

Assessing transport investments - Towards a multi-purpose tool

- Transportation Research Part B: Methodological---2010---André de Palma,Stef Proost,Saskia van der Loo

This paper presents a multi-purpose tool to assess transport investments in congestible facilities. The model can handle any combination of passenger and freight transport modes in a simplified network. Within each mode, there can be competing operators. It is calibrated to a given traffic forecast and can be used to assess the benefits and costs of combinations of strategic pricing behavior and investment. The use of the model is illustrated with examples.

Cost-benefit analysis of transport investments in distorted economies

- Transportation Research Part B: Methodological---2010---Edward Calthrop,Bruno De Borger,Stef Proost

This paper deals with cost-benefit analysis of investment in transport infrastructure. Its contribution is twofold. Firstly, we develop a general equilibrium model to explore the impact of a small budgetary-neutral investment in transport infrastructure in a second-best setting, where other markets in the economy are distorted by taxes or external costs. The model incorporates different transport modes that are used both for intermediate inputs (freight) and for final consumption (passenger travel). An intuitive operational expression for the net economic benefit of an investment is derived that depends on the way the investment is financed. This expression generalizes recent findings in the literature. Secondly, we illustrate the results numerically using a small example. Our findings show that both the specific financing instrument used and the labour market consequences may have large implications for the net benefits of transport investments. Significant errors may be made in limiting cost-benefit analysis to transport markets only.

Pricing, capacity and long-run cost functions for first-best and second-best network problems

- Transportation Research Part B: Methodological----2010---Erik Verhoef,Andrew Koh,Simon Shepherd

This paper considers the use of 'long-run cost functions' for congested networks in solving second-best network problems, in which capacity and tolls are instruments. We derive analytical results both for general cost and demand functions and for specific functional forms, namely Bureau of Public Roads cost functions and constant-elasticity demand functions. The latter are also used in a numerical simulation model. We consider second-best cases where only a sub-set of links in a network is subject to tolling and/or capacity choice, and cases with and without a self-financing constraint imposed. We will demonstrate that, under certain assumptions, second-best long-run cost (or actually: generalized price) functions can be derived for most of the cases of interest, which can be used in an applied network model as a substitute for the conventional short-run user cost functions. Doing so reduces the dimensionality of the problem and should therefore be helpful in speeding up procedures for finding second-best optima.

Optimal route allocation in a liberalizing airline market

- Transportation Research Part B: Methodological---2010---Zhi-Chun Li,William H.K. Lam,S.C. Wong,Xiaowen Fu

Airlines often encounter two major problems in expanding their international networks: (1) restrictive Air Services Agreements (ASAs) governing airlines' commercial rights, and (2) slot / capacity constraints in foreign hub airports. Government interventions are needed to solve these problems, yet few quantitative models are available to guide the design of related public policies. This paper proposes a new model for optimizing the allocation of additional routes in a liberalizing airline market, in which airport capacity constraints are explicitly considered. The proposed model captures the interactions among three types of agents: (1) a regulator who aims to maximize social welfare by optimizing the allocation of additional routes to competing carriers; (2) airlines competing with flight frequency and airfare; and (3) passengers who minimize their own travel disutility (or equivalently maximize utility) given airlines' services and prices. In the proposed model, the passenger demand elasticity is also explicitly considered. The route allocation model is formulated as a 0-1 integer programming problem, and is solved by a heuristic implicit enumeration approach. The Korean - mainland China - Hong Kong airline market serves as model illustration. The effects of airport slot constraints are examined, and the revealed value (marginal welfare gain) of airport capacity expansion is also calculated, which can potentially serve as a benchmark indicator for the planning of airport investments.

Methodological advancements in constructing designs and understanding respondent behaviour related to stated preference experiments

- Transportation Research Part B: Methodological---2010---J. de D. Ortúzar,John Rose

2010

Construction of experimental designs for mixed logit models allowing for correlation across choice observations

- Transportation Research Part B: Methodological---2010---Michiel Bliemer,John Rose

In each stated choice (SC) survey, there is an underlying experimental design from which the hypothetical choice situations are determined. These designs are constructed by the analyst, with several different ways of constructing these designs having been proposed in the past. Recently, there has been a move from so-called orthogonal designs to more efficient designs. Efficient designs optimize the design such that the data will lead to more reliable parameter estimates for the model under consideration. The main focus has been on the multinomial logit model, however this model is unable to take the dependency between choice situations into account, while in a stated choice survey usually multiple choice situations are presented to a single respondent. In this paper, we extend the literature by focusing on the panel mixed logit (ML) model with random parameters, which can take the above mentioned dependency into account. In deriving the analytical asymptotic variance-covariance matrix for the panel ML model, used to determine the efficiency of a design, we show that it is far more complex than the cross-sectional ML model (assuming independent choice observations). Case studies illustrate that it matters for which model the design is optimized, and that it seems that a panel ML model SC experiment needs less respondents than a cross-sectional ML experiment for the same level of reliability of the parameter estimates.

Hypothetical bias, choice experiments and willingness to pay

- Transportation Research Part B: Methodological---2010---David Hensher

There is growing interest in establishing the extent of differences in willingness to pay (WTP) for attributes, such as travel time savings, that are derived from real market settings and hypothetical (to varying degrees) settings. Non-experiment external validity tests involving observation of choice activity in a natural environment, where the individuals do not know they are in an experiment, are rare. In contrast the majority of tests are a test of external validity between hypothetical and actual experiments. Deviation from real market evidence is referred to in the literature broadly as hypothetical bias. The challenge is to identify such bias, and to the extent to which it exists, establishing possible ways to minimise it. This paper reviews the efforts to date to identify and 'calibrate' WTP derived from one or more methods that involve assessment of hypothetical settings, be they (i) contingent valuation methods, (ii) choice experiments involving trading attributes between multiple alternatives, with or without referencing, or (iii) methods involving salient or non-salient incentives linked to actual behaviour. Despite progress in identifying possible contributions to differences in marginal WTP, there is no solid evidence, although plenty of speculation, to explain the differences between all manner of hypothetical experiments and non-experimental evidence. The absence of non-experimental evidence from natural field experiments remains a major barrier to confirmation of under or over-estimation. We find, however, that the role of referencing of an experiment relative to a real experience (including evidence from revealed preference (RP) studies), in the design of choice experiments, appears to offer promise in the derivation of estimates of WTP that have a meaningful link to real market activity, closing the gap between RP and SC WTP outputs.

Thresholds and indifference in stated choice surveys

- Transportation Research Part B: Methodological---2010---Víctor Cantillo,Johanna Amaya,J. de D. Ortúzar

One typical aim of choice experiment designs is utility balance, that is, the alternatives defined within each choice set should have similar choice probabilities; otherwise, choice is too easy and little information about preferences may be obtained. Therefore, in a good design respondents may often find themselves close to indifference and thus perception thresholds may be an issue. We propose a discrete choice model to examine the behaviour of individuals with indifference thresholds, i.e. that would make them perceive two or more alternatives as almost identical in stated choice (SC) experiments. Such thresholds may be stochastic, differ among the population and even be a function of socio-economic characteristics and choice conditions. Two estimate this model we need SC data including an "indifference option", so that respondents are not forced to choose when finding that the two alternatives are equally attractive. Our formulation allows estimating the parameters of a threshold probability distribution using information about choices. As an illustration, the model is applied both to synthetic and real data; results clearly show that when indifference thresholds exist, using models without them can lead to errors in estimation and prediction.

Modeling simplifying information processing strategies in conjoint experiments

- Transportation Research Part B: Methodological--2010---Wei Zhu,Harry Timmermans

Conjoint experiments are usually based on the assumption that respondents consider all attributes varied in the experiment when providing preference evaluations or choosing between choice alternatives. Recently, some research has examined the validity of this assumption by empirically analyzing the impact of the number of attributes on estimated utilities. It suggests that respondents not only build up a mental representation of the decision problem in reality, but also when they provide value judgments in a conjoint experiment. It implies that explicit modeling of this process of mental representation and information processing may improve the validity of conjoint estimates. This paper puts forward such a modeling approach, based on principles of bounded rationality. The approach uses attribute thresholds to construct individuals' preference structures from which heterogeneous decision heuristics can be exactly inferred. Decisions are modeled as a two-layer process with an individual selecting a heuristic first and then applying the chosen heuristic for decision making. The whole process is modeled with a latent class structure and the choice of heuristic is assumed to be influenced by mental effort, risk perception, and expected outcome. An application of the approach is carried out using data about people's choice of a new transit system. The results show the ability of the proposed approach to estimate different decision heuristics and information search patterns in different stages of the decision.

Using conditioning on observed choices to retrieve individual-specific attribute processing strategies

- Transportation Research Part B: Methodological--2010---Stephane Hess,David Hensher

With the growing reliance on Stated Choice (SC) data, researchers are increasingly interested in understanding how respondents process the information presented to them in such surveys. Specifically, it has been argued that some respondents may simplify the choice tasks by consistently ignoring one or more of the attributes describing the alternatives, and direct questions put to respondents after the completion of SC surveys support this hypothesis. However, in the general context of issues with response quality in SC data, there are certainly grounds for questioning the reliability of stated attribute processing strategies. In this paper, we take a different approach by attempting to infer attribute processing strategies through the analysis of respondent-specific coefficient distributions obtained through conditioning on observed choices. Our results suggest that a share of respondents do indeed ignore a subset of explanatory variables. However, there is also some evidence that the inferred attribute processing strategies are not necessarily consistent with the stated attribute processing strategies. Additionally, there is some evidence that respondents who claim to have ignored a certain attribute may simply have assigned it lesser importance. The results produced by the inferring approach not only lead to slightly better fit but also more consistent results.

Preface to special issue

- Transportation Research Part B: Methodological--2010---Paul Damien,Kara Kockelman

2010

A spatial dynamic panel model with random effects applied to commuting times

- Transportation Research Part B: Methodological--2010---Olivier Parent,James LeSage

A space-time filter is set forth for spatial panel data situations that include random effects. We propose a general spatial dynamic specification that encompasses several spatiotemporal models previously used in the panel data literature. We apply the model to the case of highway induced travel demand. The theory of induced travel demand asserts that increased highway capacity will induce growth in traffic for a number of reasons. Our model allows us to quantify the spatial spillover impacts of increased highway capacity at one location in the network on travel times in neighboring locations and in future time periods.

The continuous cross-nested logit model: Formulation and application for departure time choice

- Transportation Research Part B: Methodological---2010---Jason D. Lemp,Kara M. Kockelman,Paul Damien

Discrete choice models, like the multinomial logit (MNL), have long been recognized for their ability to capture a wide array of transport-related choice phenomena. However, a number of choices are continuous response variables (e.g., location, departure time, activity duration, and vehicle usage). This paper introduces the continuous cross-nested logit (CCNL) model. The CCNL model results from generalizing the discrete cross-nested logit (CNL) model for a continuous response variable, much like the continuous logit model emerges by generalizing the MNL. The model is formulated and shown to come from the generalized extreme value (GEV) class of models. In addition, the structure of utility correlations is presented. The model's parameters are estimated for a work-tour departure time context using Bayesian estimation techniques and San Francisco Bay Area data. Empirical results suggest model predictions that are very similar to the continuous logit, but it out-performs the continuous logit in terms of out-of-sample prediction with these data. The CCNL also allows a more flexible choice behavior to emerge. Finally, a simple welfare example is illustrated and a number of model extensions are presented.

Bayesian mixture modeling approach to account for heterogeneity in speed data

- Transportation Research Part B: Methodological---2010---Byung-Jung Park,Yunlong Zhang,Dominique Lord

Speed is one of the most important parameters describing the condition of the traffic flow. Many analytical models related to traffic flow either produce speed as a performance measure, or use speed to determine other measures such as travel time, delay, and the level of service. Mathematical models or distributions used to describe speed characteristics are very useful, especially when they are utilized in the context of simulation and theoretical derivations. Traditionally, normal, log-normal and composite distributions have been the usual mathematical distributions to characterize speed data. These traditional distributions, however, often fail to produce an adequate goodness-of-fit when the empirical distribution of speed data exhibits bimodality (or multimodality), skewness, or excess kurtosis (peakness). This often occurs when the speed data are generated from several different sub-populations, for example, mixed traffic flow conditions or mixed vehicle compositions. The traditional modeling approach also lacks the ability to explain the underlying factors that lead to different speed distribution curves. The objective of this paper is to explore the applicability of the finite mixture of normal (Gaussian) distributions to capture the heterogeneity in vehicle speed data, and thereby explaining the aforementioned special characteristics. For the parameter estimation, Bayesian estimation method via Markov Chain Monte Carlo (MCMC) sampling is adopted. The field data collected on IH-35 in Texas is used to evaluate the proposed models. The results of this study show that the finite mixture of normal distributions can very effectively describe the heterogeneous speed data, and provide richer information usually not available from the traditional models. The finite mixture modeling produces an excellent fit to the multimodal speed distribution curve. Moreover, the causes of different speed distributions can be identified through investigating the components.

Bayesian inference for network-based models with a linear inverse structure

- Transportation Research Part B: Methodological--2010---Martin L. Hazelton

Network-based transport models are used for a host of purposes, from estimation of travel demand through to traffic assignment and traffic flow prediction. Before any such model can be applied in practice we must estimate its parameters and also examine its adequacy. A variety of methods have been developed to do this, but they are typically quite specific to the particular model at hand. In this paper we show that it is possible to develop a unified approach by recognizing that a statistical linear inverse structure arises when attempting to perform inference for any network-based model. This common structure provides the building blocks for the development a coherent theory for Bayesian inference for these models, which has a number of advantages of over more ad hoc methods. While calculation of the Bayesian posterior will typically be intractable, our unified framework allows us to design a generic Markov chain Monte Carlo algorithm for sampling from this distribution in practice. We illustrate the operation of this algorithm on a section of the road network in the English city of Leicester.

Bayesian flexible modeling of trip durations

- Transportation Research Part B: Methodological--2010---Hugh Chipman,Edward George,Jason Lemp,Robert McCulloch

Recent advances in Bayesian modeling have led to stunning improvements in our ability to flexibly and easily model complex high-dimensional data. Flexibility comes from the use of a very large number of parameters without fixed dimension. Priors are placed on the parameters to avoid over-fitting and sensibly guide the search in model space for appropriate data-driven model choice. Modern computational, high dimensional search methods (in particular Markov Chain Monte Carlo) then allow us to search the parameter space. This paper introduces the application of BART, Bayesian Additive Regression Trees, to modelling trip durations. We have survey data on characteristics of trips in the Austin area. We seek to relate the trip duration to features of the household and trip characteristics. BART enables one to make inferences about the relationship with minimal assumptions and user decisions.

A Bayesian semi-parametric model to estimate relationships between crash counts and roadway characteristics

- Transportation Research Part B: Methodological--2010---Thomas S. Shively,Kara Kockelman,Paul Damien

This paper uses a semi-parametric Poisson-gamma model to estimate the relationships between crash counts and various roadway characteristics, including curvature, traffic levels, speed limit and surface width. A Bayesian nonparametric estimation procedure is employed for the model's link function, substantially reducing the risk of a mis-specified model. It is shown via simulation that little is lost in terms of estimation quality if the nonparametric estimation procedure is used when standard parametric assumptions (e.g., linear functional forms) are satisfied, but there is significant gain if the parametric assumptions are violated. It is also shown that imposing appropriate monotonicity constraints on the relationships provides better function estimates. Results suggest that key factors for explaining crash rate variability across roadways are the amount and density of traffic, presence and degree of a horizontal curve, and road classification. Issues related to count forecasting on individual roadway segments and out-of-sample validation measures also are discussed.

Properties of Pareto-efficient contracts and regulations for road franchising

- Transportation Research Part B: Methodological--2010---Zhijia Tan,Hai Yang,Xiaolei Guo

Private provision of public roads through build-operate-transfer (BOT) contracts is increasing around the world. This paper investigates the properties of Pareto-efficient BOT contracts using a bi-objective programming approach under perfect information. Under certain conventional assumptions, we find that for any Pareto-efficient BOT contract: (1) the concession period should be set to be the whole road life; (2) the volume-capacity ratio (or the road service quality) and the average social cost per trip are constantly equal to those at the social optimum whenever there are constant returns to scale in road construction. Extensions are made to the cases with increasing (decreasing) returns to scale in road construction. A variety of regulatory regimes are investigated to analyze the behavior of the profit-maximizing private firm, and efficient regulations, including demand and markup charge regulations, are elucidated for both the public and private sectors to achieve a predetermined Pareto-optimal outcome.

Structure of competitive transit networks

- Transportation Research Part B: Methodological---2010---Carlos F. Daganzo

This paper describes the network shapes and operating characteristics that allow a transit system to deliver an accessibility level competitive with that of the automobile. To provide exhaustive results for service regions of different sizes and demographics, the paper idealizes these regions as squares with uniform demand, and their possible networks as a broad and realistic family that combines the grid and the hub-and-spoke concepts. The paper also shows how to use these results to generate master plans of transit systems for real cities. The analysis reveals which network structure and technology (Bus, Bus Rapid Transit, or Metro) delivers the desired performance with the least cost. It is found that the more expensive the system's infrastructure, the more it should tilt toward the hub-and-spoke concept. Bus Rapid Transit (BRT) competes effectively with the automobile unless a city is big and its demand low. This happens despite the uniform demand assumption, which penalizes collective transport. It is also found that if a city has enough suitable streets on which to run Bus and BRT systems, these outperform Metro even if the city is large and the demand high. Agency costs are always small compared with user costs; and both decline with the demand density. In all cases, increasing the spatial concentration of stops beyond a critical level increases both, the user and agency costs. Too much spatial coverage is counterproductive.

A game theoretic framework for the robust railway transit network design problem

- Transportation Research Part B: Methodological---2010---Gilbert Laporte,Juan A. Mesa,Federico Perea

This paper proposes a game theoretic framework for the problem of designing an uncapacitated railway transit network in the presence of link failures and a competing mode. It is assumed that when a link fails, another path or another transportation mode is provided to transport passengers between the endpoints of the affected link. The goal is to build a network that optimizes a certain utility function when failures occur. The problem is posed as a non-cooperative two-player zero-sum game with perfect information. The saddle points of the corresponding mixed enlarged game yield robust network designs.

Incorporation of Lagrangian measurements in freeway traffic state estimation

- Transportation Research Part B: Methodological---2010---Juan C. Herrera,Alexandre M. Bayen

Cell-phones equipped with a global positioning system (GPS) provide new opportunities for location-based services and traffic estimation. When traveling onboard vehicles, these phones can be used to accurately provide position and velocity of the vehicle as probe traffic sensors. This article presents a new technique to incorporate mobile probe measurements into highway traffic flow models, and compares it to a Kalman filtering approach. These two techniques are both used to reconstruct traffic density. The first technique modifies the Lighthill-Whitham-Richards partial differential equation (PDE) to incorporate a correction term which reduces the discrepancy between the measurements (from the probe vehicles) and the estimated state (from the model). This technique, called Newtonian relaxation, "nudges" the model to the measurements. The second technique is based on Kalman filtering and the framework of hybrid systems, which implements an observer equation into a linearized flow model. Both techniques assume the knowledge of the fundamental diagram and the conditions at both boundaries of the section of interest. The techniques are designed in a way in which does not require the knowledge of on- and off-ramp detector counts, which in practice are rarely available. The differences between both techniques are assessed in the context of the Next Generation Simulation program (NGSIM), which is used as a benchmark data set to compare both methods. They are finally tested with data from the Mobile Century experiment obtained from 100 Nokia N95 mobile phones on I-880 in California on February 8, 2008. The results are promising, showing that the proposed methods successfully incorporate the GPS data in the estimation of traffic.

Global optimum of the linearized network design problem with equilibrium flows

- Transportation Research Part B: Methodological---2010---David Z.W. Wang,Hong K. Lo

The road network design problem, typically formulated as a bi-level program or a mathematical program with equilibrium constraints, is generally non-convex. The non-convexity stems from both the traffic assignment equilibrium conditions and the non-linear travel time function. In this study, we formulate the network design problem as a single-level optimization problem with equilibrium constraints, and then we transform the equilibrium constraints into a set of mixed-integer constraints and linearize the travel time function. The final result is that we cast the network design problem with equilibrium flows into a mixed-integer linear program, whose solution possesses the desirable property of global optimality, subject to the resolution of the linearization scheme adopted.

The [alpha]-reliable mean-excess traffic equilibrium model with stochastic travel times

- Transportation Research Part B: Methodological---2010---Anthony Chen,Zhong Zhou

In this paper, we propose a new model called the [alpha]-reliable mean-excess traffic equilibrium (METE) model that explicitly considers both reliability and unreliability aspects of travel time variability in the route choice decision process. In contrast to the travel time budget (TTB) models that consider only the reliability aspect defined by TTB, this new model hypothesizes that travelers are willing to minimize their mean-excess travel times (METT) defined as the conditional expectation of travel times beyond the TTB. As a route choice criterion, METT can be regarded as a combination of the buffer time measure that ensures the reliability aspect of on-time arrival at a confidence level [alpha], and the tardy time measure that represents the unreliability aspect of encountering worst travel times beyond the acceptable travel time allowed by TTB in the distribution tail of 1Â -Â [alpha]. It addresses both questions of "how much time do I need to allow?" and "how bad should I expect from the worse cases?" Therefore, travelers' route choice behavior can be considered in a more accurate and complete manner in a network equilibrium framework to reflect their risk preferences under an uncertain environment. The METE model is formulated as a variational inequality problem and solved by a route-based traffic assignment algorithm via the self-adaptive alternating direction method. Some qualitative properties of the model are rigorously proved. Illustrative examples are also presented to demonstrate the characteristics of the model as well as its differences compared to the recently proposed travel time budget models.

Managing evacuation routes

- Transportation Research Part B: Methodological---2010---Stella K. So,Carlos F. Daganzo

This paper shows that evacuation routes, such as a building's stairwell or an urban freeway, may discharge inefficiently if left unmanaged, and that setting priority rules can speed up egress. Therefore, a simple control strategy is proposed. The strategy is decentralized and adaptive, based on readily available real-time data. The strategy is shown to be optimal in two senses: (i) it evacuates the maximum number of people at all times, and (ii) it finishes the evacuation in the least possible time. In both cases, it favors the people most at risk. The results shed light on other traffic problems.

Pre-positioning of emergency supplies for disaster response

- Transportation Research Part B: Methodological---2010---Carmen G. Rawls,Mark A. Turnquist

Pre-positioning of emergency supplies is one mechanism of increasing preparedness for natural disasters. The goal of this research is to develop an emergency response planning tool that determines the location and quantities of various types of emergency supplies to be pre-positioned, under uncertainty about if, or where, a natural disaster will occur. The paper presents a two-stage stochastic mixed integer program (SMIP) that provides an emergency response pre-positioning strategy for hurricanes or other disaster threats. The SMIP is a robust model that considers uncertainty in demand for the stocked supplies as well as uncertainty regarding transportation network availability after an event. Due to the computational complexity of the problem, a heuristic algorithm referred to as the Lagrangian L-shaped method (LLSM) is developed to solve large-scale instances of the problem. A case study focused on hurricane threat in the Gulf Coast area of the US illustrates application of the model.

A continuum approximation approach to reliable facility location design under correlated probabilistic disruptions

- Transportation Research Part B: Methodological---2010---Xiaopeng Li,Yanfeng Ouyang

This paper studies the reliable uncapacitated fixed charge location problem (RUFL) where facilities are subject to spatially correlated disruptions that occur with location-dependent probabilities (due to reasons such as natural or man-made disasters). If a facility fails, its customers are diverted to other facilities and incur excessive transportation cost. We develop a continuum approximation (CA) model to minimize the sum of initial facility construction costs and expected customer transportation costs under normal and failure scenarios. The paper presents ways to formulate the correlation among adjacent facility disruptions, and incorporates such correlations into the CA model. Numerical experiments are conducted to illustrate how the proposed model can be used to optimize facility location design, and how the correlations influence the total system cost.

A matching model for the backhaul problem

- Transportation Research Part B: Methodological---2010---Erhan Demirel,Jos van Ommeren,Piet Rietveld

The 'backhaul problem' is characterized by an imbalance in transport flows between locations. In a perfectly competitive framework with perfect information, the price of transport from low demand locations to high demand locations, the so-called backhaul price, drops to zero when the imbalance is sufficiently large. However, this result is inconsistent with empirical observations for many competitive transport markets (e.g. taxi and inland navigation markets). In this paper, we develop a matching model to show that a deviation from perfect information may address this inconsistency. We argue that carriers' search time to locate customers plays an important role in the determination of prices. We demonstrate that carriers are compensated for a part of the transport cost and for the time they search for customers. This implies positive backhaul prices. The matching model is numerically applied to the inland navigation shipping market in the Rhine river area in Western-Europe. We find that backhaul prices are substantial.

A multiple discrete-continuous nested extreme value (MDCNEV) model: Formulation and application to non-worker activity time-use and timing behavior on weekdays

- Transportation Research Part B: Methodological---2010---Abdul Rawoof Pinjari,Chandra Bhat

This paper develops a multiple discrete-continuous nested extreme value (MDCNEV) model that relaxes the independently distributed (or uncorrelated) error terms assumption of the multiple discrete-continuous extreme value (MDCEV) model proposed by Bhat [Bhat, C.R., 2005. A multiple discrete-continuous extreme value model: formulation and application to discretionary time-use decisions. Transportation Research Part B 39 (8), 679-707; Bhat, C.R., 2008. The multiple discrete-continuous extreme value (MDCEV) model: role of utility function parameters, identification considerations, and model extensions. Transportation Research Part B 42 (3), 274-303]. The MDCNEV model captures inter-alternative correlations among alternatives in mutually exclusive subsets (or nests) of the choice set, while maintaining the closed-form of probability expressions for any (and all) consumption pattern(s). The MDCNEV model is applied to analyze non-worker out-of-home discretionary activity time-use and activity timing decisions on weekdays using data from the 2000 San Francisco Bay Area data. This empirical application contributes to the literature on activity time-use and activity timing analysis by considering daily activity time-use behavior and activity timing preferences in a unified utility maximization-based framework. The model estimation results provide several insights into the determinants of non-workers' activity time-use and timing decisions. The MDCNEV model performs better than the MDCEV model in terms of goodness of fit. However, the nesting parameters are very close to 1, indicating low levels of correlation. Nonetheless, even with such low correlation levels, empirical policy simulations indicate non-negligible differences in policy predictions and substitution patterns exhibited by the two models. Experiments conducted using simulated data also corroborate this result.

An integrated behavioral model of the land-use and transport systems with network congestion and location externalities

- Transportation Research Part B: Methodological---2010---Mario Bravo,Luis Briceño,Roberto Cominetti,Cristián E. Cortés,Francisco Martínez

The agents' decisions, from their residential location to their members' trip choices through the network, are jointly analyzed as an integrated long term equilibrium in which the location, travel decisions, and route choices are represented by logit or entropy models. In this approach, consumers optimize their combined residence and transport options represented as paths in an extended network built by connecting the transport sub-network to a fictitious sub-network that represents land-use and transport demand options. We model a static land-use and transport equilibrium by considering road congestion and location externalities. The latter include trip destination choices based on land-use attractions, as well as endogenous neighborhood characteristics that determine residential choices and segregation phenomena. The model can deal with heterogeneous populations and locations as well as multiple trip purposes, though it assumes only private transport modes. In a previous paper we studied the case with road congestion externalities only, characterizing equilibria by a strictly convex and coercive unconstrained minimization problem. This characterization fails for more general externalities, so we restate the model as a fixed-point problem, establishing the existence of equilibria, providing sufficient conditions for its uniqueness and for the convergence of a fixed-point iteration. A small numerical example is used to illustrate the model.

A link-based day-to-day traffic assignment model

- Transportation Research Part B: Methodological---2010---Xiaozheng He,Xiaolei Guo,Henry X. Liu

Existing day-to-day traffic assignment models are all built upon path flow variables. This paper demonstrates two essential shortcomings of these path-based models. One is that their application requires a given initial path flow pattern, which is typically unidentifiable, i.e. mathematically nonunique and practically unobservable. In particular, we show that, for the path-based models, different initial path flow patterns constituting the same link flow pattern generally gives different day-to-day link flow evolutions. The other shortcoming of the path-based models is the path-overlapping problem. That is, the path-based models ignore the interdependence among paths and thus can give very unreasonable results for networks with paths overlapping with each other. These two path-based problems exist for most (if not all) deterministic day-to-day dynamics whose fixed points are the classic Wardrop user equilibrium. To avoid the two path-based problems, we propose a day-to-day traffic assignment model that directly deals with link flow variables. Our link-based model captures travelers' cost-minimization behavior in their path finding as well as their inertia. The fixed point of our link-based dynamical system is the classic Wardrop user equilibrium.

Stability of user-equilibrium route flow solutions for the traffic assignment problem

- Transportation Research Part B: Methodological---2010---Shu Lu,(Marco) Nie, Yu

This paper studies stability of user-equilibrium (UE) route flow solutions with respect to inputs to a traffic assignment problem, namely the travel demand and parameters in the link cost function. It shows, under certain continuity and strict monotonicity assumptions on the link cost function, that the UE link flow is a continuous function of the inputs, that the set of UE route flows is a continuous multifunction of the inputs, and that the UE route flow selected to maximize an objective function with certain properties is a continuous function of the inputs. The maximum entropy UE route flow is an example of the last. On the other hand, a UE route flow arbitrarily generated in a standard traffic assignment procedure may not bear such continuity property, as demonstrated by an example in this paper.

The competition game on hub network design

- Transportation Research Part B: Methodological---2010---Cheng-Chang Lin,Shwu-Chiou Lee

In a competitive market, carriers in network industries design their hub networks and operations plans to maximize their respective profits. The long-term Cournot-Nash equilibrium steady state requires that none of the carriers may unilaterally alternate their hub networks or operations plans to increase profits. We study an integral-constrained game theoretic model for time-definite less-than-truckload freight services in an oligopolistic market. The research showed that carriers favor geographic central than outlying hub locations. With price-elastic demand in the freight market, the higher the network density is, the higher the profit is. Thus, the stable Cournot-Nash equilibrium solution states that all carriers respectively possess a similarly dense hub network, which is robust even with uneven changes in carrier cost structures. However, there is a prorogation effect in that an operating cost reduction will increase the individual carrier's and also the competitors' profits. The results also showed that there are cooperative equilibria that can make all carriers better off, but are unstable solutions in the non-cooperative game.

Economic analysis of airport congestion

- Transportation Research Part B: Methodological---2010---Jan Brueckner

2010

Congestion pricing, slot sales and slot trading in aviation

- Transportation Research Part B: Methodological---2010---Erik Verhoef

This paper studies the regulation of an airline duopoly on a congested airport. Regulation should then address two market failures: uninternalized congestion, and overpricing due to market power. We find that first-best charges are differentiated over airlines if asymmetric, and completely drive out the least efficient airline from the market. This is not generally the case for an undifferentiated charge, which is found to be a weighted average of first-best charge rules for the two airlines, and is less-than-optimally efficient because of its inability to differentiate between them. Tradable slots may yield the first-best outcome if the congestion externality is relatively important and the market power distortion relatively unimportant, but may be less efficient than non-intervention when the reverse is true.

An empirical analysis of airport slot trading in the United States

- Transportation Research Part B: Methodological--2010---Hideki Fukui

The purpose of this paper is to examine whether the manipulative or strategic behaviors of slot-holding carriers have resulted in restricted market entry and service expansion by other carriers, especially rival carriers, at the four US airports that have secondary slot markets. Airport congestion and flight delays at many major airports have become a serious problem. It has been suggested that a secondary slot market is one of the most practical options for addressing airport congestion, which would increase the possibility of competitive entry and efficient use of scarce resources. A secondary slot market would work in the same manner as a congestion toll system or an auction system, provided that carriers' manipulative or strategic behaviors do not have serious effects on slot trading. However, the empirical effects of slot markets have not been investigated systematically. This paper examines empirically whether carriers' manipulative or strategic behaviors have impeded effective functioning of slot markets. Slot transfer data from four US airports between 1994 and 1999 were examined using regression analysis. Results of the analysis are mixed, suggesting that the most effective way of congestion management depends on conditions unique to each airport, and that subsequent interventions should reflect those conditions.

Congested hubs

- Transportation Research Part B: Methodological--2010---Ricardo Flores-Fillol

Hub congestion is a major concern and a relevant policy issue because it causes important problems at airports such as flight delays, cancellations and missed connections that end up affecting both air travelers and airlines. We address the interplay between flight frequency and aircraft size in a congestion-pricing model, finding that airlines schedule too many flights using overly small aircraft, which constitutes a major contributor to congestion. Then we work out the needed congestion tolls, which account for the congestion imposed on other carriers and the congestion imposed on all passengers. Finally, we analyze the effects on congestion of network size, airport capacity, alliances and competition in layover time.

Airport congestion management under uncertainty

- Transportation Research Part B: Methodological--2010---Achim I. Czerny

This paper is about single airports and airport networks. Linear and non-linear model specifications are applied to analyze the relative welfare effects of slots and congestion pricing under uncertainty. Uncertainty refers to passenger benefits and congestion costs. I show that, from a welfare perspective, congestion pricing is the right choice for single airports in a linear context, but that slots might be preferred, if non-linearities (quadratic marginal external congestion costs) exist. I also show that uncertainty about congestion costs increases the relative welfare benefits of congestion pricing while airport networks increase the relative welfare benefits of slots.

Pricing vs. slot policies when airport profits matter

- Transportation Research Part B: Methodological--2010---Leonardo J. Basso,Anming Zhang

This paper analyzes pricing and slot-allocation mechanisms to manage airport capacity when profits are important to an airport, owing to budget constraints or profit maximization. We find that congestion pricing and slot trading/slot auctioning do not lead to the same results. Total traffic is higher under slot auctions than under congestion pricing. Furthermore, if airport profits matter just marginally, then slot auctions will outperform congestion pricing in terms of achieving a higher objective-function value. On the other hand, if airport profits matter sufficiently highly, which mechanism is better is then very much dependent on parameter values. In particular, congestion pricing may be strongly preferred over slot auctions for certain parameter values. The impact of congestion-remedy mechanisms on individual carriers is also examined.

Determinants of delays at European airports

- Transportation Research Part B: Methodological---2010---Georgina Santos,Maël Robin

Using flight data for the period 2000-2004 we find that four significant variables in explaining delays at European airports are market concentration, slot coordination, hub airports and hub airlines. We find evidence for the hypothesis that airlines internalize the effects of self-imposed congestion, but the results for the hub variables are somewhat puzzling. While delays are higher at hub airports, hub airlines experience lower delays than non-hub airlines. This may be at least partly explained by the special characteristics of the hub-and-spoke system in Europe, which is less extensive and more constrained, relative to the US. If introduced in Europe, efficient airport congestion tolls should be carrier-specific to account for the differences in internalization of delays.

Airport capacity and congestion pricing with both aeronautical and commercial operations

- Transportation Research Part B: Methodological---2010---Anming Zhang,Yimin Zhang

In this paper, we study airport decisions on pricing and capacity investment with both aeronautical and concession operations. In addition, the airport under consideration is serving air carriers who have market power. We find that a profit-maximizing airport would over-invest in capacity in the sense that the marginal (social) benefit of capacity is smaller than the marginal (social) cost. This tendency of overinvestment still holds when the private airport is under the regulatory constraint of cost recovery in its aeronautical operation (the dual-till regulation). We also find that the capacity investment by a public airport will be socially efficient in the sense that the marginal benefit of capacity is equal to the marginal cost of capacity. However, somewhat surprisingly, the capacity investment of the public airport will be inefficient if it is under regulatory constraints. Specifically, the airport will also over-invest in capacity, whether it is under a single-till regulation or a dual-till regulation. Finally, it is noteworthy that the inefficiency in airport investment is driven by the interaction between the airport and the carriers who have market power.

Linear complementarity formulation for single bottleneck model with heterogeneous commuters

- Transportation Research Part B: Methodological---2010---Gitakrishnan Ramadurai,Satish V. Ukkusuri,Jinye Zhao,Jong-Shi Pang

This paper formulates the dynamic equilibrium conditions for a single bottleneck model with heterogeneous commuters as a linear complementarity problem. This novel formulation offers a formal framework for the rigorous study and solution of a single bottleneck model with general heterogeneity parameter assumptions, enabling the adoption of well established complementarity theory and methods to analyze the model, and providing a significant contribution to the existing literature that either lacks a rigorous formulation or solves the problem under a limited set of heterogeneity parameter assumptions. The paper presents theoretical proofs for solution existence and uniqueness, and numerical results and insights for different heterogeneity assumptions.

Scheduling extra freight trains on railway networks

- Transportation Research Part B: Methodological--2010---Valentina Cacchiani,Alberto Caprara,Paolo Toth

We study the problem of freight transportation in railway networks, where both passenger and freight trains are run. While the passenger trains have a prescribed timetable that cannot be changed, freight train operators send the infrastructure manager requests to insert new freight trains. For each freight train, the associated train operator specifies a preferred ideal timetable, which can be modified by the infrastructure manager in order to respect safeness operational constraints. In particular, this modification may correspond to routing the train along a path which is different with respect to the one in the ideal timetable. Roughly speaking, the objective is to introduce as many new freight trains as possible by assigning them timetables that are as close as possible to the ideal ones. For this timetabling problem on a generic railway network, we present an integer linear programming formulation, that generalizes some formulations already presented for the case of a single railway line, and a Lagrangian heuristic based on this formulation. Computational results on real-world instances are reported.

Modeling and solving the Tactical Berth Allocation Problem

- Transportation Research Part B: Methodological--2010---Giovanni Giallombardo,Luigi Moccia,Matteo Salani,Ilaria Vacca

In this paper we integrate at the tactical level two decision problems arising in container terminals: the berth allocation problem, which consists of assigning and scheduling incoming ships to berthing positions, and the quay crane assignment problem, which assigns to incoming ships a certain quay crane profile (i.e. number of quay cranes per working shift). We present two formulations: a mixed integer quadratic program and a linearization which reduces to a mixed integer linear program. The objective function aims, on the one hand, to maximize the total value of chosen quay crane profiles and, on the other hand, to minimize the housekeeping costs generated by transshipment flows between ships. To solve the problem we developed a heuristic algorithm which combines tabu search methods and mathematical programming techniques. Computational results on instances based on real data are presented and compared to those obtained through a commercial solver.

An improved ant colony optimization based algorithm for the capacitated arc routing problem

- Transportation Research Part B: Methodological--2010---Luís Santos,João Coutinho-Rodrigues,John R. Current

The capacitated arc routing problem is a well-studied problem in the Transportation/Logistics/OR literature. The problem consists of identifying the minimum cost routes required to service (e.g., pickup or deliver) demand located along the edges of a network. Unfortunately, the problem belongs to the set of NP-Hard problems; consequently, numerous heuristic and meta-heuristic solution approaches have been developed to solve it. In this article, an ant colony optimization based metaheuristic is presented. Modifications are introduced for various components of the ant colony metaheuristics; specifically for those associated with the "initial population", the "ant decision rule" and the "local search procedure". The new metaheuristic was tested on seven standard test networks for the capacitated arc routing problem. The results demonstrate that the proposed approach performs extremely well vis-à-vis the state-of-the-art metaheuristics for the problem.

Optimizing facility use restrictions for the movement of hazardous materials

- Transportation Research Part B: Methodological---2010---Yashoda Dadkar,Linda Nozick,Dean Jones

The modeling tools that have been developed over the last 25Â years for the identification of routes for hazmat shipments emphasize the tradeoffs between cost minimization to the shipper/carrier and controlling the "natural" consequences that would stem from an accident. As the terrorist threat has grown, it has become clear that a new perspective, which allows for the representation of the goals and activities of terrorists, must be incorporated into these routing models. Government agencies can determine which specific facilities to restrict for each class of material and for which times of the day and/or week. This paper develops a game-theoretic model of the interactions among government agencies, shippers/carriers and terrorists as a framework for the analysis. It also develops an effective solution procedure for this game. Finally, it illustrates the methodology on a realistic case study.

Optimal traffic plate scanning location for OD trip matrix and route estimation in road networks

- Transportation Research Part B: Methodological---2010---R. Mínguez,S. Sánchez-Cambronero,E. Castillo,P. Jiménez

During the last decade, there has been a substantial interest in how to determine the optimal number and locations of traffic counters for origin-destination (OD) trip matrices estimation. On the contrary, the optimal allocation of plate scanning devices has received very limited attention, even though several authors have demonstrated that plate scanning (route identification) techniques are much more informative than those based on traditional link count information. This paper provides techniques for obtaining the optimal number and location of plate scanning devices for a given prior OD distribution pattern under different situations, i.e. maximum route identifiability or budget constraints. Two rules analogous to the counting location problem are developed, and several integer linear programming models fulfilling these rules are proposed. The proposed methods are finally illustrated by their application into Nguyen-Dupuis and Cuenca networks.

From heterogeneous drivers to macroscopic patterns in congestion

- Transportation Research Part B: Methodological---2010---Nicolas Chiabaut,Ludovic Leclercq,Christine Buisson

This paper first presents a method to estimate Newell's car-following model parameters in congestion at a microscopic scale. I-80 NGSim data analysis shows that at this scale driving behaviors vary from one vehicle to the another. Then, relations between stochastic Newell's model with heterogeneous drivers and its associated macroscopic pattern are established. This proves that the mean jam spacing is the arithmetic mean of individual jam spacings whereas the mean wave speed is the harmonic mean of individual wave speeds. These new insights are valuable for (i) calibrating a macroscopic model from individual observations and (ii) establishing the equivalence between the stochastic and the well-calibrated deterministic versions of Newell's model for a sufficiently large number of vehicles.

Exact and heuristic methods for public transit circulator design

- Transportation Research Part B: Methodological---2010---Nicholas E. Lownes,Randy B. Machemehl

This work presents a new mixed integer model for a single-route circulator design problem. An exact method that performs well in practice on medium-sized networks is presented that utilizes 1-trees as lower bounds and a stopping criterion relevant in non-Steiner networks. Proof of the correctness of this stopping criterion is provided. A heuristic method is presented for large networks. Both methods are tested on sample networks along a commuter rail line in Austin, TX in several problem variations and results of these tests presented. The practical and theoretical implications of this work are outlined.

Measurement and estimation of traffic oscillation properties

- Transportation Research Part B: Methodological---2010---Xiaopeng Li,Fan Peng,Yanfeng Ouyang

The paper proposes a frequency spectrum analysis approach to improve measurements of traffic oscillation properties (e.g., periodicity, magnitude) from field data. The approach builds on standard signal processing techniques to effectively distinguish useful oscillation information from noise and nonstationary traffic trends. Compared with conventional time-domain methods, the proposed methodology systematically provides a range of information on oscillation properties. This paper also shows how to estimate oscillations experienced by drivers using detector data. Applications to real-world data from two sites show that the dominant oscillation period remains relatively invariant at each site when an oscillation propagates. Although the average oscillation periods displayed in detector data significantly vary across sites, the range of oscillations experienced by drivers are found to be more consistent.

Robust congestion pricing under boundedly rational user equilibrium

- Transportation Research Part B: Methodological---2010---Yingyan Lou,Yafeng Yin,Siriphong Lawphongpanich

This paper investigates congestion pricing strategies in static networks with boundedly rational route choice behavior. Under such behavior, users do not necessarily choose a shortest or cheapest route when doing so does not reduce their travel times by a significant amount. A general path-based definition and a more restrictive link-based representation of boundedly rational user equilibrium (BRUE) are presented. The set of BRUE flow distributions is generally non-convex and non-empty. The problems of finding best- and worst-case BRUE flow distributions are formulated and solved as mathematical programs with complementarity constraints. Because alternative tolled BRUE flow distributions exist, our congestion pricing models seek a toll vector or pattern that minimizes the system travel time of the worst-case tolled BRUE flow distribution. As formulated, the models are generalized semi-infinite min-max problems and we propose a heuristic algorithm based on penalization and a cutting-plane scheme to solve them. Numerical examples are presented to illustrate key concepts and results.

Grandfather rights in the market for airport slots

- Transportation Research Part B: Methodological---2010---Gernot Sieg

Grandfather rights are currently used in the European Union to allocate airport slots. This article shows that airports prefer such a use-it-or-lose-it rule to unconditional property rights. Assuming that there are informational asymmetries between airports and air carriers because air carriers have better information on passenger demand, the use-it-or-lose-it rule increases slot use when demand for air transport is low. Airport profits increase and those of the air carriers, together with social welfare, decrease. The profit-maximizing slot-use ratio is less than one.

The value of reliability

- Transportation Research Part B: Methodological---2010---Mogens Fosgerau,Anders Karlström

We derive the value of reliability in the scheduling of an activity of random duration, such as travel under congested conditions. Using a simple formulation of scheduling utility, we show that the maximal expected utility is linear in the mean and standard deviation of trip duration, regardless of the form of the standardised distribution of trip durations. This insight provides a unification of the scheduling model and models that include the standard deviation of trip duration directly as an argument in the cost or utility function. The results generalise approximately to the case where the mean and standard deviation of trip duration depend on the starting time. An empirical illustration is provided.

Bidline scheduling with equity by heuristic dynamic constraint aggregation

- Transportation Research Part B: Methodological---2010---Khaled Boubaker,Guy Desaulniers,Issmail Elhallaoui

The bidline scheduling problem with equity arises in several North American airlines. It consists of determining anonymous monthly schedules, called bidlines, that will be subsequently assigned to the crew members according to their bids and seniority. These bidlines must satisfy safety and collective agreement rules. Furthermore, to ensure an equity between the employees, each bidline should have as much as possible the same number of days off and the same number of credited (paid) hours. In this paper, we propose an approximate set partitioning type formulation for this problem and two heuristics for solving it. The first one is a standard branch-and-price heuristic that relies on a rounding procedure to derive integer solutions. The second one is obtained by combining this first heuristic with a dynamic constraint aggregation method that was recently proposed in the literature. Computational results show that, for the largest tested instances, the dynamic constraint aggregation heuristic can produce better quality solutions in a fraction of the computational time required by the standard branch-and-price heuristic.

Equilibrium analysis of macroscopic traffic oscillations

- Transportation Research Part B: Methodological---2010---Nie, Yu (Marco)

Using a simple network model with two parallel links connecting a diverge and a merge, this paper studies under what conditions traffic oscillations may be initiated and propagated in a traffic stream, specially at freeway bottlenecks. Drivers are assumed to minimize either the experienced or instantaneous travel times, and in doing so, they settle at a Wardrop (day-to-day) equilibrium or a Boston (within-day) traffic equilibrium, respectively. We prove that the path travel time function in our model is not monotone, and show that this property leads to multiple Wardrop equilibria, of which only one is both stable and efficient. The paper shows that periodic traffic oscillations do not arise from Wardrop equilibria. Trivial oscillations exist at Boston equilibria, which are caused by drivers' overreaction to traffic conditions. However, periodic oscillations are likely to emerge when (1) transitions between stable and unstable equilibria take place, and more importantly, (2) drivers make decisions based on out-of-date information of traffic conditions. The latter finding is useful in guiding control practice at freeway bottlenecks and work zones to prevent traffic oscillations.

A class of bush-based algorithms for the traffic assignment problem

- Transportation Research Part B: Methodological---2010---Nie, Yu (Marco)

This paper studies a class of bush-based algorithms (BA) for the user equilibrium (UE) traffic assignment problem, which promise to produce highly precise solutions by exploiting acyclicity of UE flows. Each of the two building blocks of BA, namely the construction of acyclic sub-networks (bush) and the solution of restricted master problems (RMP), is examined and further developed. Four Newton-type algorithms for solving RMP, which can be broadly categorized as route flow and origin flow based, are presented, of which one is newly developed in this paper. Similarities and differences between these algorithms, as well as the relevant implementation issues are discussed in great details. A comprehensive numerical study is conducted using both real and randomly generated networks, which reveals that the relative performance of the algorithms is consistent with the analysis. In particular, the results suggest that swapping flows between shortest and longest route segments consistently outperforms other RMP solution techniques.

Stability and attraction domains of traffic equilibria in a day-to-day dynamical system formulation

- Transportation Research Part B: Methodological---2010---Jing Bie,Hong K. Lo

We formulate the traffic assignment problem from a dynamical system approach. All exogenous factors are considered to be constant over time and user equilibrium is being pursued through a day-to-day adjustment process. The traffic dynamics is represented by a recurrence function, which governs the system evolution over time. Equilibrium stability and attraction domain are then analyzed by studying the topological properties of the system evolution. Stability is important because unstable equilibrium is transient. Even for stable equilibrium, only points within its attraction domain are attracted to the equilibrium. We show that the attraction domain of a stable equilibrium is always open. Furthermore, its boundary is formed by trajectories towards unstable equilibria. Through an understanding of these properties, computation schemes can be devised to determine the ranges of the attraction domains, as demonstrated in this study. Once this is accomplished, a partition chart can be drawn on the state space where each part represents the attraction domain of an equilibrium point. We trust that charting the attraction domains of user equilibria, as presented in this paper, will open up innovative ways for transportation network management.

Bayesian inference for vehicle speed and vehicle length using dual-loop detector data

- Transportation Research Part B: Methodological---2010---Baibing Li

A dual-loop detector consists of two connected single-loop detectors placed several feet apart. Compared with a single-loop detector, it is able to provide more useful information on traffic flow with a higher precision. In this paper we investigate statistical inference for vehicle speed and vehicle length using dual-loop detector data. A Bayesian analysis is performed to combine current observations on traffic flow with prior knowledge, which results in a set of simple formulas for the online estimation of both vehicle speed and vehicle length. As a by-product, vehicle classification is also investigated on the basis of posterior classification probabilities. The computational overhead of updating the estimates is kept to a minimum when new information on traffic flow becomes available. The method is illustrated using real traffic data.

Probabilistic models for queues at fixed control signals

- Transportation Research Part B: Methodological---2010---Francesco Viti,Henk J. van Zuylen

The estimation of queues at signalized intersections is a classical problem in transportation engineering and operations research. Nevertheless, a general theory able to explain how queues form and cause delays to the drivers is still missing. Typically, queue dynamics are modelled as deterministic, causal phenomena, and under rather limiting assumptions; however, especially in urban networks, these are far from being deterministic or certain. This paper presents a new probabilistic queuing model that can explain the dynamic and stochastic behaviour of queues at fixed controlled signals. The probabilistic approach allows one to capture the temporal behaviour of queues, and to measure the uncertainty of a queue state prediction by computing the evolution of its probability in time, assumed any temporal distribution of the arrivals. This can be fundamental information in, e.g., travel time estimation, network reliability, design and planning of urban areas, and to estimate complex effects that can be observed in congested networks such as spillback or gridlock. Comparison with microscopic simulation shows very good consistency both under the assumption of stationary and non-stationary arrival distributions.

The information content of a stated choice experiment: A new method and its application to the value of a statistical life

- Transportation Research Part B: Methodological---2010---Jan Rouwendal,Adriana Blaeij,Piet Rietveld,Erik Verhoef

This paper presents a new method to assess the distribution of values of time, and values of statistical life, over participants to a stated choice experiment. The method does not require the researcher to make an a priori assumption on the type of distribution, as is required for example for mixed logit models. It requires a few assumptions to hold true, namely that the valuations to be determined are constant for each individual, and that respondents make choices according to their preferences. These assumptions allow the derivation of lower and upper bounds on the (cumulative) distribution of the values of interest over respondents, by deriving for each choice set the value(s) for which the respondent would be indifferent between the alternatives offered, and next deriving from the choice actually made the respondent's implied minimum or maximum value(s). We also provide an extension of the method that incorporates the possibility that errors are made. The method is illustrated using data from an experiment investigating the value of time and the value of statistical life. We discuss the possibility to improve the information content of stated choice experiments by optimizing the attribute levels shown to respondents, which is especially relevant because it would help in selecting the appropriate distribution for mixed logit estimates for the same data.

Development and calibration of the Anisotropic Mesoscopic Simulation model for uninterrupted flow facilities

- Transportation Research Part B: Methodological---2010---Yi-Chang Chiu,Liang Zhou,Houbing Song

This paper presents the development, analysis, and calibration of the Anisotropic Mesoscopic Simulation (AMS) model for uninterrupted flow facilities, such as freeways. The proposed AMS model is a vehicle-based mesoscopic traffic simulation approach that explicitly considers the anisotropic property of traffic flow into the vehicle state update at each simulation step. The advantage of AMS is its ability to address a variety of uninterrupted flow conditions in a relatively simple, unified and computationally efficient manner. The discussions focus on the key modeling concepts, the analytical properties and numerical analysis, and the calibration process and results. The addressed analytical properties are the overtaking conditions, acceleration and deceleration rate bounds, and shockwaves. The numerical analysis includes both freeway segments as well as merging junctions. Considerable efforts were devoted to employ the Next-Generation Simulation (NGSIM) program datasets to calibrate the AMS model parameters. The high traffic fidelity and satisfactory computational efficiency make AMS a promising simulation approach for large-scale regional dynamic traffic simulation and assignment.

A tabu search algorithm for rerouting trains during rail operations

- Transportation Research Part B: Methodological---2010---Francesco Corman,D'Ariano, Andrea,Dario Pacciarelli,Marco Pranzo

This paper addresses the problem of train conflict detection and resolution, which is dealt every day by traffic controllers to adapt the timetable to delays and other unpredictable events occurring in real-time. We describe a number of algorithmic improvements implemented in the real-time traffic management system ROMA (Railway traffic Optimization by Means of Alternative graphs), achieved by incorporating effective rescheduling algorithms and local rerouting strategies in a tabu search scheme. We alternate a fast heuristic and a truncated branch and bound algorithm for computing train schedules within a short computation time, and investigate the effectiveness of using different neighborhood structures for train rerouting. The computational experiments are based on practical size instances from a dispatching area of the Dutch railway network and include complex disturbances with multiple late trains and blocked tracks. Several small instances are solved to optimality in order to compare the heuristic solutions with the optimum. For small instances, the new tabu search algorithms find optimal solutions. For large instances, the solutions generated by the new algorithms after 20Â s of computation are up to more than 15% better than those achieved within 180Â s by the previous version of ROMA.