Sixth Triennial Symposium on Transportation Analysis
TRISTAN VI
Phuket Island, Thailand, June 10-15, 2007

Book of Abstracts

TRISTAN VI
JUNE 10-15, 2007
Phuket Island – Thailand

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Plenary sessions

Moshe Ben-Akiva - Hybrid Choice Models: From Static to Dynamic

Monday 06/11 11:00 - 12:00 Room: Karon A
Chairman: Michel Bierlaire
We present new developments in discrete choice modeling that aim at bridging the gap with behavioral theory. Our approach is based on the Hybrid Choice Model (HCM) which has been proposed to integrate latent variable models, latent class models, flexible error structures, and multiple data sources with discrete choice methods. We extend the HCM in two major ways. First, we argue that choices are often the result of a multi-staged decision process involving plans and actions where observed actions are preceded by latent plans. We show how to explicitly model these unobserved plans. Second, we extend the HCM framework to model dynamics of individual behavior. Our approach is based on the integration of the Hidden Markov Model and discrete choice methods. We introduce state dependence and interactions between plans and actions into choice models involving hidden decision layers and explicitly model the evolution of latent plans and observed actions. The extended HCM makes behavioral models more realistic and their predictions more accurate. We present the application of the dynamic HCM with a two-layer decision hierarchy involving plans and actions to driving behavior and show significant improvements in statistical performance and realism of the simulated behavior.

George Nemhauser - Scheduling On-demand Air Transpotation

Tuesday 06/12 11:00 - 12:00 Room: Karon A
Chairman: Pitu Mirchandani
A non-scheduled airline provides regional "on demand" air transportation on small jet planes having a capacity of 3 passengers. A request for travel specifies an origin, destination, earliest departure time, and latest arrival time. Based on requests already accepted for that day, the accept/reject problem is to determine whether the new request can be accommodated. At the beginning of the day an optimal schedule that minimizes flying time is created for all of the accepted requests for that day. DayJet will begin providing this service in 2007 using the Eclipse 500, which costs about one million dollars, is fuel efficient and has a range of over a thousand miles. They expect to have several hundred jets covering overlapping regions of the U.S. in a few years. This service is especially useful for areas that are not well served by large airports. By using small airports, they eliminate the hassles associated with long drives to the airport, packed parking lots, security lines, etc. For many travelers, this service will yield huge time savings in comparison to the alternatives of a scheduled airline or driving. In this talk, I will discuss the optimization models and algorithms that we have developed for scheduling DayJet's forthcoming service. These include a multi-commodity flow model with side constraints for solving small instances, which is imbedded into a local search algorithm with an asynchronous parallel implementation for solving real-life instances.

Piet H. L. Bovy - Route Choice Set Generation: a Preliminary Synthesis

Thursday 06/14 10:30 - 11:30 Room: Karon A
Chairman: Otto Anker Nielsen
Choice sets of individual travelers play a paramount role in analyzing travel choice behavior. It is well known that the size and composition of choice sets do matter in cases of choice model estimation and demand prediction. Incorrect choice sets (e.g. because of captivity) can lead to misspecification of choice models and to biases in predicted demand levels. While this has been demonstrated for relatively simple choice types such as mode choice, we may assume that it holds as well for the more complex case of route choice. The critical role of choice sets in choice modeling has given rise to profound research into choice set modeling in the transportation field, although largely confined to mode choice. We state that these insights gained on choice set modeling and choice set generation cannot simply be transferred to the route choice realm. For a variety of reasons, the specification of route sets for route choice modeling is different and more complex, reason why this topic deserves special attention from researchers and practitioners. This paper is devoted to a number of topics related to the modeling and generation of route choice sets, specifically for application in large networks including multi-modal networks. The paper above all tries to synthesize existing knowledge on this topic into a single conceptual framework giving ample attention to a theoretical underpinning. We will first summarize in what respect route

choice sets differ from other travel choices implying that some proposed choice set modeling approaches cannot be adopted for routes. Then we will argue that it is necessary and advantageous to distinguish the processes of choice set formation and choice per se on the part of the traveler, but also to explicitly separate the modeling steps of choice set generation and choice modeling from given choice sets instead of implicitly combining these steps into a single one. Before going into more detail of route choice set modeling, we will discuss the various notions of choice sets and the various purposes for which choice sets may be used. We state that these different purposes, that is supply analysis, model estimation, and demand prediction do matter in choice set modeling. We then present a generic conceptual scheme relating the distinct key elements inherent in each route choice set generation approach. This scheme helps in classifying and characterizing the various approaches proposed. This scheme is then followed by a generic formalization of the route generation modeling procedures. Some indications for their empirical validity will be presented derived from applications to various uni-modal and multi-modal networks.

Session 1A: Road pricing I

Monday 06/11 09:00 - 10:30 Room: Kata
Chairman: Piet Bovy

Congestion Pricing: Gaining Public Acceptance
Authors: *Lawphongpanich, Yin, Hearn*
Speaker: Siriphong Lawphongpanich - University of Florida
Congestion pricing has been around for over 80 years and many have since recognized it as an efficient method for regulating congestion. On the other hand, getting the public to accept congestion pricing is still an obstacle. Transportation economists have pointed out recently that pricing schemes advocated in the literature such as marginal cost pricing are "most likely doomed to be political failures" because users will find themselves worse off. To make congestion pricing more appealing to the public, we propose a pricing scheme under which some users are better off and no one is worse off when compared to the condition without pricing.

Optimal Toll Design From Reliability Perspective
Authors: *Li, Bliemer, Bovy*
Speaker: Hao Li - Delft University of Technology
Optimal toll design from a network reliability point of view is addressed in this paper. Improving network reliability is proposed as a policy objective of road pricing. A reliability-based optimal toll design model, where on the upper level network travel time reliability is optimized, while on the lower level a dynamic user-equilibrium is achieved, is presented. Road authorities aim to optimize network travel time reliability by setting tolls in a network design problem. Travelers are influenced by these tolls and make route and trip decisions by considering travel times and tolls. Network performance reliability is analyzed for a degradable network with elastic and fluctuated travel demand, which integrates reliability and uncertainty, dynamic network equilibrium models, and Monte Carlo methods. The formulated design problem belongs to the class of Stochastic Network and Stochastic User Equilibrium (SN-SUE) problems which models the stochastic network characteristics including stochastic link capacities and the travel demand fluctuations simultaneously. The proposed model is applied to a small hypothesized network for which optimal tolls are derived that optimize the network travel time reliability. The network travel time reliability is indeed improved after implementing optimal tolling system. Trips may have a somewhat higher, but more certain, travel time.

Heterogeneous Users and Variable Road Pricing: Model and Algorithm for the Bi-criterion Dynamic User Equilibrium Problem On Large Networks
Authors: *Lu, Mahmassani*
Speaker: Hani Mahmassani - University of Maryland
This study presents a dynamic traffic assignment model and its solution algorithm for the bi-criterion dynamic user equilibrium (BDUE) problem in which heterogeneous trip-makers have different value of time (VOT) preferences in response to time- varying toll charges. By assuming the VOT as a continuously distributed random variable across the population of trip-makers, the BDUE problem is formulated as an infinite dimensional variational inequality (VI), and solved by a column generation- based algorithmic framework which embeds (1) a bi-criterion time-dependent least generalized cost path algorithm to generate the set of time-dependent extreme efficient paths and the corresponding breakpoints that partition the entire VOT interval and hence naturally define the multiple user classes; (2) a simulation-based dynamic network loading model to determine experienced path travel costs for any given path flow pattern; and (3) a projection-based descent direction method to solve the restricted multi-class dynamic user equilibrium (RMDUE) problem defined by a subset of feasible paths. A set of numerical experiments are conducted on several large-scale real road networks to explore the convergence behavior of the algorithm and investigate how the VOT distributions affect the path flow pattern and toll road usage under different dynamic road pricing scenarios.

Session 1B: Routing I

Monday 06/11 09:00 - 10:30 Room: Kamala
Chairman: Michel Gendreau

A Large Neighborhood Search Algorithm for the Vehicle Routing Problem with Time Windows

Authors: *Desaulniers, Prescott-Gagnon, Rousseau*
Speaker: Louis-Martin Rousseau - École Polytechnique de Montréal

Given a fleet of vehicles assigned to a single depot, the vehicle routing problem with time windows (VRPTW) consists of determining a set of feasible vehicle routes to deliver goods to a set of customers while minimizing, first, the number of vehicles used and, second, total mileage. A large number of heuristic approaches for the VRPTW have been proposed in the literature, but none have taking advantage of the power of branch-and-price which is the leading methodology for the exact solution of the VRPTW. In this paper, we present a large neighborhood search algorithm that relies on a heuristic branch-and-price method for neighborhood exploration. To ensure diversification during the search, this approach uses different procedures for defining the neighborhood to explore at each iteration. Computational results on the Solomon's and Homberger's benchmark instances will be presented.

A Robust Optimization Approach to Dispatching Technicians Under Stochastic Service Times

Authors: *Cortés, Ordóñez, Souyris, Weintraub*
Speaker: Cristian Cortés - Universidad de Chile

We consider the problem of dispatching technicians to provide repair services to a set of geographically dispersed clients, which have service windows and uncertain service times. We find routes that minimize a combination of delay and travel time for all the requests for service. Since the variation in service time can be substantial an optimal route that ignores this uncertainty can be very inefficient in practice. We present a robust optimization approach, which finds routes that minimize the worst case delay and travel time costs. An efficient implementation of a branch and price algorithm combined with constraint programming for the column generation phase is proposed to solve the problem. We present computational results evaluating the robust solutions and solve a real sized instance of dispatching copier repairmen in Santiago, Chile.

A Multi-restart Deterministic Annealing Metaheuristic for the Fleet Size and Mix Vehicle Routing Problem with Time Windows

Authors: *Hasle, Braysy, Dullaert, Mester, Gendreau*
Speaker: Geir Hasle - SINTEF ICT

We present a new deterministic annealing metaheuristic for the fleet size and mix vehicle routing problem with time windows. The objective is to service a set of customers at minimal cost within their time windows by a heterogeneous capacitated vehicle fleet. The suggested metaheuristic comprises three phases. In the first phase, high quality initial solutions are generated by means of a savings-based heuristic combining diversification strategies with learning mechanisms. An attempt is then made to reduce the number of routes in the initial solution with a new local search procedure in phase two. The solution is further improved in phase three by a set of four local search operators that are embedded in a deterministic annealing framework. Computational experiments show that the suggested method outperforms the previously published results.

Session 1C: Railway optimization

Monday 06/11 09:00 - 10:30 Room: Nai Harn
Chairman: Janny Leung

Rail Crew Re-scheduling: From Planning Towards Operations
Authors: *Potthoff, Huisman*
Speaker: Daniel Potthoff - Erasmus University Rotterdam
In this presentation, we will discuss several variants of the Crew Re-Scheduling Problem (CRSP). In earlier work, we looked at the situation with planned maintenance activities. For that case, we proposed a set covering formulation and a column generation based algorithm to solve it. The results showed that practical instances of the Dutch largest rail operator, NS, could be solved. In this presentation, we will extend this algorithm to the case of unplanned maintenance and disruptions. Therefore, the computation times should be reduced drastically. We will discuss several methods to do this.

Multi-carrier Train Scheduling for Freight Transport
Authors: *Kuo, Miller-Hooks*
Speaker: April Kuo - University of Maryland
The multi-line, multi-carrier, multi-objective freight train scheduling problem is addressed. Column generation is proposed for its solution. The solution technique is embedded in an iterative framework that allows solution of the scheduling problem with elastic demand. The technique is tested on a multi-national European rail network known as the REORIENT corridor.

Approximate Dynamic Programming In Rail Operations
Authors: *Powell, Bouzaiene-Ayari*
Speaker: Warren Powell - Princeton University
We summarize research in the development of production models for a major railroad for the management of both locomotives and freight cars using approximate dynamic programming. ADP has proven to be an exceptionally powerful strategy for decomposing large, complex problems, and in particular those exhibiting uncertainty, that arise in freight transportation. The locomotive distribution problem includes complex rules in the assignment of groups of locomotives to move a single train. The car distribution problem includes a number of different sources of uncertainty. We show that ADP produces higher quality, and more realistic, solutions for problems that would otherwise be computationally intractable. We summarize the status of projects implementing this technology at a major railroad in the United States.

Session 3A: Pedestrian flow models

Monday 06/11 14:50 - 15:50 Room: Kata
Chairman: Serge Hoogendoorn

Delays, Variation and Anticipation In Walker Models
Authors: *Daamen, Hoogendoorn, Campanella, Bovy*
Speaker: Winnie Daamen - Delft University of Technology
A large variety of pedestrian flow models have been proposed in the last two decades, ranging from macroscopic models, Cellular Automata, and microscopic simulation models that are continuous in time and space. Especially the latter models are able to correctly describe collective phenomena in empirical pedestrian flow, such as the emerging relation between flow and speed, spatiotemporal patterns, and self-organisation of lanes, diagonal stripes, etc. Recently, a parameter estimation approach was developed that enabled identification of the behavioural parameters for individual pedestrians based on trajectory data. This study yielded a couple of important new insights into the microscopic properties of a pedestrian flow, in particular with respect to the inter-pedestrian differences. Judging from the large variance in the estimated parameters, it turns out that the inter- pedestrian behavioural variability is considerable. Another aspect that turned out to be of importance, is the presence of a finite reaction time in the walking decision process: using the new estimation technique, it was shown that the response to stimuli is in fact delayed by (on average) 0.3 seconds. The main contributions of the presented paper are an empirically based theory of walking behaviour featuring finite reaction times, anticipation and estimation and control errors, and finally inter-pedestrian differences. Based on this new theory, a novel walker model is proposed. This model is applied to a simple test-case example in order to show effects of the new behavioural theory on aggregate flow characteristics such as capacity and total congestion time.

Map-based Autonomous Personal Localisation and Tracking
Authors: *Spassov, Bierlaire, Merminod*
Speaker: Michel Bierlaire - Ecole Polytechnique Fédérale de Lausanne
An autonomous localisation and tracking method is a method independent from the reception of external data. In our approach we ignore methods like GPS- and WiFi- positioning and we focus on the use of inertial navigation system (INS) carried by the person and connected to a map database. The walking person is considered as a dynamic system, whose movements are measured by the INS. His trajectory is modified with respect to a dedicated motion model. User's location is estimated in the frame of Bayesian inference and is based on the association of the trajectory to the map database, a technique known as map- matching. Because of the non-linear nature of the estimation problem, non-linear filtering techniques like particle filters (Sequential Monte Carlo methods) are applied. In tracking mode simple geometric constrains will be observed in order to associate every point of the trajectory to element of the map database. In parallel the localisation mode rest active in order to keep the knowledge on the history of measurements. The algorithm is tested on the campus of EPFL; the process of localisation is entirely autonomous and gives promising results. That method of localisation can be applied to many pedestrian navigation tasks, in particular for the needs of the fire- brigades and security services.

Session 3B: Routing applications

Monday 06/11 14:50 - 15:50 Room: Kamala
Chairman: Richard Hartl

An Effective Heuristic for Ready Mixed Concrete Delivery
Authors: *Schmid, Doerner, Hartl, Savelsbergh, Stoecher*
Speaker: Verena Schmid - University of Vienna
A medium-sized company in the concrete industry located in Upper Austria is facing the following problem when scheduling their daily operations: The company has several plants producing concrete and a heterogeneous fleet of vehicles at their disposal, used for delivering concrete to their customers' construction sites. The objective is to deliver concrete to the customers' sites in a timely, but cost-effective manner. In this talk we focus on the implementation of the hybridization of an exact mixed-integer-problem formulation with metaheuristic approaches. By combining the strength of those two methods high-quality solutions can be obtained in a reasonable amount of time.

Column Generation for a Real World Vehicle Routing Problem
Authors: *Ceselli, Righini, Salani*
Speaker: Alberto Ceselli - DTI - University of Milan
In this work we present the optimization core of a real world application, which we developed for an Italian software provider of planning tools for distribution logistics companies. This tool provides a daily based planning for an heterogeneous fleet of vehicles, which can depart from different depots and must visit a set of customers for pickup and delivery operations. Like many real world applications, the problem involves several complicating constraints, which seriously challenge standard optimization techniques: for instance, both vehicles and customers are available only in between particular working time windows, matching predetermined calendars; hazardous or fragile goods have to be handled by suitable vehicles, which can neither load couples of incompatible goods nor visit particular locations; vehicles have limited travelling and loading capabilities: the trade union rules impose an upper limit on the number of consecutive driving hours, and rest periods must be carefully planned. Moreover, the cost of each vehicle route is computed through an involved system of fares, depending on the locations visited by the vehicle, the distance traveled, the vehicle load and the number of stops during the day. In order to exploit column generation techniques, we model the problem as an ILP set covering problem with side constraints: in this formulation, each column represents a feasible route for a particular vehicle. The pricing problem, which is a particular resource constrained shortest path problem, is solved through a bounded bidirectional dynamic programming algorithm. We describe how to encode the cost function and the complicating constraints by an appropriate use of resources. We present preliminary computational results on real instances obtained from the software company.

Session 3C: Discrete choice models I

Monday 06/11 14:50 - 15:50 Room: Nai Harn
Chairman: Quentin K. Wan

Mode and Carrier Choice In the Quebec City - Windsor Corridor: a Random Parameters Approach

Authors: *Patterson, Ewing, Haider*
Speaker: Zachary Patterson - EPFL - TRANSP-OR

The Quebec City-Windsor corridor (the Corridor) is the busiest and most important trade and transportation corridor in Canada. Transportation is the second largest contributor to greenhouse gas (GHG) emissions in the country. Governments around the world, including Canada, are considering increased mode share by rail as a way to reduce transportation emissions. To understand whether freight mode shift is a realistic means to reduce transportation emissions, an analytical model is needed that can predict the effect of government policy on mode split. This paper presents findings from an analysis of the first stated preference carrier choice survey of shippers in the Corridor. The survey was conducted between August and December 2005 and produced responses from 392 "end-shippers". Previous analysis of this data concentrated on the use of a mixed-logit random effects approach to estimate carrier choice models. The results of these models showed that shippers are very mistrustful of using rail to move their consignments and suggests that increasing rail's share of freight faces tremendous challenges. This paper will present the results of an extension of this mixed-logit analysis to include a random parameters approach. Of particular interest is the distribution on the coefficient estimating the effect on utility of knowledge that a shipment will be shipped intermodally.

Modeling Residential Mobility and Spatial Search Behaviour: Evidences From Greater Toronto Area

Authors: *Habib, Miller*
Speaker: Muhammad Habib - University of Toronto

As residential mobility and location choice is an important part of integrated land use and transportation models to understand relationships between transportation and land uses, it is necessary to explicitly model the "decision-making process" incorporating its underlying behaviours. This papers attempts to conceptualize a Residential Mobility and Location Choice (REMLOC) model to be implemented within a microsimulation framework and presents empirical results of mobility and search behaviour using Greater Toronto Area (GTA) retrospective survey data. For mobility decisions, binary panel discrete choice models have been examined including fixed effects, random effects and random coefficient models for twenty-seven years of housing career, employment history, life-cycle dynamics of a sample of 280 GTA households and their surrounding neighbourhood and transportation system characteristics. The fixed effects model specification is used to accommodate individual heterogeneity and state dependence in the panel models by examining one- way (group specific effect) and two-way (an additional time specific effect) effects. The estimator in the two-way fixed effect models is computed by adding time-specific dummy variables into the model. Due to concern over incidental parameters problem for fixed effects models an alternative approach of conditional maximum likelihood estimation is also tested. Then, a random effects model is examined by introducing a time invariant component, which is the latent unobserved heterogeneity that enters into the model in the form of a random effect. Finally, a random coefficient binary choice model is investigated which proves very promising in explaining individual mobility decision-making process where most of the dynamic variables are found random. Job change, increase and decrease of jobs, age, number of persons per room, duration of residence and expectations of a child's birth proves significant stressors that trigger residential mobility decisions for GTA households. Again, a comprehensive search algorithm has been developed to mimic spatial search behaviour of households active in searching and evaluating dwellings. It is expected that implementation of search stage using retrospective data would provide immense insights in evaluating residential locations in relation to the transportation system and fill the gaps to combat challenges in microsimulating urban systems.

Session 4A: Network design

Monday 06/11 16:00 - 17:00 Room: Kata
Chairman: Teodor Gabriel Crainic

Stochastic Service Network Design: a Deterministic Primal Heuristic
Authors: *Wallace, Crainic, Lium, Kaut*
Speaker: Stein W. Wallace - Molde University College
We have earlier demonstrated that introducing stochastic demand into a service network design model produces solutions qualitatively different from those stemming from deterministic models. These structural differences are now used to create a primal deterministic heuristic for finding solutions to the stochastic program. For the study reported in this paper, we use a version of a multi-period service network design model inspired by less-than-truckload motor carrier cases with repetitive schedules. Based on the knowledge of the demand distributions, we propose a two-phase approach, consisting of a construction followed by an improvement heuristic to build a feasible solution to the deterministic formulation. The construction and improvement operations follow from the major patterns observed in the previous study. In the talk, we will discuss the problem and the approach, present the primal heuristic, and analyse the available results.

Introducing Asset Management to Capacitated Multicommodity Network Design
Authors: *Andersen, Crainic, Christiansen*
Speaker: Marielle Christiansen - Norwegian University of Science and Technology
In this extended abstract we present the capacitated multicommodity network design problem with asset management considerations (CMNDAM). The problem is an extension of the design balanced fixed charge network design problem (DBCMND). DBCMND problems arise in design of transportation networks, where node balance of vehicles has to be ensured. For problems where advanced asset management necessitates repetitiveness in the operations, we propose alternative formulations of the model. In the alternative formulations we establish new design variables based on an analogy to the introduction of path flow variables in standard fixed charge capacitated network design problems. We solve instances based on real data in order to analyze the strengths and weaknesses of the various model formulations.

Session 4B: Dynamic routing

Monday 06/11 16:00 - 17:00 Room: Kamala
Chairman: M. Grazia Speranza

Short Term Strategies for a Dynamic Multi-period Routing Problem
Authors: *Mansini, Speranza, Angelelli, Bianchessi*
Speaker: Enrico Angelelli - University of Brescia
In this paper we study the problem faced by a company that has to deal with pick-up requests by means of a fixed fleet of vehicles. When a request is issued, a deadline of k days (k less or equal 2) is associated to it. This means that if k = 1 the service has to be performed on the same day (unpostponable), if k = 2 the service has to be performed either today or tomorrow (postponable). The objective of the company is to guarantee the accomplishment of all the requests received while minimizing the average cost per day. The company has to face two factors of dynamism. First, each day the company has to decide whether to serve postponable requests or not. The decision has to be taken without knowing what the set of new requests will be tomorrow. Secondly, it is also assumed that the company can react to on-line requests and possibly make new plans for the service on the day. The dynamic nature of the problem creates new modeling challenges and the need of new solution approaches. We call this class of problems Dynamic Multi-Period Routing Problems (DMPRP) which can be synthetically defined as follows. A set of requests need to be served by a given fleet of un-capacitated vehicles over a time horizon of T days. Each request has a deadline k less or equal 2. Every day the vehicles leave the depot in the morning and have to return to the depot at the end of the day. At the beginning of each day a set of requests is already known, while other requests may arrive over time. On-line requests with deadline k=1 can arrive only before a fixed time limit L for each day. At any time during the day the company is able to route and re-route the vehicles. At time L no more unpostponable requests are accepted and the company is able to decide the set of unpostponable requests which can be serviced with its fleet and the set of requests that will be forwarded to a back-up service. The objective is to minimize the average operational costs per day. These operational costs includes a very high cost paid for each request forwarded to the back-up service. We present the results of the computational analysis carried out to study the impact of different short term routing strategies on the long term objective.

Dynamic Vehicle Routing Systems - Survey and Classifications
Authors: *Madsen, Larsen, Solomon*
Speaker: Oli B G Madsen - Centre for Traffic and Transport, DTU
The classical or basic vehicle routing problem (VRP) deals with customers which are known in advance to the planning process. Furthermore, all other information such as the driving time between the customers and the service time at the customers are used to be known prior to the planning. In contrast to this, the dynamic vehicle routing problem considers a VRP in which a subset (or the full set) of customers arrive after the day of operation has begun. The dynamic vehicle routing problem will have to be able to consider how to include the new requests into the already designed routes. This paper discusses important characteristics seen within dynamic vehicle routing problems. We discuss the difference between the traditional static vehicle routing problems and its dynamic counterparts. We give an in-depth introduction to the degree of dynamism measure which can be used to classify dynamic vehicle routing systems. Methods for evaluation of the performance of algorithms that solve on-line routing problems are discussed and we list some of the important issues to include in the system objective. Finally, we provide a three-echelon classification of dynamic vehicle routing systems based on their degree of dynamism and the system objective. References [1] Psaraftis, H.N. (1988), Dynamic Vehicle Routing, in Vehicle Routing: Methods and Studies, B.L. Golden and A.A. Assad (eds), 223-248, North-Holland, Amsterdam. [2] Larsen, A., Madsen, O.B.G. and Solomon, M. (2002), Partially Dynamic Vehicle Routing - Models and Algorithms, Journal of the Operational Research Society 38, 637- 646.

Session 4C: Route Choice I

Monday 06/11 16:00 - 17:00 Room: Nai Harn
Chairman: Emma Frejinger

On Numerically Solving Continuous Space Dynamic Route Choice Problems
Authors: *Hoogendoorn, Daamen, Campanella*
Speaker: Serge Hoogendoorn - Delft University of Technology
This contribution describes a new approach to numerically solve the problem of finding optimal routes in continuous time and space, for instance in modeling pedestrian route choice modelling (see Hughes (2002), Hoogendoorn and Bovy (2005), and in location choice theory (see Beckman (1952), Puu and Beckman (1999), Yang and Wong (2000)). This contribution focuses on the numerical solution of the problem. The numerical solution approach proposed by Hoogendoorn and Bovy (2004) entails using an equidistant, rectangular grid. This method yields problems in particular when considering areas that have a complex shape, or in which complex obstacles are present. Using an equidistant grid then often requires one to use a fine-grained mesh, which may yield computational difficulties in terms of computation time and memory use. For many applications, a non-equidistant mesh will be beneficial since this will allow use a fine-grain mesh, only where necessary. Finite element approaches have been put forward to solve the static shortest path problem in continuous space (Ho and Wong,2005). These approaches use triangulatization to approximate the area modeled. However, the approach is quite complex and computationally demanding. The approach put forward in this contribution is more straightforward and based on the analogy with controlled Markov jump processes. It is computationally efficient, while maintaining the flexibility to use a non-equidistant triangular mesh.

Trip-based Route Choice Models - a Method to Eliminate Aggregation Bias In Activity-based Models
Authors: *Nielsen*
Speaker: Otto Anker Nielsen - Technical University of Denmark (DTU)
The paper compares trip-based assignment procedures with traditional matrix-based procedures. The main benefits of trip-based procedures are 1) that the full information about trips from the demand modelling can be utilised in the assignment, and 2) that the calculation of Level of Services (LoS) are consistently feed back into the demand model. This is especially beneficial in activity-based models, as the detailed casual relationships in the demand model can then be reflected in the assignment procedure. Traditionally, trip-based assignment models are rejected due to calculation times. In the paper it is shown, that this indeed may not be a valid argument concerning the tendency to increase the number of zones, time of day intervals and trip purposes in demand models, including especially activity-based models. It is shown that the theoretical calculation complexity of large-scale models may indeed be comparable or even smaller in trip-based assignment procedures than in traditional matrix-based. This is exemplified on the Copenhagen traffic model. The core issue concerning calculation complexity is that the trip-based assignment depends on the number of trips and the network size. The zone-based models depend on the number of matrices, zones and the network size. This means, that the trip-based models are slower than zone-based, if the network is small or the number of zones and trip-matrices is low. In small cases calculation time is usually not an issue though. If - however - the model consists of many zones and matrices, then the trip-based assignment seams to be more efficient in terms of calculation time.

Session 5A: Congestion and spillback models

Monday 06/11 17:30 - 19:00 Room: Kata
Chairman: Michael Ball

An Analytic Finite Capacity Queueing Network Model Capturing Congestion and Spillbacks
Authors: *Osorio, Bierlaire*
Speaker: Carolina Osorio - TRANSP-OR, EPFL
Analytic queueing networks constitute a flexible tool for the study of network flow. They are simple to manipulate and their analytic aspect renders them suitable for use within an optimization framework. Queueing network models often assume infinite capacity for all queues. For real systems this infinite capacity assumption does not hold, but is often maintained due to the difficulty of grasping the between-queue correlation structure present in finite capacity networks. This correlation structure helps explaining bottleneck effects and spillbacks, the latter being of special interest in networks containing loops because they are a source of potential gridlocks. We present an analytic queueing network model which acknowledges the finite capacity of the different queues. The between-queue correlation is captured via structural parameters. By explicitly modelling the blocking phase the model yields a description of the congestion effects and their scope upon the rest of the network. A decomposition method allowing the evaluation of the model is also described. Unlike pre-existing methods the network topology and its configuration are preserved throughout the analysis, this renders the method suitable for use within an optimization framework. This method has been validated by comparison to both pre-existing methods and to exact models. These results are available and will be presented. This is an ongoing project and we are currently working on the application of this method on a large scale case study which will also be presented.

The Need Of Spillback Simulation In Assessing Robustness: Concepts and a Case Study with Dynamic Route Choice
Authors: *Knoop, Hoogendoorn*
Speaker: Victor Knoop - Delft University of Technology
Robustness of a network is, as main aim for road network managers these days, becoming an important study area for transportation scientists now. This paper studies one specific aspect of robustness: the consequences of the blocking of a link in a road network using a traffic simulator. In a regional size road network simulation study, sequentially links are blocked and the simulation program determines the network performance, both with a route choice adapted to daily congestion and a route choice adapted to the actual situation. A special feature in the new simulator proposed here is that the representation of spillback can be switched on and off; thus, effects of spillback can be examined explicitly. Road network robustness and characteristics of vulnerable links are evaluated for both spillback and non-spillback cases. It is found that spillback simulation is necessary for the estimation of the robustness of the network as a whole. Simulation of spillback is also needed to assess the impact of the blocking of a specific links; furthermore, without simulating spillback, it is not possible to identify correctly the most vulnerable links for the network performance. Using a simulator with spillback, it is found that the blocking of a freeway link has more impact than the blocking of a non-freeway link.

Queueing Models Revisted: Analysis Of Vehicular Delays and Queues Using Adaptive Control at Intersections and Ramps
Authors: *Mirchandani, Zou*
Speaker: Pitu Mirchandani - University of Arizona
Microsimulation models are normally used to evaluate traffic-adaptive signal control systems. In this paper we develop a new analytical model for analyzing vehicular delays and queue distributions at an undersaturated intersection operating with a two-phase signal, where the vehicle arrival process is Poisson, for both fixed-timing signal control and traffic-adaptive signal control. A numerical algorithm is developed to compute steady-state performance measures. Comparison of numerical results shows the benefits of adaptive signal control over optimized fixed-timing control. We show specifically that, with adaptive control, the average delays are significantly decreased over the fixed-timing case. We also compare the results with simulation-based results and, indeed, the analytical models predict well the simulation results.

This type of analysis is also used for locally adaptive ramp metering where the metering rate changes depending on arrivals and queues at an on-ramp. We develop a model to analyze a simple strategy where the metering rate increases (i.e. more cars are let through the ramp) when a spillback detector reaches a specified occupancy rate.

Session 5B: Inventory I

Monday 06/11 17:30 - 19:00 Room: Kamala
Chairman: Frederic Semet

A Multi-item Transportation Problem By Capacitated Vehicles with a Joint Set-up Cost
Authors: *Anily, Tzur, Wolsey*
Speaker: Shoshana Anily - Tel Aviv University
We consider a multi-item transportation problem by capacitated vehicles in which there are item-periodic demands, and unit production and storage costs. In addition, transportation of any mix of items is done by vehicles of fixed size, and there is a fixed set-up cost per vehicle in each period. Suppose that the unit production costs are constant over time, the storage costs are nonnegative, and for any two items the one that has a higher storage cost in one period has a higher storage cost in every period. Then we show that there is a linear program with $O(mT^2)$ constraints and variables that solves the multi-item transportation problem, thereby establishing that it is polynomially solvable, where m is the number of items and T the number of time periods. This generalizes an earlier result of Anily and Tzur who presented a $O(mT^{m+5})$ dynamic programming algorithm for essentially the same problem. Under additional conditions, a similar linear programming result is shown to hold in the presence of backlogging when the vehicles' capacity is arbitrarily large. Brief computational results with varying vehicle sizes are presented and discussed.

Formulations, Bounds and Heuristic Methods for a Multi-echelon Location-distribution Problem
Authors: *Gendron, Semet*
Speaker: Bernard Gendron - CIRRELT-Université de Montréal
We consider a multi-echelon location-distribution problem arising from an actual application in fast delivery service: a mail-order company offers several products that must be delivered on time to the customers requesting them. To satisfy these requests, the firm operates a multi-echelon distribution system: starting their trips from a small set of hubs, a fleet of medium-size trucks delivers the products to depots, where they are transferred on small-size trucks, and then shipped to satellites, where the products are sorted and delivered to the customers. The company exploits existing facilities for the depots and the satellites, but has to pay to use them. The problem is to ensure that customers' requests are satisfied on time at minimum cost, taking into account the transportation costs and the location costs for using the depots and the satellites. We model the problem by defining a network for which the only possible connections are those that may ensure on time delivery of the products to the customers. In addition, we assume that for each satellite, the set of customers and the routes used to satisfy their requests have been determined in a preprocessing phase. Hence, the model does not include any routing aspect. Transportation costs between hubs and depots, and between depots and satellites, vary with the distance travelled, and with the number of vehicles used on each arc, each type of vehicle having an associated capacity. A fixed cost is incurred when using any depot, while the satellite location cost increases with the number of batches of products handled at the satellite. We present two formulations for this problem: an arc-based model and a path-based model. We show that the linear programming (LP) relaxation of the path-based model provides a better bound than the LP relaxation of the arc-based model. We also compare the binary relaxations, which are obtained by relaxing the integrality constraints for all but the 0-1 design variables. We show that the binary relaxations of the two models provide the same bound, but that the path-based binary relaxation is preferable from a computational point of view, since it can be reformulated as a simple plant location problem (SPLP). We also show that the LP relaxation of this SPLP reformulation provides a better bound than the LP relaxation of the path-based model. Finally, we present computational results on solving a large-scale application with heuristic methods.

Planning a Distribution Chain - a Case From the Swedish Pulp Industry
Authors: *Andersson*
Speaker: Henrik Andersson - Linköpings universitet
In this extended abstract, two different planning philosophies for a distribution chain management problem are analyzed and compared. The distribution chain is taken from a real world case in the pulp industry, and the main focus is on the ship routing and scheduling. Unlike many other models for ma-

rine distribution chains, the customers are not located at the discharge harbors in this case. This means that the model proposed also incorporates the distribution planning from the discharge harbors to the customers. All customers are not served from the discharge harbors; some are served directly from the mill using trucks and trains to distribute the pulp and these decisions are also included in the model. The problem is modeled as a mixed integer linear program and solved using the branch and price scheme. Due to the complexity of the problem, the solution strategy is divided in two phases, where the first emphasizes the generation of schedules for the fleet operated by the company while the second deals with the chartering of vessels on the spot market.

Session 5C: Origin-destination flow estimation

Monday 06/11 17:30 - 19:00 Room: Nai Harn
Chairman: Philippe Toint

Handling Inconsistency Of Traffic Counts In Path Flow Estimator
Authors: *Chen, Chootinan*
Speaker: Anthony Chen - Utah State University
Path Flow Estimator (PFE) is a one-stage network observer proposed to estimate path flows and hence origin-destination (O-D) flows from traffic counts in a transportation network. Although PFE does not require traffic counts to be collected on all network links when inferring unmeasured traffic conditions, it does require all available counts to be reasonably consistent. This requirement is difficult to fulfill in practice due to errors inherited in data collection and processing. The original PFE model handles this issue by relaxing the requirement of perfect replication of traffic counts through the specification of error bounds. This method enhances the flexibility of PFE by allowing the incorporation of local knowledge, regarding the traffic conditions and the nature of traffic data, into the estimation process. However, specifying appropriate error bounds for all observed links in real networks turns out to be a difficult and time-consuming task. In addition, improper specification of the error bounds could lead to a biased estimation of total travel demand in the network. This paper therefore proposes the norm approximation method capable of internally handling inconsistent traffic counts in PFE. Specifically, three norm approximation criteria are adopted to formulate three Lp-PFE models for estimating consistent path flows and O-D flows that minimize the deviation between the estimated and observed link flows. A partial linearization algorithm embedded with an iterative balancing scheme and a column generation procedure is developed to solve the three Lp-PFE models. In addition, the proposed Lp-PFE models are illustrated with numerical examples and the characteristics of solutions obtained by these models are discussed. Keywords: Origin-destination estimation, path flow estimator, stochastic user equilibrium, norm approximation, partial linearization method.

A Continuously Differentiable Optimization Approach for the Equilibrium-based Origin-destination Matrix Estimation Problem
Authors: *Meng, Yang*
Speaker: Qiang Meng - Department of Civil Engineering, National University of Singapore
This paper addresses the origin-destination matrix estimation problem from link traffic counts with asymmetric user equilibrium constraints. It first presents a mathematical program with equilibrium constraints (MPEC) model for the O-D matrix estimation problem. The MPEC model is then reformulated as a classical continuously differentiable optimization problem by means of the gap functions derived for variational inequalities. After developing an exact mathematical expression for the gradient of the gap function in the reformulated problem, this paper employs an augmented Lagrangian algorithm for finding a solution of the origin-destination matrix estimation problem. The model and algorithm are finally demonstrated with several numerical examples.

Investigating the Reliability Of the O-d Matrix Correction Procedure Using Traffic Counts
Authors: *Marzano, Papola, Simonelli*
Speaker: Vittorio Marzano - Università di Napoli
The estimation/correction of the o-d matrix from traffic counts is one of the most classical problems in transport engineering, by means of which practitioners usually address the overall simulation model reliability. In spite of that, few researchers have focused their attention on a systematic analysis of to what extent this procedure is reliable enough to correct the whole system of models. This paper aims at generalizing the results of a recent work by Papola and Marzano (2006), who proposed an investigation of the properties of the GLS estimator in the static un- congested case, confirming the shortcomings of the GLS estimator and analysing its performances in a pseudo-dynamic context. In more detail, the possibility of using more subsets of link counts observed in sub-intervals of the time interval chosen for the o-d matrix estimation is explored as a way to provide for a more effective balance of equations and unknowns in the GLS estimation procedure and, consistently, to increase its performances. For this aim, a pseudo-dynamic laboratory experiment has been carried out. In more detail, referring to a time interval wherein the distribution shares could be assumed as constant, “true” generation demand profiles and a

matrix of “true” distribution shares have been used as input for an assumed “true” dynamic assignment model in order to obtain the “true” link flows profiles. Then, the GLS estimator has been applied to a number of scenarios, wherein perturbations of the distribution shares as well as of the link count profiles have been introduced analysing to what extent the link counts information was able to effectively correct the distribution shares in the different cases. The laboratory experiments have been carried out on several test networks with different size and centroids, as well as on real networks. The join between the results of this work and the previous analyses carried out in the static case allows lightening the GLS-based o-d matrix correction procedure from a practical perspective.

Session 6A: Hazardous material transportation

Tuesday 06/12 09:00 - 10:30 Room: Kata
Chairman: Louis-Martin Rousseau

A Bi-level Network Flow Model for Planning Hazmat Shipments
Authors: *Bianco, Caramia, Giordani*
Speaker: Stefano Giordani - Dip. Ingegneria Impresa - University of Rome Tor Vergata
In the global route planning of hazmat shipments, hazmat routing is a many to many routing problem with multiple origins and multiple destinations, and the objective is to define multi-commodity and multiple origin-destination route plans. If these plans are made independently with respect to each other without taking into consideration the general context, certain links of the transport network tend to be overloaded with hazmat traffic. This could result in a considerable increase of accident probabilities on some road links as well as leading to inequity in the spatial distribution of risk. In this paper we propose a bi-level network flow model for the hazmat shipment global route planning based on the concept of k-splittable flow. The model addresses both the total risk minimization and the equity distribution of the risk over the population.

An Exact Algorithm for a Vehicle Routing Problem with Time Windows and Multiple Use Of Vehicles
Authors: *Gendreau, Azi, Potvin*
Speaker: Michel Gendreau - CIRRELT/Université de Montréal
We consider a variant of the standard Vehicle Routing Problem with Time Windows where each vehicle can be assigned to several routes during a given planning period. This problem is encountered in the home delivery of perishable goods, for which routes must be of short duration and need to be combined to form complete working days. We first recall an exact algorithm for the case where the fleet is limited to a single vehicle. Our problem-solving approach is divided into two phases: all feasible routes are first identified; then, we create a working day for the vehicle, by combining the feasible routes generated previously. We then show how our solution approach can be extended to tackle situations where several vehicles are present. This involves imbedding the single-vehicle algorithm in a column generation framework and using branch-and-price to obtain integer solutions. Extensive computational results on problem instances derived from Solomon's benchmark problems (for the Vehicle Routing Problem with Time Windows) will be reported and discussed.

A Lead-time Based Approach for Planning Rail-truck Intermodal Transportation Of Dangerous Goods
Authors: *Verter, Verma*
Speaker: Vedat Verter - McGill University
Intermodal transportation has experienced a phenomenal growth over the past two decades, and continues to be one of the rapidly growing segments of the transportation industry. This has been attributed to the competitive pressures on global supply chains, the increasing demand for new service patterns driven by ocean carriers as well as the globalization of industry. Rail-truck intermodal transportation (IM) combines accessibility advantage of road networks with scale economies associated with railroads in moving shipments. In comparison with the use of traditional train services, the main attractiveness of IM for shippers is its reliability in terms of on-time delivery. In addition to regular freight, IM has been used for moving hazardous materials (hazmats) since 1970s. The volume of cargo that is potentially harmful for human health and the environment have increased significantly over the past two decades. For example, the Bureau of Transportation Statistics estimated that in 1997 over one and half million tons of hazmats were shipped across the U.S. intermodal transportation system. This statistic is already qualified as an underestimate by the 2002 Commodity Flow Survey in the U.S. In addition, the U.S. Chemical Manufacturers Association estimates that the total volume of hazmats shipped by 2020 will be 5.1 billion tons, which according to the U.S. Department of Transportation will be increasingly carried via intermodal transportation channels. Despite the increasing significance of IM in carrying hazmats, this is an area that has not been studied in hazmat logistics literature. In this paper, we present a first attempt for the development of an analytical framework for planning rail- truck intermodal transportation of hazmats. As a basic problem, we focus on a single pair of intermodal rail terminals (IMRTs),

with a number of intermodal train services between them. Since the current network of IMRTs is rather sparse in North America, a significant majority of the shippers have a single IMRT in their vicinity. A bi-objective optimization model to plan and manage intermodal shipments where route determination is driven by the delivery-time (or, lead-time) specified by the customers is developed. Transport risk is represented by population exposure due to the truck and rail shipments. The proposed solution methodology takes advantage of the analytical properties of the problem. A realistic size problem instance from Canada is solved, and will be used for presenting a number of managerial insights.

Session 6B: Routing II

Tuesday 06/12 09:00 - 10:30 Room: Kamala
Chairman: Martin Savelsbergh

Network Design, Scheduling and Deployment Planning In Shipping Applications
Authors: *Andersen*
Speaker: Martin W. Andersen - Centre for Traffic and Transport, Technical University of Denmark
This paper discusses the problem of designing a service network in a liner container shipping context. The problem consist of determining a strat- egy for routing and scheduling a heterogeneous řeet of vessels over a pre- determined set of nodes (ports). The design is determined by a set of com- modities that are assumed known and which must be routed across the network. Furthermore, a number of business, physical and regulatory con- straints restrict the feasible routings. The liner container shipping (LCS) problem is implemented as a MIP model which is fundamentally an extension of the multicommodity capac- itated network design problem (MCND). The LCS model takes transship- ments, distinctive vessels, and node balance constraints into account. The model is relaxed in a Lagrangian fashion which yields a number of subproblems that are essentially minimum cost circulations with resource constraints. These are recast and solved as shortest path problems with resource constraints. Experiments are conducted based on randomly gen- erated data and the obtained bounds from the Lagrangian relaxed problem are compared to the ordinary LP bounds.

An Optimization-based Heuristic for the Split Delivery Vehicle Routing Problem
Authors: *Archetti, Savelsbergh, Speranza*
Speaker: Claudia Archetti - University of Brescia
In vehicle routing problems (VRPs) a set of customers needs to be served and a fleet of capacitated vehicles is available to do so. The objective is the minimization of costs, which usually means minimizing the total distance traveled. In most VRPs it is assumed that the demand of a customer is less than or equal to the capacity of a vehicle and that each customer has to be served by exactly one vehicle, i.e., there is a single-visit assumption. While it is obvious that when a customer's demand exceeds the vehicle capacity it is necessary to visit that customer more than once, it requires only a little more thought to see that even when all customer demands are less than or equal to the vehicle capacity, it may be beneficial to use more than one vehicle to serve a customer. In the split delivery vehicle routing problem (SDVRP) the single-visit assumption is relaxed and each customer may be served by more than one vehicle. While the SDVRP has received little attention in the past, compared to other variants of the VRP, it has recently been studied by a number of researchers. In this work we propose a solution approach for the SDVRP that integrates heuristic search with optimization. The proposed approach is based on two main ideas. The first is to use the information provided by a tabu search heuristic to identify parts of the solution space that most likely contain good solutions. The second idea is to explore these parts of the solution space by means of a suitable integer programming model. The computational results we have obtained are encouraging and validate the interest in non-traditional uses of integer programming. The proposed optimization-based heuristic was able to improve the solution produced by the tabu heuristic in all but one instance in our test set.

A Metaheuristic Approach for the Operational Planning Of Freight Intermodal Transportation
Authors: *Siri, Sacone, Paolucci, Anghinolfi*
Speaker: Silvia Siri - University of Genova - Dept. of Communication, Computer and System Science
The objective of this work is the definition of an optimization problem for the quasi-operational planning of intercity freight transportation operations, with the possibility of intermodal (road and rail) transport. More specifically, this optimization problem, named Intermodal Assignment Problem (IAP), refers to the planning of transportation operations of fruit and vegetable products from a certain origin to a given destination, in order to meet some specific constraints (such as requested place and time of picking up and delivering, required service level, availability of trucks and trains) and minimizing the total transportation costs. We are thus facing a long-haul transportation problem, in which quasi-operational planning decisions are needed, concerning the static allocation of transportation resources with some specific constraints, and the timetabling of the necessary transportation operations. In order to face the

IAP also when the required computation time makes the use of the mathematical programming formulation not practical, an Ant Colony Optimization metaheuristic approach is proposed. In particular, the ACO algorithm is basically inspired by the Ant Colony System and Max-Min Ant System versions of the basic algorithm.

Session 6C: Route Choice II

Tuesday 06/12 09:00 - 10:30 Room: Nai Harn
Chairman: Otto Anker Nielsen

Stochastic Path Generation Algorithm for Route Choice Models
Authors: *Frejinger, Bierlaire*
Speaker: Emma Frejinger - TRANSP-OR, EPFL
Defining choice sets is necessary when modeling route choice behavior using random utility models. Since the number of paths between a given origin-destination pair may be intractable, path enumeration algorithms are used for this purpose. In this paper, we present a new point of view on choice set generation. In contrast to existing approaches, we hypothesize that all paths connecting the origin to the destination belong to the "true" choice set. In this context, we view stochastic path enumeration algorithms as importance sampling of alternatives. For this type of sampling protocol it is necessary to correct the path utilities in order to obtain unbiased parameter estimates. We propose a stochastic path enumeration algorithm that makes the definition of such a sampling correction possible. Some preliminary numerical results are presented.

Estimation Of a Route Choice Model with Congestion and Congestion Charging Explicitly Described
Authors: *Rich, Mabit, Nielsen*
Speaker: Jeppe Rich - Centre for Traffic and Transport
Route choice models are the behavioral component in traffic assignment algorithms and serves as the important linkage between travel demand and network effects. In this paper we present a model for route choices explicitly taking congestion and congestion charging into account. Based on a large pool of routes, which has been monitored by GPS technology, we suggest a choice set algorithm, which allow alternatives to be formed as sub-path candidates as well as "complete" candidates as they are present in the GPS data. In this way, large potential choice sets can be formed allowing for a discrete choice estimation. The paper has three contributions. First is consolidates the still limited use of route choice models based on GPS data. Second it proposes a new choice-set generation method based on the use of sub-path candidates. Third it investigates the valuation of congested time compared to free flow time and the valuation of congestion charging compared to other out-of-pocket costs to be used in assignment models.

Some Properties and Implications Of Stochastically Generated Route Choice Sets
Authors: *Bliemer, Bovy, Li*
Speaker: Piet Bovy - Delft University of Technology
Choice sets of individual travelers are important in analyzing travel choice behavior. In this paper the focus will be on route choice sets, which are generated using a repeated stochastic shorthest path method. This simple method is illustrated on two simple example networks, showing that the method can distinguish easily between attractive and unattractive routes. By analyzing statistical properties of the route choice set, it is possible to determine some general rules for determining the number of necessary iterations for obtaining a choice set of a certain size and composition. Finally, it is shown that the route choice set has a large impact on the route choice proportions in applications. It turns out that the path-size logit model predicts very different choice proportions for the same routes, depending on the route choice set considered, as shown in a simple network example.

Session 8A: Online routing

Tuesday 06/12 14:50 - 15:50 Room: Kata
Chairman: Enrico Angelelli

New Competitive Ratios for Generalized Online Routing
Authors: *Wagner, Jaillet*
Speaker: Michael Wagner - California State University East Bay
We consider online routing optimization problems where the objective is to minimize the time needed to visit a set of locations under various constraints; the problems are online because the set of locations are revealed incrementally over time. We make no probabilistic assumptions whatsoever about the problem data. We consider two main problems: (1) the online Traveling Salesman Problem (TSP) with precedence and capacity constraints and (2) the online TSP with m salesmen. For both problems we propose online algorithms, each with a competitive ratio of 2; for the m-salesmen problem, we show our result is best-possible. We also consider polynomial-time online algorithms as well as various generalizations of our results.

Online Routing with Nonlinear Disutility Functions In Networks with Markovian Arc Costs
Authors: *Boyles, Waller*
Speaker: S. Travis Waller - The University of Texas at Austin
In networks with dynamic and stochastic arc costs, minimizing expected travel cost may not be the most relevant goal, and one might also wish to minimize the uncertainty in cost as well. This paper investigates this problem for transportation networks with Markovian arc costs, where travelers may use information learned en route to update their routing decisions. A pseudopolynomial algorithm is developed that determines the online routing policy when a traveler's preferences are specified by any piecewise polynomial disutility function, which generalizes some previous research in reliable routing by allowing risk-averse or risk-loving behavior to be modeled. Complications in cyclic networks are briefly discussed, and bounds on cycling behavior are introduced to address these.

Session 8B: Collaborative Logistic

Tuesday 06/12 14:50 - 15:50 Room: Kamala
Chairman: Mikael Rönnqvist

A Column Generation Approach for the Door Assignment In Ltl-terminals
Authors: *Chmielewski*
Speaker: Annette Chmielewski - University of Dortmund
In less-than-truckload (LTL) terminals arriving trucks, so-called tours, have to be assigned to inbound doors and to suitable time slots for unloading. Simultaneously, waiting trucks - each representing an offered relation in the underlying transportation network - have to be allocated to outbound doors. During a couple of hours, shipments from all incoming trucks have to be unloaded, sorted according to their relation, transported to the right outbound door and loaded on the outgoing truck. The overall assignment decision and the resulting inner material flow determine the utilization level of the inner resources, e.g. forklift trucks and buffer areas. One aim is to minimize the total distance when transshipping units, the second aim is to minimize the waiting time for each truck. A time-discrete multi-commodity flow model with side constraints has been developed to represent the assignment decisions to doors and to time slots as well as the inner material flow. Inbound and outbound doors as well as buffer areas and relations are represented by different node layers in the network which is closed by a common source and sink node. Arcs are implemented between the node layers. The first arc layer represents the assignment decision of arriving tours to inbound doors. The fifth arc layer represents the assignment of waiting relations to outbound doors. Arc layers three, four and five stand for the logistical processes unloading, inner transport and loading. A flow variable for each arriving tour is implemented on the arcs (commodities). The nodes and arcs are duplicated for each time slice in the optimization period. Resources can be assigned to each subset of arcs indicating a certain inner process in a certain time slice. Their capacities have to be kept when assigning flow variables to the arcs. Unsplittable flow conditions apply for subsets of nodes in the first and fifth layer as trucks can just be assigned to one door. The underlying model is related to quadratic assignment problems and NP-hard. The Branch-and-Cut algorithm (CPlex 10.0) has been applied to 30 test scenarios and showed too slow solution times. Nevertheless, reinterpretation of the optimization results to the world of logistics showed that the time-discrete multi-commodity flow model with side constraints is suitable for the task. Therefore, the challenge for research in this paper was to develop a faster algorithm that is based on the applicable model. In this regard, a decomposition approach has been introduced by defining feasible 'routings for each tour' through the time-discrete network. Based on this decomposition, a binary model for the optimal choice of routings for each tour was created. Within this model, certain common resource capacities and technical assignment restrictions have to be kept. The decomposition approach allows to work in two models, one for the creation of good single routings and one for the optimal choice of routings for each incoming tour. After introducing a relaxation to the binary variables of the choice model, the concept of implicit column generation can be applied to the problem and the relaxed choice model acts as restricted master problem (RMP). A column is equivalent to a routing for a certain tour through the time-discrete network. If the original time-discrete multi-commodity flow model with side constraints is defined solely for a single tour and enlarged by the dual variables of the RMP, it can be used as pricing model. After having solved the RMP, the dual variables are passed to the pricing model to create new routes or columns with negative reduced costs. An iterative process has started. At the end of this process, the integrality property is restored for the choice model and the Branch-and-Cut algorithm is applied on the current column pool. Experiments have shown that the new approach outperforms the standard algorithm for mixed-integer problems concerning objective function value especially for middle-sized and big problems. In a future work the column generation approach will be integrated in a Branch-and- Price concept.

Collaborative Planning In a Log Truck Pickup and Delivery Problem
Authors: *Audy, D'Amours, Rousseau*
Speaker: Sophie D'Amours - Université Laval
In this paper, we detail the collaborative pickup and delivery problem (PDP) of a network of business units in the forest products industry. This vehicle routing problem involves a set of new practical considerations adding other constraints to the classical PDP and modifying its basic cost structure. A solution methodology for the given vehicle routing problem is described and tested in order to demonstrate trans-

portation cost-savings by collaborative planning. A case study involving a network of business units in Canada shows interesting cost-savings and reduction in traveling distance through collaboration.

Session 8C: Airline optimization

Tuesday 06/12 14:50 - 15:50 Room: Nai Harn
Chairman: Manoj Lohatepanont

Airline Disruptions: Aircraft Recovery with Maintenance Constraints
Authors: *Eggenberg, Bierlaire, Salani*
Speaker: Niklaus Eggenberg - EPFL - ENAC
In this paper we consider the recovery of an airline schedule after an unforeseen event, commonly called disruption, that makes the planned schedule unfeasible. In particular we consider the aircraft recovery problem for an heterogeneous fleet of aircrafts, made of regular and reserve planes, where the maintenance constraints are explicitly taken into account. We propose a multicommodity network flow model, where each commodity represents a plane, a dynamic programming algorithm to build the underlying network and an heuristic algorithm based on column generation. We provide some computational results on instances obtained from a medium-sized airline.

Robust and Dynamic Airline Scheduling
Authors: *Barnhart, Marla*
Speaker: Cynthia Barnhart - Massachusetts Institute of Technology
Robust and Dynamic Airline Scheduling Cynthia Barnhart Lavanya Marla Massachusetts Institute of Technology Cambridge, MA USA 02139 (barnhart @mit.edu) Airline flight and crew scheduling problems, with inherent complexity arising from their large-scale nature and tight coupling of their various elements, are ideal candidates for the application of optimization techniques. Conventional optimization techniques, however, often include simplifying and unrealistic assumptions, such as deterministic model inputs. These simplifications lead to the generation of solutions that lack robustness, thereby: 1. creating the need to re-plan at regular intervals when realized operations do not match those for which the plan was developed; and 2. resulting in added costs and increased complexity of operations. In this research, we develop new models and algorithms aimed at providing robust solutions. These robust approaches are designed to provide solutions that: 1) are less fragile to disruption; 2) are easier to repair if needed; and 3) optimize the realized, rather than planned, problem objective. There are various approaches to dealing with uncertainties affecting planned routes and schedules. One approach is to allow operating conditions to be realized, and then respond to disruptions by altering the plan when the original plan is rendered non-operational. A more proactive approach is to anticipate potential plan disruptions in the planning stage, either by: 1. Building robustness into the plan; and/ or 2. Dynamically altering the plan to reflect the additional information available as the time of plan operation approaches. Our research, as detailed below, is organized around these two strategies. Robust Planning Airlines typically construct their schedules assuming that every aircraft departure and arrival will occur as planned. Because this optimistic scenario rarely, if ever, occurs, plans are frequently disrupted and airlines incur significant costs to repair and operate the modified plans. To reduce the added costs and operational complexity that results from responding to disruptions, and to reduce the need to repair previously optimized plans, we develop optimization approaches aimed at generating robust solutions that require fewer repairs and minimize the sum of planned and recovery costs. In developing our robust planning approaches, we pursue two different modeling directions, namely: 1. We expand upon the parameterized, robust optimization methods presented by Bertsimas and Sim (2004) and Charnes and Cooper (1963). In both the Bertsimas and Sim and Charnes and Cooper approaches, the robust optimization models contain robustness parameters that can be tuned to reflect the desired trade-off between cost and time. Achieving the desired trade-off can be accomplished by solving the optimization model repeatedly, each time with different values of the robustness parameters. Because we are interested in solving large-scale problems for which achieving multiple solutions can be impractical, we modify the Bertsimas and Sim and the Charnes and Cooper approaches to determine, in a single solution of the models, the most robust solution attainable for a given robustness budget. We define a robustness budget as the deviation from the optimal (deterministic) solution value that is allowed to provide a more robust solution. Like Bertsimas and Sim and Cooper and Charnes, we model our budget-constrained robust optimization model as a non-linear, integer program and show that there exists an equivalent linear, integer formulation. 2. We expand on attribute-driven robust optimization approaches in which robust solutions are generated by identifying attributes of a robust solution. (For a survey of these approaches in the airline industry,

see Ball, et al. 2006). This is achieved through model modifications ensuring that optimal solutions are those for which the presence of these attributes is maximized. Using this attribute-driven robust optimization approach, we define new models for aircraft routing and scheduling. In our research, we describe how attribute-driven robust optimization models can sometimes be cast equivalently in the framework of parameterized robust optimization models. We then develop algorithms tailored for the solution of these robust optimization models, especially for large-scale problem instances. Finally, we apply all of these parameterized and attribute-driven models and algorithms to a particular routing and scheduling problem arising in the airline industry, and evaluate the relative performance of the corresponding solutions using data obtained from airlines. Dynamic Planning A major source of uncertainty that affects plan robustness is, demand stochasticity. Demand stochasticity is a major challenge for carriers in their quest to produce profit maximizing schedules. Even with an optimized schedule, many aircraft upon departure have empty seats, while others suffer a lack of seats to accommodate passengers who desire to travel. We approach this challenge, recognizing that demand forecast quality for a particular operating date improves as the date approaches, by developing a dynamic scheduling approach that re- optimizes elements of the plan during the passenger booking process. The goal is to match capacity to demand, given the many operational constraints that restrict possible assignments. We introduce re-timing as a dynamic scheduling mechanism and develop re-optimization models that integrate re-timing and re-fleeting mechanisms. Our re-optimization approach, re-designing the plan at regular intervals, utilizes information from both booking data and forecasts available at the time of re-optimization. Using data provided by airlines, we demonstrate that significant potential profitability improvements are achievable using our approach. Moreover, we evaluate the sensitivity of our approach to the quality of the forecasted demands and show that, even with simplistic approaches to demand forecasting, estimated profit improvements can remain significant. Finally, we compare and contrast the individual contributions of robust planning and dynamic scheduling techniques, and evaluate whether or not their effects are synergistic. References Ball, M., Barnhart, C., Nemhauser, G., and Odoni, A. (2006). “Managing Air Traffic and Airline Operations for Schedule Reliability,” to appear in Operations Research Handbook on Transportation, Gilbert Laporte and Cynthia Barnhart (co-editors). Bertsimas, D., and Sim, M., (2004). “The Price of Robustness”, Operations Research, Vol. 52 (1) 35-53. Charnes, A., Cooper, W.W., (1963). “Deterministic Equivalents for Optimizing and Satisficing under Chance Constraints”, Operations Research, Vol. 11(1), 18-39.

Session 9A: Cost and pricing analysis

Tuesday 06/12 16:00 - 17:00 Room: Kata
Chairman: Luce Brotcorne

Cost Allocation Principles In Transportation
Authors: *Ronnqvist, Gothe-Lundgren, Jornsten, Frisk*
Speaker: Mikael Rönnqvist - Norwegian School of Economics and Business Administration
Transportation planning is an important part of the wood flow chain in forestry. There are often several forest companies operating in the same region and co-ordination between two or more companies is however rare. Lately, there has been an increased interest in collaborative planning as the potential savings are large, often in the range 5-15

Pricing and Scheduling Strategies for Carriers and Shippers In Sequential Transportation Auctions
Authors: *Mes, Van der Heijden*
Speaker: Martijn Mes - University of Twente
In this paper we study the interaction between carriers and shippers in a transportation marketplace. Shippers offer time-sensitive truckload pickup-and-delivery jobs through sequential auctions. Carriers compete with each other to service these jobs. We focus on profit maximizing strategies for both, shippers and carriers. To model this marketplace we use a multi-agent system where carrier decisions are taken by vehicle agents and shipper decisions by shipper agents. For the vehicle agents we focus on pricing and scheduling decisions where not only the direct costs of jobs are taken into account, but also the impact on future opportunities. For the shipper agents we focus on reserve prices and decommitment penalties. Shippers use reserve prices to make a trade-off between a certain price that can be paid immediately and a possible lower price that can be paid if the job is sold at a later pint in time. Decommitment penalties are used to enable carriers to break a commitment against a certain penalty. We use simulation to evaluate the benefits of different strategies and to study their interrelation.

Session 9B: Inventory routing I

Tuesday 06/12 16:00 - 17:00 Room: Kamala
Chairman: Luca Bertazzi

Inventory Routing Problem for the Lng Business
Authors: *Gronhaug, Christiansen, Desaulniers, Desrosiers*
Speaker: Roar Grønhaug - Norvegian University of Science and Technology
In this paper we analyze the transportation of liquefied natural gas (LNG) in close cooperation with a worldwide actor within the LNG business. We consider the routing and scheduling of the LNG tankers between the liquefaction plants and regasification terminals, in addition to the management of the inventories at these plants and terminals. This problem can be categorized as a maritime inventory routing problem. Such problems are rarely described in the literature. We are solving the problem with a column generation solution approach where the master problem handles the inventory management and the subproblems handle the ship routing and scheduling. Two different network structures are developed for the subproblems. Comparisons of them will be given.

Multi-item Inventory Routing Problem for Ship Distribution Of Liquid Oil Bulk Products
Authors: *Giesen, Munoz, Silva, Leva*
Speaker: Ricardo Giesen - Pontificia Universidad Catolica de Chile
In this work a real ship planning problem is presented, which is a combined multi-item inventory management and a ship routing problem. In this sea transportation system, a fleet of ships transport multiple liquid oil bulk products. These products are transported from a set of production harbors, wherein refineries are located, to a set of consumption harbors where different customers have their tanks located. Customers in this system operate under Vendor Managed Inventory (VMI) agreements in which the supplier takes control of their tanks' inventory levels, ensuring that adequate service levels are maintained. Thus, the supplier needs to determine ships routes, i.e. sequence of harbors to be visited for each ship, quantities to be loaded and discharged for each product at each harbor, and oil products allocation to different ships' compartments so that security regulations are satisfied. A mixed-integer programming (MIP) formulation and a GRASP metaheuristic are proposed for this problem. Since the proposed MIP cannot be solved in reasonable computation time, a decomposition approach to solve this problem is presented. Finally, the proposed decomposition approach is compared against the GRASP metaheuristic.

Session 9C: Discrete choice models II

Tuesday 06/12 16:00 - 17:00 Room: Nai Harn
Chairman: Takayuki Morikawa

Implementation Of Model for Departure Time Choice
Authors: *Kristoffersson*
Speaker: Ida Kristoffersson - Royal Institute of Technology
Following rerouting, changes in departure time is one of the most common responses by car travellers to new network conditions. Yet there are few transportation models taking departure time choice into account. In this paper the project SILVESTER (SImuLation of choice betWEen Starting TimEs and Routes) is presented. Based on stated preference and revealed preference data on travel behaviour of drivers in Stockholm, a departure time and mode choice model has been estimated in a mixed logit framework. In the second, ongoing stage of the project the estimated model is implemented and connected to a dynamic traffic assignment model. Through iterations between the departure time and assignment model the objective is to forecast effects of congestion charges and infrastructure investments on departure time choice. Keywords: congestion charges, departure time choice, mixed logit, traffic simulation

Model Of Weekly Working Participation for a Belgian Synthetic Population
Authors: *Cirillo, Cornelis, Toint*
Speaker: Philippe Toint - FUNDP- University of Namur
We present in the talk an attempt to extend the analysis of the household work patterns to a weekly horizon, rather than the most common daily one. Our model is based on three surveys, MOBEL, ERMM and OVG, all conceived as travel diary and held between 1999 and 2003 in Belgium. The proposed model is based on a utility maximizing principle and assumes a weekly cycle for a household working participation program. We also discuss the parallel construction of a synthetic population for Belgium. This population consists in a set of households, themselves containing individuals. The model calibrated is then applied to the Belgian synthetic population and the activity participation shares will be compared to those reported in the surveys. A geographic performances is also envisaged; in fact accuracy of the model will be calculated both on regional and national scale.

Session 10A: Traffic prediction and assignment

Tuesday 06/12 17:30 - 19:00 Room: Kata
Chairman: Carolina Osorio

A Method Real-time Short and Long-term Traffic Prediction
Authors: *Wynter, Amemiya, Min*
Speaker: Laura Wynter - IBM Research
Real-time traffic prediction is an important component of both traffic operations and intelligent transporation systems. In addition, it is an input in many end-user route planning tools. We present a method that is effective in both short-term prediction and medium and long-term settings. Furthermore, it has the important feature of providing results in real-time.

Dynamic Queuing and Spillback In an Analytical Multiclass Dynamic Network Loading Model
Authors: *Bliemer*
Speaker: Michiel Bliemer - Delft University of Technology
In this paper a new analytical multiclass dynamic network loading (DNL) model as part of a simulation-based dynamic traffic assignment (DTA) model is proposed. In contrast to many other proposed DNL models, this model will explicitly deal with queuing and spillback without having to rely on link travel time functions as input. Different vehicle types (e.g., cars and trucks) are considered with different speeds. As will be illustrated in the paper, using link travel times is likely to under- or overestimate the true travel times in a dynamic model if queues are considered. The proposed DNL model consists of a link model and a node model, and can correctly handle dynamically changing queue lengths and outflow capacities. The link model computes queue inflows and potential outflows, while the node model determines the actual outflows depending on the node structure. In the end, the link travel times are computed backwards in time for each vehicle type separately. The model has been implemented in the INDY DTA software and an application shows that the approach is viable in real-life networks.

A Multi-agent Approach to Dynamic Traffic Assignment Based On Activity
Authors: *Ma, Lebacque*
Speaker: Tai-Yu Ma - Institut National de Recherche sur les Transports et leur Securite
The road choice behavior of travelers is closely related to their activity planning and location choice. This approach has led to the increasing development of multi-agent and activity-oriented modeling. This work attempts to model travelers' dynamic departure time/route/destination choice behavior in a queuing network. In this respect, we propose an activity-based predictive dynamic traffic assignment model based on a multi-agent approach with two interacting levels: the travelers' adaptive reaction level and the network propagation level. For the first level, traffic conditions change according to travelers' departure time/route/destination choices, dynamic traffic information and network supply constraints. En-route dynamic traffic assignment is reflected by travelers' strategies in response to the traffic state and the activity distribution information. For the second level, traffic congestion is modeled by point queue dynamics concept on a network. As a solution method of the predictive equilibrium, we propose an ACO (ant colony optimization) algorithm based on a time-dependent multi-type pheromone scheme in order to solve the proposed dynamic traffic assignment model. This algorithm focuses on how to provide dynamic on-route information and off-route information to guide travelers to make the best travel decision in a dynamic environment. The algorithm can be adapted to communication and information exchange schemes closer to actual traveler behaviour. A numerical example is given to illustrate the performance of the proposed method.

Session 10B: TSP variants

Tuesday 06/12 17:30 - 19:00 Room: Kamala
Chairman: Bernard Gendron

Heuristic Algorithms for the Robust Traveling Salesman Problem with Interval Data
Authors: *Montemanni, Barta, Mastrolilli, Gambardella*
Speaker: Roberto Montemanni - IDSIA - Istituto Dalle Molle di Studi sull Intelligenza Artificiale
The traveling salesman problem is one of the most famous combinatorial optimization problems, and has been intensively studied in the last decades. Many extensions to the basic problem have been also proposed, with the aim of making the resulting mathematical models as much realistic as possible. We study an extension to the basic problem where travel times are specified as a range of possible values. This model reflects the intrinsic diśculties to estimate travel times exactly in reality. The robust deviation criterion is adopted to drive optimization over the interval data problem so obtained. A negative result about the approximability of the problem is presented together with fast and easy-to-implement heuristic approaches. Computational experiments are presented and discussed.

Exact and Heuristic Approaches to the Double Tsp with Multiple Stacks
Authors: *Petersen*
Speaker: Hanne L. Petersen - CTT, Technical University of Denmark
The Double Travelling Salesman Problem with Multiple Stacks (DTSPMS), is concerned with determining the shortest routes for performing pickups and deliveries in two separated networks using only one container. The items can be packed in several rows in the container, such that each row must obey the LIFO (Last-In-First-Out) principle, while there are no mutual constraints between the rows. All items are uniform and no stacking is allowed. Previous work has obtained good metaheuristic solutions to the problem, and these can now be compared to results based on optimal solutions approaches.

The Capacitated Team Orienteering and Profitable Tour Problems
Authors: *Speranza, Archetti, Hertz, Feillet*
Speaker: M. Grazia Speranza - University of Brescia
In this paper we study two new problems belonging to the class of VRPs with profit, namely the Capacitated version of the Team Orienteering Problem (CTOP) and the Capacitated version of the Profitable Tour Problem (CPTP). These problems model several practical situations where a set of potential customers is given and a subset has to be identified and served. We consider a complete undirected graph, where a vertex is the depot and the other vertices represent potential customers. Each customer has a demand to be served. A nonnegative profit is associated with each customer. A symmetric travel time and a cost are associated with each edge. A set of vehicles is available to visit the customers. Each vehicle has a capacity and can visit any subset of the potential customers without exceeding the capacity. The profit of each customer can be collected by one vehicle at most. In the Capacitated Team Orienteering Problem (CTOP) a subset of the potential customers has to be selected in such a way that the constraint on the capacity of each vehicle is satisfied and the duration of the route of each vehicle does not exceed a time limit. The objective is to maximize the total collected profit. In the Capacitated Profitable Tour Problem (CPTP) a subset of the potential customers has to be selected in such a way that only the constraint on the capacity of each vehicle is satisfied. The objective in this case is to maximize the difference between the total collected profit and the cost of the total distance traveled. We propose, both for the solution of the CTOP and of the CPTP, two variants of a tabu search algorithm and a variable neighborhood search algorithm. These algorithms are compared with an exact method based on column generation and are shown to be able to find optimal or near-optimal solutions for most of the instances.

Session 10C: Models and algorithms

Tuesday 06/12 17:30 - 19:00 Room: Nai Harn
Chairman: Hani Mahmassani

A Fluid Model for the Anticipatory Route Guidance
Authors: *Kachani, Bottom, Perakis*
Speaker: GEORGIA PERAKIS - MIT
The anticipatory route guidance problem (ARG), an extension of the dynamic traffic user-equilibrium problem, consists of providing messages, based on forecasts of traffic conditions, to assist drivers in their path choice decisions. Guidance becomes inconsistent when the forecasts on which it is based are invalidated by drivers' reactions to the provided messages. In this talk, we consider the problem of generating consistent anticipatory guidance that ensures that the messages based on dynamic shortest path criteria do not become self-defeating prophecies. We design and study a framework for the ARG problem based on a fixed-point formulation and develop an equivalent variational inequality formulation of the problem. We examine the efficient solution of the problem based on averaging methods and more advanced algorithmic methods. Finally, we validate our results computationally on various test networks.

Nonlinear Global Optimization with Application to Discrete Choice Models Estimation
Authors: *Thémans, Bierlaire, Zufferey*
Speaker: Michaël Thémans - EPFL - ENAC - INTER - TRANSP-OR
In most applications related to transportation, it is of major importance to be able to identify the global optimum of the associated optimization problem. The work we present in this paper is motivated by discrete choice models widely used in transportation contexts. More particularly, we are interested in optimization problems arising in the maximum likelihood estimation procedure of those models. Estimating advanced discrete choice models becomes more and more problematic. The objective function becomes highly nonlinear and non concave. Moreover, the computational cost of evaluating the objective function and its derivatives becomes significantly high. In the case where the log-likelihood function presents several (and often many) local optima, classical unconstrained optimization algorithms can no longer be applied and we thus need specific and efficient optimization algorithms able to deal with many local optima and to identify the global one. Our goal is to propose a new efficient algorithm designed for discrete choice models estimation making a better use of information on the objective function compared to existing methods and limiting the number of objective function evaluations. More precisely, we propose an adaptation of the Variable Neighborhood Search meta-heuristic used in discrete optimization, which we combine with efficient algorithms for (local) nonlinear optimization. Contrarily to the classical VNS framework, we do not apply the local search (until we get a local optimum) to each point generated in a VNS phase. Instead, during the course of the VNS phase, we decide, by using information on the function and its derivatives, if it is worth to continue applying the local search algorithm from a given point (identifying a promising area of research) or if it is better to stop and generate new points inside the VNS (identifying a useless area of research). Different types of neighborhoods adapted for the continuous case are also considered. Local search are performed using advanced quasi-Newton algorithms globalized by the mean of trust-region and filter-trust-region techniques as well as inexact linesearch techniques. In the paper, we will first present the main features of our algorithm. Then we will present numerical results on classical optimization problems known to have several local optima. Results will be compared with different available algorithms designed to solve such problems.

The Highway Problem: Models, Complexity and Valid Inequalities
Authors: *Heilporn, Labbé, Marcotte, Savard*
Speaker: Martine Labbé - Université Libre de Bruxelles
Consider the tarification problem of maximizing the revenue generated by tolls set on a subset of arcs of a transportation network, and where origin-destination flows are assigned to shortest paths with respect to the sum of tolls and initial costs. The Highway Problem studied here is a particular case of the above problem, as one imposes that toll arcs cannot appear everywhere in the network but must constitute a path. In this paper, NP-hardness of this problem is proved. Then we address a more realistic version of the problem, for which NP-hardness is also proved. Finally, the links between the Highway Problem and a Pricing Problem in economics are investigated.

Session 11A: Road pricing II

Thursday 06/14 09:00 - 10:00 Room: Kata
Chairman: Anton Kleywegt

A Computable Theory Of Dynamic Congestion Pricing
Authors: *Friesz, Kwon, Chow, Heydecker*
Speaker: Andy Chow - University College London
The advent of new commitments by municipal, state and federal governments to construct and operate roadways whose tolls may be set dynamically has brought into sharp focus the need for a computable theory of dynamic tolls. By a computable theory we mean a mathematical representation which is detailed enough to capture the key behavioral and technological considerations relevant to dynamic tolling and which is nonetheless numerically tractable enough to obtain accurate approximations of optimal dynamic toll trajectories. Accordingly, we introduce in this paper the dynamic optimal toll problem with user equilibrium constraints whose acronym will be DOTPEC. We provide a proof of existence for plausible regularity conditions. We also present two algorithms and test both on a numerical example.

A Tabu Search Algorithm for a Pricing Problem On a Transportation Network
Authors: *Brotcorne, Cirinei, Marcotte, Savard*
Speaker: Luce Brotcorne - LAMIH/ROI University of Valenciennes
We consider a bilevel pricing problem where a company (a leader) strives to maximize its revenue raised from tariffs imposed on a set of arcs while taking into account the cost minimizing behaviour of the customers. We propose a tabu search algorithm based on the characterization of feasible followers solutions as a set of paths. The tabu moves are evaluated through the resolution of an inverse optimization proram. To assess the efficiency of the method, a comparison with proposed heuristics is made on several instance families solved to optimality

Session 11B: Stochastic Routing

Thursday 06/14 09:00 - 10:00 Room: Kamala
Chairman: Ricardo Giesen

Robust Duration-constrained Tours for Vehicle Routing Problems with Stochastic Demands
Authors: *Erera, Morales, Savelsbergh*
Speaker: Alan Erera - Georgia Institute of Technology
We propose and study a robust optimization framework for vehicle routing problems with uncertain demands and tour duration considerations. Demand at a customer is uncertain, but is assumed to fall within a known range, i.e., lower and upper bounds on possible demand realizations at customers are known by the dispatcher at the time a set of routes must be constructed. In the proposed robust framework, efficient methods are developed for determination of the maximum additional travel time required for the recourse actions of each individual vehicle under any demand realization. A traditional myopic recourse policy as well as anticipatory policies that plan preemptive return trips to the depot are analyzed. Two types of problems can be addressed using the framework: (1) minimax problems with the objective of minimizing the sum of the maximum possible tour costs, and (2) expected cost minimization problems with hard constraints on tour duration. We implement the robust tour evaluation methods within a tabu search heuristic, and present computational results on test problems. First, we compare expected cost solutions with minimax solutions for single vehicle problems, and second, we quantify the potential expected cost impacts of enforcing hard duration constraints on problems with multiple vehicles.

A Pickup-and-delivery Routing Problem with Stochastic Demands
Authors: *Louveaux, Gonzalez*
Speaker: Juan Jose Salazar Gonzalez - Universidad de La Laguna
This paper studies the one-commodity Pickup-and-Delivery Travelling Salesman Problem where some of the customer demands are stochastic. It first considers feasibility issues. This includes finding the smallest vehicle capacity and some initial load such that a given tour is feasible for all scenarios. It then analyzes the case where some penalties are paid for routing a tour unable to handle customer demands. Various types of penalties are considered. The paper studies properties of the minimal expected penalty of a given tour, which are then used to provide approaches to find near-optimal tours. Computational results are presented.

Session 11C: Airline modeling and optimization

Thursday 06/14 09:00 - 10:00 Room: Nai Harn
Chairman: Niklaus Eggenberg

The Greenland Air Transport Model System - a Joint Transport Modelling and Optimisation Problem

Authors: *Nielsen, Rich, Knudsen, Frederiksen*
Speaker: Mette Knudsen - Centre for Traffic and Transport, Technical University of Denmark

SHORT ABSTRACT The paper describes a model for air transport in Greenland, which as a lower level problem forecast demand and route choice for passenger and freight flows, and as an upper level problem design the service network, flight schedules (time-table optimization), decide on airplane types considering cost and capacity, and finally creates airplane schedules. Due to quite special capacity restrictions combined with the need for a schedule based assignment model, this bi-level problem could not be solved analytically, as the lower level model is a non-analytical non-linear non-continuous mapping of the solution of the upper level problem. The paper describes how this model is solved. The model is used by the Greenland Home Rule to decide upon the new airport structure in Greenland (change of main airports and creation of new airports), policies to obtain more competition and to liberalise the market, and to design the main air transport system. As such the whole model system is operational and used for policy making in Greenland.

Using Optimization and Queuing Models to Estimate Long-term Average Flight Delays and Cancellation Rates

Authors: *Ball, Mukherjee, Lovell, Churchill, Odoni*
Speaker: Michael Ball - University of Maryland

In this paper, we present models for estimating long-term average flight arrival and departure delays, and cancellation probabilities for an airport. We employ a set of capacity scenarios and develop estimates under each scenario. Long-term averages are then computed based on scenario probabilities. The arrival delay model has a stochastic queuing model at its core. Departure delays are strongly correlated with arrival delays from earlier time periods, and therefore are estimated from arrival delays using a linear regression model. To estimate cancellation rates, we employ a network flow model that develops a cancellation profile to achieve certain delay objectives. The parameters of this model are adjusted so that the model's output matches longer-term cancellation and delay statistics. The models are validated for Chicago's O'Hare and Atlanta's Hartsfield airports. The models have been used in real strategic (human-in-the- loop) simulations to evaluate the impacts of various market-based resource allocation mechanisms at a single airport.

Session 13A: Dynamic pricing

Thursday 06/14 14:50 - 15:50 Room: Kata
Chairman: Martijn Mes

New Methods to Compute Dynamic Bid-prices In Network Revenue Management
Authors: *Topaloglu, Kunnumkal*
Speaker: Topaloglu Huseyin - Cornell University
We present two new methods for computing bid-prices in network revenue management. The fundamental idea is to formulate the network revenue management problem as a dynamic program and to relax certain constraints by associating Lagrange multipliers with them. As a result, the network revenue management problem decomposes by the flight legs and we can concentrate on one flight leg at a time. The methods that we present partially incorporate the temporal dynamics of the arrivals of the itinerary requests, naturally yield upper bounds on the maximum expected revenue over the planning horizon, remain applicable in the presence of cancellations, and provide a new and refined deterministic linear program for the network revenue management problem.

Dynamic Pricing with Buyer Learning
Authors: *Kleywegt*
Speaker: Anton Kleywegt - Georgia Institute of Technology
Many traditional dynamic pricing models such as the ones widely used in revenue management assumed that the demand at each point in time depends on the price at that point in time only, that is, it is independent of prices at other points in time. Recently some models of so-called strategic customer behavior have been studied, in which buyers' purchasing decisions at a point in time depend on the prices at other points in time, or more generally, on the sellers' pricing policies. Many new questions are associated with such models. One question is how the buyers can be expected to obtain and process all the information necessary to make such complicated decisions. We study several models in which buyers learn quantities that are simpler than the pricing policies of the sellers. We investigate the convergence of the buyers' estimates, and compare the limits with equilibria associated with full information.

Session 13B: Ship scheduling

Thursday 06/14 14:50 - 15:50 Room: Kamala
Chairman: Kjetil Fagerholt

Approximate Column Generation for some Ship Scheduling Problems
Authors: *Nygreen, Bronmo, Lysgaard*
Speaker: Bjørn Nygreen - Norwegian University of Science and Technology
We present a Dantzig-Wolfe procedure for the ship scheduling problem with flexible cargo sizes. This problem is similar to the well-known pickup and delivery problem with time windows, but the cargo sizes are defined to be within intervals instead of having fixed values. We show that the introduction of flexible cargo sizes to the column generation framework is not straightforward, and we handle the flexible cargo sizes heuristically when solving the subproblems. This leads to convergence issues in the branch-and-price search tree, and an optimal solution cannot be guaranteed. Hence we have introduced a method that generates an upper bound on the optimal maximization objective. We have compared our method with an a priori column generation approach, and our computational experiments on real world cases show that the Dantzig-Wolfe approach is faster than the a priori generation of columns, and we are able to deal with larger or more loosely constrained instances. By using the techniques introduced here, a more extensive set of real world cases can be solved either to optimality or within a small deviation from optimality.

A Tabu Search Heuristic for Ship Scheduling Problems
Authors: *Korsvik, Fagerholt, Laporte*
Speaker: Jarl Eirik Korsvik - Norwegian University of Science and Technology
We present a planning problem faced by many shipping companies dealing with transport of bulk products. These shipping companies typically have a certain amount of contract cargoes that they are committed to carry, while trying to maximize the profit from optional spot cargoes. In order to ensure quick decision support to the planner, we propose an efficient tabu search heuristic to solve the problem. We will report results were the heuristic solution apporach is tested on real-life instances of the problem.

Session 13C: Signal traffic control

Thursday 06/14 14:50 - 15:50 Room: Nai Harn
Chairman: Hillel Bar-Gera

A Quadratic-programming Approach for the Signal Control Problem In Large-scale Congested Urban Road Networks
Authors: *Aboudolas, Papageorgiou, Kosmatopoulos*
Speaker: Konstantinos Aboudolas - Technical University of Crete
In view of the imminent traffic congestion and lack of possibilities for infrastructure expansion in urban road networks, the importance of efficient signal control strategies, particularly under saturated traffic conditions, can hardly be overemphasized. It is generally believed that real-time (traffic-responsive) systems responding automatically to the prevailing traffic conditions, are potentially more efficient than clock-based fixed-time control settings, possibly extended via a simple traffic-actuated (micro-regulation) logic. On the other hand, the development of real-time signal control strategies using elaborated network models is deemed infeasible due to the combinatorial nature of the related optimization problem; as a consequence, the developed or implemented signal control strategies include many simplifications or heuristics. These simplifications and heuristics may render the strategies less efficient, particularly under saturated traffic conditions, unless a high effort is put in the fine-tuning of many parameters included in the signal control strategy. In this paper we investigate the efficiency of a new signal control methodology, which offers a computationally feasible technique for real-time network-wide control of the junction green times. This methodology combines traffic flow modeling based on the so-called store-and-forward modeling philosophy, mathematical optimization and optimal control. More specifically, a generic mathematical model for the traffic flow process in large-scale urban networks is developed first, upon which an optimal control approach is applied for the design of traffic signal control strategies that aim at minimizing and balancing the link queues so as to reduce the risk of queue spillback. The derived optimization problem is of the quadratic-programming type, i.e. it involves a quadratic objective function with linear constraints. In contrast to other similar proposed methods for urban signal control, the control decisions are based on the explicit minimization of a suitable objective criterion subject to all control and state constraints, without the need to consider nominal green times. In order to evaluate the efficiency of the proposed approach (QPC), we compare its open-loop behaviour with the open-loop behaviour of a nonlinear optimal control (NOC) approach that is based on a more accurate traffic flow model. Towards this goal two hypothetical simple networks are considered and several tests were conducted for different scenarios. For these scenarios, the calculated optimal state and control trajectories demonstrate the efficiency of both control strategies to solve the urban signal control problem. However, taking into account that QPC needs less computational effort than NOC, QPC may be considered as a quite satisfactory, generic, and practicable method for the solution of the real-time urban signal control problem in large-scale networks of arbitrary topology and characteristics. For real-time field application, the algorithm may be embedded in a rolling horizon (model-predictive) scheme because the derived optimal control is of an open-loop nature.

Strategies for Signal Traffic Control and Dynamic Traffic Modelling
Authors: *Bielli, Fusco, Genitle, Meschini, Felici, Cipriani, Gori, Nigro*
Speaker: Maurizio Bielli - National Research Council
The paper illustrates methodology and preliminary results obtained in the project of basic research "Interaction between signal settings and traffic flow patterns on road networks", funded by the Italian Ministry of University and Research. The object of the project is to develop a general procedure to study, model and solve the problem of the optimal road network signal settings, by taking into account the interaction between signal control systems and traffic flow patterns. Different macroscopic and microscopic modelling approaches are discussed and applied to test cases. Moreover, different signal control strategies are introduced and tested by numerical experiments on a wide area of the road network of Roma.

Session 14A: Traffic flow models and applications

Thursday 06/14 16:00 - 17:00 Room: Kata
Chairman: Tom Thomas

Applications Of Vehicular Traffic Theory to Blood Rheology
Authors: *Kachani, Shmatov, Weinberger*
Speaker: Soulaymane Kachani - Columbia University
In this talk, we develop a framework for modelling vascular blood flow using the vehicular traffic approach and show the theoretical and computational gains it yields. The application of the vast body of knowledge of transportation science to the modelling of blood flow appears to outperform existing fluid dynamics-based approaches in modelling of arterial blood flow, and proves very promising in other areas of computational medicine. We derive the fundamental flow diagram within the kinetic traffic model, and apply it to problems of vascular blood flow, use it to explore atherosclerotic patterns in practice, and compare against real measurement data obtained via Doppler ultrasonography techniques. Finally, we use the traffic modelling approach to investigate the red blood cells' clustering phenomena.

Continuum Traffic Flow Modelling Inside the Mont Blanc Tunnel
Authors: *Henn, Lesort*
Speaker: Vincent Henn - LICIT (ENTPE-INRETS)
The problem considered in this paper is modelling the distances between vehicles in the Mont Blanc tunnel and evaluating the effect on traffic of a system enforcing spacing rules. Though the problem is basically of microscopic nature (individual distances), the paper shows that a continuum model, associated to a wave-tracking resolution method which provides accurate waves trajectories, may capture various motorists behaviours concerning vehicular spacing and describe into some details the effects of an enforcement system. The interest of such an approach is to avoid calibration difficulties always met with a microscopic modelling, explicit consideration of the stochastic aspects for which no measurements exist in the Mont Blanc tunnel, and thus to result in practical conclusions with a minimum measurement effort.

Session 14B: Maritime optimization

Thursday 06/14 16:00 - 17:00 Room: Kamala
Chairman: Der-Horng Lee

Ship Routing and Scheduling with Inventory and Stowage Constraints
Authors: *Christiansen, Fagerholt, Haugen, Lund*
Speaker: Kjetil Fagerholt - Norwegian University of Science and Technology
We present a real planning problem where cement is transported by a fleet of ships from several production factories to many consumption silos along the Norwegian coast. The planners are responsible for both the ship routing and the inventory management at all production and consumption facilities. There exist several types of cement and the various types have to be allocated in separate cargo holds onboard the ships. The utilization of a ship's cargo carrying capacity depend on the stowage. We have developed a heuristic to solve this real complex inventory ship routing and scheduling problem with stowage constraints. Computational results from the real case study will be presented. Various objective functions have also been tested, and it seems that using cost-per-ton gives best solutions for the real problem.

An Optimization Model for Empty Container Reposition Under Uncertainty
Authors: *Crainic, Di Francesco, Zuddas*
Speaker: Teodor Gabriel Crainic - ESG - UQAM
An important factor for their competitiveness is the availability of empty containers in ports to meet customer orders. Due to the global trade imbalance, some ports tend to accumulate empty containers, resulting in unnecessary storage costs, while others face shortages that expose shipping companies to the risk of competitors providing containers as requested. As a consequence, shipping companies must be reactive to meet customer needs and perform the maritime repositioning of empty containers. A major difficulty in this operation is the many sources of uncertainty regarding, e.g., the number of containers that may be requested in the future, the time when empty containers become available, and the vessel capacity for empty containers. Several deterministic models were proposed but they take into account a single realization of uncertain parameters. Stochastic optimization models were presented as well. However, they require a good knowledge of random variable distributions to avoid low quality solutions. We present a description of a general transportation network over which empty container repositioning is performed. We then propose an optimization model to solve this issue for a heterogeneous fleet of empty containers, taking into account uncertainty through a set of representative scenarios. A weight can be assigned to each scenario to characterize its relative importance. Weights may represent probabilities of occurrence or subjective parameters assigned by managers according to the particular application. Finally, the most significant results of the study are introduced and discussed.

Session 14C: Intelligent transportation systems

Thursday 06/14 16:00 - 17:00 Room: Nai Harn
Chairman: Song Gao

Decentralized Algorithms for Multiple Path Routing In Urban Transportation Network
Authors: *Flamini, Adacher, Nicosia*
Speaker: Ludovica Adacher - Roma Tre University
In the last decades, the increase of traffic and the limited capacity of urban networks, led to the development of algorithms for traffic management and route guidance. GPS technology can be used for fleet monitoring in urban or suburban areas and may provide useful information concerning the movement of all vehicles. Current route guidance systems are simple from an algorithmic point of view, since they compute shortest paths to the destination, but they have to deal with very large networks. For this reason, a decentralized approach, in which each vehicle independently calculates its own route, is desirable. Usually, the main drawback of this approach is the possibility that too many vehicles choose the same route, thus causing oversaturation phenomena. Hence, to allow path diversification, we propose a decentralized algorithm in which each vehicle computes its own route on the basis of (i) its specific settings and (ii) traffic information provided by a reference station based on other vehicles forecasted routes.

A Model for New Data - Using Air Borne Traffic Flow Measurement for Traffic Forecast
Authors: *Ruhé, Kuhne, Hipp*
Speaker: Martin Ruhé - German Aerospace Centre
In this paper an approach for a new model is described. In the last 3 years a complex system for real-time air borne traffic flow measurement was developed. The system was used during the world soccer champion chip in Germany to show the current traffic situation and to predict the changes during the next 30 minutes. Up to now just the classical parameters like average of density and average of speed were used. With this remote sensing hardware it is possible to measure the real density and to extract the filed of trajectories of all cars of a street section. Looking back to the beginning of traffic flow description a new approach is developed at least based on the work of Treiterer in the 1970th and on the data of the word soccer champion chip 2006. In this paper the approach has been described and the very first results are shown.

Session 15A: Railways timetabling

Thursday 06/14 17:30 - 18:30 Room: Kata
Chairman: Daniel Potthoff

Effects Of Flexible Timetables In Real-time Scheduling Of Rail Operations
Authors: *Pacciarelli, D'Ariano, Pranzo*
Speaker: Dario Pacciarelli - Roma Tre University
In this talk, we discuss the concept of flexible timetable as an effective policy to improve the reliability of railway service without decreasing the capacity of the lines. With a flexible timetable, exact values of the arrival/departure times are replaced by time windows of [minimum, maximum] arrival/departure times, the proper value being defined in real-time. Given the actual train positions, signaling and safety constraints, the future evolution of the railway traffic is predicted accurately by means of a detailed job shop scheduling model, based on the alternative graph. The objective function is the minimization of the maximum consecutive delay with respect to the published timetable. A branch and bound procedure is employed to find optimal or near-optimal schedules for a general railway network within short computation time. The relations among flexibility, reliability and robustness of a timetable are investigated. An extensive computational study based on a bottleneck area of the Dutch railway network has been carried out. Computational experience shows that flexible timetables are preferable to the ones commonly used by railway managers. Moreover, more robust are the timetables, more relevant are the advantage of flexibility. Finally, the use of advanced scheduling algorithms is necessary to fully exploit the potential of flexible timetables.

Optimising Timetable Syncronisation for Mass Transit Railways
Authors: *Leung, Wong, Yuen, Fung*
Speaker: Janny Leung - The Chinese University of Hong Kong
Nothing to do but to look for the next transfer train is the passenger's plight when taking public transit in many places. To be able to design timetables with good co-ordination between train-lines so that passengers could enjoy 'immediate' transfer is a service goal of the Mass Transit Railway Corporation (MTRC), which runs six railway lines with 13 interchange stations in Hong Kong. Whilst important, this problem has not received widespread research attention. In this paper, we propose a mixed integer programming (MIP) optimization model for this timetable synchronization problem. The objective is to minimize the sum of all waiting times of all passengers at interchange stations in a railway system. By adjusting the trains' run-times and station dwell-times during their trips, and their dispatch times, turnaround times and headways at the terminals, we can construct high-quality timetables that optimize the objective of minimizing passenger waiting times. A novelty in our formulation is the use of binary variables to determine the relative sequencing of trains on different lines with passenger transfers, which enables the correct representation of the waiting times for transfers to the 'next available' train at interchange stations. Furthermore, in our model, we not only adjust run times and dispatch times of trains but also dwell times, turnaround times and headway of trains, which are not studied in other papers. Numerical results will be reported, which indicate that our approach improves the synchronization of the current schedule significantly. With trains departing every few minutes from each terminal, there are a large number of trips to consider, and hence the MIP formulation for the timetable synchronization contains thousands of binary variables and tens of thousands of continuous variables and constraints. We also investigated an optimization-based heuristic for this problem, where we heuristically 'fix' the values of 'most' of the binary values (based on the solution to the LP-relaxation), which determine the relative sequencing of the trains on different lines. We then solve the resulting MIP formulation, which is much smaller than the original MIP. By iteratively and heuristically searching for the subsets of integer variables to fix, we can get good-quality solutions within a reasonably short time. In our preliminary study, we consider the train schedule in the MTR system in Hong Kong for both rush-hour and non-rush-hour periods. Using our model formulation, we constructed a schedule that reduces the waiting time for transferring passengers significantly compared to the current schedule. We also explore the trade-offs among different operational parameters and flexibility and their impact on overall passenger waiting-times.

Session 15B: Port scheduling

Thursday 06/14 17:30 - 18:30 Room: Kamala
Chairman: Matteo Salani

An Approximation Algorithm for Quay Crane Scheduling with Non-interference Constraints In Port Container Terminals
Authors: *Lee, Wang, Miao*
Speaker: Der-Horng Lee - National University of Singapore
The quay crane scheduling problem studied in this paper is to determine a handling sequence of holds for quay cranes assigned to a container vessel considering interference between quay cranes. This paper provides a mixed integer programming model for the considered quay crane scheduling problem that is NP-complete in nature. An approximation algorithm is proposed to obtain near optimal solution and its worst case is analyzed. Computational experiments are conducted to examine the proposed model and solution algorithm. The computational results show that the proposed approximation algorithm is effective and efficient in solving the considered quay crane scheduling problem.

Barge Rotation Planning and Quay Scheduling In the Port Of Rotterdam
Authors: *Douma, Schuur*
Speaker: Albert Douma - University of Twente
We consider the problem how to align barge rotations with quay schedules of terminals in the port of Rotterdam. In the port of Rotterdam, barges are used to transport containers to the hinterland and from the hinterland back to the port. Every time a barge visits the port, it has to make a rotation along on average eight terminals to load and unload containers. To plan a rotation in practise, the barge operator (who contracts the barge) communicates with the concerning terminal operators about time slots the barge can be handled. A central solution, in the form of a trusted party that coordinates the activities of all barges and terminals, is not feasible for several reasons. One of the reasons is that barges and terminals want to stay autonomous and in control of their own operations. We therefore propose a multi-agent based approach of the problem, since a multi-agent system can mirror to a large extent the way the business network is currently organized and can provide a solution that is acceptable by each of the parties involved. A simple multi-agent control, which is currently implemented in the port of Rotterdam, was developed in a previous project. We examine the application of more sophisticated agents and evaluate the performance by means of simulation. We compare the results with an off-line scheduling algorithm. Besides theoretical insides, we focus also on application in practise in the near future.

Session 15C: Models and algorithms

Thursday 06/14 17:30 - 18:30 Room: Nai Harn
Chairman: Hanne L. Petersen

Designing Mechanisms for Sustainable Carrier Alliances In Transportation Networks
Authors: *Ergun, Agarwal*
Speaker: Richa Agarwal - Georgia Institute of Technology
In today's transportation industry, in the midst of increasing customer expectations and squeezed profit margins alliances between carriers are an important factor in staying competitive. However, alliances pose many challenging questions, such as the design of a large scale service network (which results from integrating the service networks of different members of an alliance) and a fair allocation of the benefits of an alliance among its members. In this paper, we study transportation problems where a minimum frequency on the operated routes is required to maintain the market share. We link mathematical game theory with optimization techniques and design a mechanism to guide the members of an alliance to pursue an optimal collaborative strategy. The mechanism provides side payments to the members as an added benefit to motivate them to act in the best interest of the alliance while satisfying their own self profits. Our computational results indicate that the suggested solution approach has the potential to help carriers form sustainable alliances.

Forecasting Freight Demand at Intermodal Terminals Using Neural Networks - an Integrated Framework
Authors: *Bilegan, Crainic, Gendreau*
Speaker: Ioana-Codrutsa Bilegan - LAMIH, Université de Valenciennes
In this communication the design of a neural network based demand forecasting methodology is presented. The context is intermodal rail transportation and the demand is forecasted in terms of containers released from a port terminal, where they arrive by ship and from where they depart by train toward their destination. The goal is to improve the efficiency of intermodal container transportation within the framework of a scheduled with bookings rail operations management system and under the constraints imposed by a full-asset-utilisation policy (fixed train services daily). The forecasting system proposed is easily adaptable to a continuously changing functioning of the intermodal terminal that it was designed for (as long as big, structural changes do not intervene), without explicitly taking into account the complex operations details of a port container terminal. This powerful and flexible methodology can be adapted to processes that dynamically adjust the offer of service to demand.

Session 16A: Traffic equilibrium and assignment I

Friday 06/15 09:00 - 10:30 Room: Kata
Chairman: Michaël Thémans

Schedule-based Transit Assignment Model with Travel Strategies and Capacity Constraints
Authors: *Hamdouch, Lawphongpanich*
Speaker: Younes Hamdouch - United Arab Emirates University
In this paper, we propose a user equilibrium transit assignment model that takes into account transit schedules and individual vehicle capacities explicitly. The model assumes that passengers use travel strategies that can be adaptive over time and graphically represented as generalized hyperpaths. When loading a vehicle, on-board passengers wanting to continue to the next stop have priority and waiting passengers are loaded on a First-Come-First-Serve basis or in a random manner if they mingle on waiting platforms. When a vehicle is full or the system is congested, passengers unable to board must wait (thereby lengthening their trips) for the next vehicle to arrive. The model is formulated as a variational inequality involving a vector-valued function of expected strategy costs. Although the function is non-monotonic, a solution to the variational inequality exists. To find a solution, we propose a method that takes successive averages as its iterates and generates strategies during each iteration by solving a dynamic program. We show that the algorithm empirically converges to a user equilibrium solution in a transit network.

Assignment Over a Transit Corridor Considering Congestion
Authors: *Munoz, Larrain*
Speaker: Juan Carlos Munoz - Universidad Catolica de Chile
We consider a transit corridor with a given set of stops and a known origin destination demand. A set of lines serve this corridor but each line stops only at a subset of bus stops. On-vehicle travel times depend on the number of passengers boarding and alighting at each stop within a trip. This paper shows that equilibrium assignments will most likely require identical passengeres taking different strategies for their trips. A novel algorithm is proposed for reaching such an equilibrium.

Stochastic Network Equilibrium Model Under Uncertain Demand
Authors: *Nakayama*
Speaker: Shoichiro Nakayama - Kanazawa University
Evaluation of the uncertainty of traffic networks is very important for network design and traffic management. It is assumed that the travel demands are also stochastic and that drivers choose their routes stochastically based on the logit model. A network equilibrium model with stochastic route choice under stochastic demands is formulated as both a fixed point problem and a complementary problem. The model is then applied to a simple example. It is found from the example that the model proposed is useful in assessing the network's uncertainty and in the evaluation of the effects of providing traffic information.

Session 16B: Stochastic traffic models

Friday 06/15 09:00 - 10:30 Room: Kamala
Chairman: Victor Knoop

Predictions Of Urban Flow Volumes and Incident Detection
Authors: *Thomas, Van Berkum*
Speaker: Tom Thomas - University of Twente
Macroscopic models are widely used in evaluating traffic flows in urban areas. These models often include input of link volumes. The quality of model forecasts therefore depends on reliable volume predictions. We developed a prediction scheme based on an extensive study of volume patterns that were collected for about 20 urban intersections in the Dutch city of Almelo. Our scheme contains of: (1) a priori predictions for a given pre-classified day, (2) predictions with a 24 hours time horizon and (3) short term predictions with horizons smaller than 80 minutes. For a fair assessment of the errors in our prediction scheme it is essential to know the amount of noise in the traffic volumes. We found that the noise can be well approximated by a Poisson distribution, and that errors in short term predictions are on average well below the noise level. They are also significant lower than errors in a priori predictions. Errors in short term and 24 hours predictions are in general quite similar, although in some cases errors are significant lower for short term predictions. We use our knowledge about the noise level to construct a simple 3 plus 4-sigma clipping method to remove outlying measurements. Most of these measurements are caused by incidents or events. We briefly discuss how the detection of these outliers can be used in a practical application.

Parking Search Model
Authors: *Beltran, Carrese, Negrenti*
Speaker: Stefano Carrese - University Roma Tre
The methodology proposed has been developed in the framework of the VPQ HEARTS project (Health Effects and Risks of Transport Systems) that address the need for more integrated methods for health risk assessment which consider the full range of exposures and health effects and can be applied in the policy or planning process. Parking and re-entering traffic are a source of traffic congestion and pollution: half of the cars driving downtown during peak hours in heavily congested areas cruise for parking . Parking, on street and off street, can create pollution problems regarding additional emissions because of vehicle movements at low speed and low gear, number of decelerations and accelerations, long searching time, low temperature of engine during cold and warm start operations or presence of ramps on parking lots. The behavior of the parking and inserting vehicle flows (going to and leaving from parking areas) can be described by means of simplified speed cycles, based on the vehicle kinematics during the parking and the re-insertion. Parameters defining the shape of such cycles are searching speed, searching time and time of warm up, on which our research is focused. Parking search phase is represented by dedicated 'searching speed' and 'searching time' models. Such models are further split in two sub-models depending on the category of parking: on-street and off-street. In the on-street parking, searching speed is modeled by a fuzzy model as a function of the linear traffic density and the occupation rate of the parking facility. Searching time for on street parking uses a probabilistic approach to calculate the searching time based on the occupation rate of the link connecting parking areas and searching speed. The second aspect related to parking emissions is the cold start phase. For this specific phase a model to calculate the time of warm up, the start up temperature and the cold start fraction have been proposed and validated. The next step concerns the validation of the models with the data collected during a experimental campaign conducted in conjunction with the IM-CNR in Naples and it has been conceived to simulate parking by means of car with a on board acquisition system in a set of streets monitored by traffic cameras at the intersections. Monitoring cameras in the street provide traffic data as flows and speeds that are necessary to correlate the results given by the models. The software version developed in the HEARTS Project has been tested in the city of Florence for the analysis of the effects of various transport measures and the most representative results have been reported in the paper.

Probabilistic Models for Travel Time
Authors: *Van Zuylen*
Speaker: Francesco Viti - Delft University of Technology

Many traffic processes are irregular and difficult to predict with a high accuracy. That applies also to travel times. The cause of the uncertainty of travel time prediction is the probabilistic character of the traffic processes, such as queuing at a controlled intersection and driving speeds on a freeway. The simple deterministic processes are not suited to describe reality sufficiently. An alternative approach is presented where the entities to be modeled are not the direct observable parameters of the traffic system like queue length and speed, but their probability distribution. A traffic model should describe how such probability distributions change in time under influence of external and internal conditions. For delays at a controlled intersection a distribution function is derived and for travel times at a freeway the relation between unreliability and the occurrence of synchronized flow is shown.

Session 16C: Flexible and responsive transportation systems

Friday 06/15 09:00 - 10:30 Room: Nai Harn
Chairman: Cristian Cortés

Patient Transportation - Dynamic Dial-a-ride and Emergency Transportation Problems
Authors: *Kiechle, Doerner, Gendreau, Hartl*
Speaker: Karl Doerner - University of Vienna
In Austria, the transportation of patients to and from hospitals is organized by non-profit organizations. In most regions, it is the Austrian Red Cross that is responsible for the transportation of patients. The regular patient transportation, as well as the emergency transportation, are performed by scheduling the same fleet within the same control center. Therefore a dial-a-ride problem for the regular patient transportation orders with disruption has to be solved. Disruptions occur due to the fact that vehicles 'disappear' in order to serve emergency requests and reappear at a hospital after the service of an emergency case. This problem is highly dynamic and a robust plan has to be computed for the regular dial-a-ride orders in order to serve also the emergency requests. When a disruption occurs because of an emergency, the fleet size is reduced and the remaining patient transport orders have to be carried out with this reduced fleet size. After the execution of an emergency transport, the available vehicle can be integrated to serve the regular dial-a-ride orders. We analyze different scheduling strategies for the regular dial-a-ride orders in order to minimize routing costs and to minimize the response time for servicing an emergency request.

Towards Designing Flexible Transportation Systems
Authors: *Errico, Crainic, Malucelli, Nonato*
Speaker: Fausto Errico - DEI, Politecnico di Milano
The Demand Adaptive System (DAS) is a hybrid flexible transit system which joins some features of traditional line services with some features of the purely on demand systems, such as Dial a Ride. The DAS attempts to offer demand-responsive services within the framework of traditional scheduled bus transportation: passengers call to request service between two given stops and, in so doing, induce detours in the vehicle routes. At the same time, thought, a given set of compulsory stops is always served according to a predefined schedule, regardless of the current set of active requests, thus allowing also a traditional use of the transport service without requiring reservations. For hybrid systems as DAS, a design phase is essential. In this work we analyse the problem of designing a flexible line, in particular for what concerns the selection of the compulsory stops, their sequencing and the partition of the service area. This problem turns out to be particularly challenging especially if we consider its stochastic aspects. A natural approach decomposes the problem into simpler problems. After presenting the general design problem, we propose two families of mathematical models arising from the decomposition which are of particular interest. Then we focus on several solution methods for two single mathematical models, one from each family. In the presentations we will discuss algorithmic developments and computational results for some of the proposed approaches.

Hybrid Predictive Control Strategy for a Public Transport System with Uncertain Demand
Authors: *Cortés, Saez D., Saez A., Núñez, Tirachini*
Speaker: Doris Saez - Universidad de Chile
In most public transport systems, the movement of transit vehicles is affected by different disruptions as the day progresses, which hinders the dispatch of vehicles either following a pre-planned schedule or trying to maintain a regular headway. In this paper, we develop a model integrating three strategies (holding, expressing and transit signal priority) to solve the dynamic control problem associated with the operation of public transport systems, assuming uncertain passenger demand, and relying on online information of system behaviour. Unlike most studies found in the transit control literature, the proposed model is formulated as a predictive control problem, since the theory nicely fit the dynamic conditions of typical public transport problems. For the design of the predictive controller, an objective function to be optimized is defined, comprising three terms: one capturing the regularization of bus headways, another including the travel time of passengers on board the buses, and a third component considering the additional waiting time of passengers when staying at bus stops skipped by expressing vehicles. A hypothetical transit corridor with realistic dynamic demand arriving to bus stops is constructed. Genetic

algorithms are proposed to efficiently solve the problem. Some preliminary tests are conducted to show the potentialities of such an approach to deal with the dynamic control of realistic transit systems

Session 17A: Traffic equilibrium and assignment II

Friday 06/15 11:00 - 12:30 Room: Kata
Chairman: Michael Mahut

Traffic Assignment By Paired Alternative Segments
Authors: *Bar-Gera*
Speaker: Hillel Bar-Gera - Ben-Gurion University of the Negev
The user equilibrium (UE) traffic assignment is a corner stone in travel forecasting and traffic impact analysis. Many algorithms have been proposed over the years for solving the UE model. Recently, attention is given not only to the total link flow results of the UE model, but also to the route flow results of the model, and particularly to the Maximum Entropy User Equilibrium (MEUE) route flow solution that maintains desirable consistency properties. In this research we experiment with a new algorithmic approach, that focuses on local paired alternative route segments. The approach relies on a fundamental understanding that paired alternative segments "capture" the essence of route choices in the UE model in an extremely compact manner. Traffic Assignment by Paired Alternative Segments (TAPAS) is superior to previous algorithms in several respects. First, it converges to equilibrium very quickly, as we demonstrate with several examples including a large-scale network. In addition, the set of routes used by the method is relatively consistent throughout the iterative process, thus allowing to achieve reasonable consistency even at moderate levels of convergence. Last but not least, while certain aspects of the algorithm rely on non-trivial theoretical insights, the key principle is rather simple and likely to be widely understood by the general professional transportation community.

Existence, Uniqueness and Stability Of Equilibrium In Dynamic Traffic Networks
Authors: *Mounce*
Speaker: Richard Mounce - University of Sheffield
Models of traffic flow in networks must take account of travellers re-routing. Naturally one is interested in a flow pattern for which no re-routing occurs, i.e. when the network is at equilibrium. Three key questions arise regarding equilibrium; whether there exists a flow-pattern that is an equilibrium, whether such an equilibrium flow-pattern is unique and whether the dynamical system converges to equilibrium. If no equilibrium exists, the network traffic would keep changing from one day to the next. If equilibrium exists, is it known that the system will converge to an equilibrium state over time? Even if this is known, if there are multiple equilibria, how does know which equilibrium the system will converge to? These are all extremely important issues in transport modelling and planning. In the steady state model, the dynamical system in which travellers swap to less costly routes converges to the convex set of user equilibrium. In the dynamic model, there are various traffic performance models. Our focus here is on the bottleneck queueing model; but any reasonable model can be expected to satisfy the continuity and non-decreasing properties that are required for existence and uniqueness respectively. The bottleneck queueing model has deterministic queueing at link exits when flow exceeds capacity and inelastic demand (time-varying within-day but unchanging from day to day) for travel between each origin-destination (OD) pair in the network. Within-day time is considered as continuous, and inflows into routes connecting OD pairs are represented by functions of time. The day-to-day route- swapping is modelled by a continuous dynamical system that is derived naturally from the dynamic user equilibrium condition. Existence of equilibrium is guaranteed provided that the route cost vector is a continuous function of the route flow vector, which holds in the bottleneck model. Costs at dynamic user equilibrium are unique in the single origin case and in the single destination case provided that certain (natural) non-decreasing properties are satisfied; the bottleneck model satisfies these properties. In the bottleneck model, if costs are unique then link flows are unique when there is congestion. In the case where there are both multiple origins and multiple destinations, we only know that dynamic user equilibrium is unique in the single bottleneck per route case, but in general it may not be. It has been shown that the dynamical system converges to equilibrium if the route cost is either monotone or decay-monotone; essentially this is true in the bottleneck model in the single bottleneck per route case, but not in the multiple bottlenecks per route case.

Wardrop's Equilibrium Assignment Scheme Without Traffic Volume for Estimating Link Travel Time

Authors: *Iryo, Sumalee*
Speaker: Takamasa Iryo - Kobe University
This study shows a theory of Wardrop's equilibrium assignment without the concept of traffic volume and applies it to the congestion estimation problem in road networks. Traffic assignment is one of the methods to analyse the degree of congestion in the network. Though the concept of traffic volume, such as OD demand volume and link travel time function, is necessary to solve equilibrium assignment problems, it has been known that measuring OD demand correctly is quite difficult. To avoid this difficulty, this study tries to make a theoretical framework of Wardrop's equilibrium assignment without the concept of traffic volume. This theory does not contain any traffic volume variables and therefore both OD demand and link travel time function do not have to be determined to solve the problem. This study formulates the equation system first, and then analysing its theoretical properties. As an application of this theory, a methodology to estimate the level of congestion of road networks with the limited measurement of link travel time is proposed.

Session 17B: Inventory routing II

Friday 06/15 11:00 - 12:30 Room: Kamala
Chairman: Ioana-Codrutsa Bilegan

Vendor-managed Inventory Policies for an Integrated Production-distribution System
Authors: *Bertazzi, Archetti, Paletta, Speranza*
Speaker: Luca Bertazzi - University of Brescia
We consider a production-distribution system, where a facility produces several products which are distributed to a set of retailers by a fleet of vehicles. The production policy, the retailers replenishment policies and the transportation policy have to be determined so as to minimize the total system cost. The cost includes the fixed and variable production costs at the facility, the inventory costs at the facility and at the retailers and the routing costs. We study two different types of Vendor-Managed Inventory (VMI) policies, i.e. policies in which the facility knows the inventory levels of the retailers and takes care of their replenishments: The well known Order-Up to Level policy (OU), in which the quantity delivered to each retailer is such that the maximum level of the inventory at the retailer is reached, and the Maximum Level policy (ML), in which the quantity shipped to each retailer is not greater than the order-up to level quantity. The problem is NP-hard, both when OU and ML policies are applied, as it reduces to the VRP in a specific class of instances. We first study the computational complexity of the problem in which the transportation is outsourced. Then, we show the worst- case performance of the OU policy with respect to the ML policy. We propose a heuristic algorithm for the solution of the problem with the ML policy. In particular, we decompose the problem into two subproblems, one concerning the production and one concerning the distribution. The subproblem concerning the production is optimally solved, while the subproblem concerning the distribution is solved by applying a constructive heuristic algorithm in which at each iteration a retailer is inserted in the solution. For each retailer, a problem, which is a generalization of the dynamic lot-size problem with time-varying capacity constraints, is optimally solved by an exact algorithm based on properties of the optimal solution and on feasibility and dominance relations among partial solutions proved in the paper. Then, we evaluate the performance of the heuristic algorithm with respect to the optimal solution of the problem on instances in which one vehicle only can be used at each delivery time instant. The optimal solution is obtained by a branch-and-cut algorithm. Finally, we compare the performance of the OU policy with respect to the ML policy on the basis of a large set of randomly generated problem instances. The results show that the ML policy allows us to significantly reduce the total cost with respect to the OU policy.

Scenario Tree Based Heuristics for Stochastic Inventory Routing Problems
Authors: *Hvattum, Lokketangen, Laporte*
Speaker: Arne Løkketangen - Molde University College
In the Inventory Routing Problem (IRP) the goal is to coordinate inventory replenishment and transportation in order to minimize costs. We look at Stochastic IRPs, where the customers have stochastic demands, and where the overall problem being formulated as a discounted, infinite-horizon Markov Decision Process. Here we focus on applying GRASP as a meta-heuristic for solving finite scenario trees that are used to approximate the Markov Decision Process. Our version of GRASP uses the principle of MCV - Marginal Conditional Validity to be able to leqarn between constructive runs. Computational results will be given on standard testcases from the literature

Inventory Routing Problem Solved By Heuristic Based On Column Generation
Authors: *Michel, Vanderbeck*
Speaker: Sophie MICHEL - University Bordeaux 1
We consider an application of the inventory routing problem. A fleet of vehicles is devoted to collecting a single product from geographically dispersed sites. Each site has its own accumulation rate and stock capacity. On each visit, the vehicle empties the stock of accumulated product. In the tactical planning phase, we search for a periodic solution to be repeated on an infinite time horizon. The objectives are to minimise the vehicle fleet size as well as the transportation cost, while achieving some form of regional clusterisation in partitioning the sites between the vehicles. The structure of the problem is exploited to develop a Dantzig-Wolfe decomposition approach. The column generation subproblem yields periodic routes. It reduces to a multiple choice knapsack problem. The issues related to the construction of the

planning are dealt with in a master program. The latter program is reformulated in terms of aggregated variables to avoid the symmetry in time. Cutting planes are added to improve the formulation. Dual bounds are obtained by LP relaxation and tightened through partial branching. Primal bounds are derived through rounding and local search procedures specially developed for use in the context of a column generation approach. Real-life instances of the problem are solved with reasonable optimality gaps.

Session 17C: Models and algorithms

Friday 06/15 11:00 - 12:30 Room: Nai Harn
Chairman: Zachary Patterson

Use Of a Relational Reinforcement Learning Algorithm to Generate Dynamic Activity-travel Patterns
Authors: *Vanhulsel, Wets, Janssens*
Speaker: Marlies Vanhulsel - Hasselt University - Transportation Research Institute
In the course of the past decade activity-based models have entered the area of transportation modelling. Such models simulate the generation of individual activity-travel patterns while deciding simultaneously on the different dimensions of activity-travel behaviour, such as the type of activity, the activity location, the transport mode used to reach this location, the start time and duration of the activity, etc. However, as real-world activity-travel patterns do not prove to be static due to short-term adaptation and long-term learning, the scheduling algorithm needs to be adapted in order to be able to account for these dynamics. Short-term adaptation refers to within-day rescheduling as the result of the occurrence of unexpected events in the course of the execution of the individual planned activity program, for instance congestion, or unexpected changes in the duration of an activity. Long-term learning denotes the change in activity-travel behaviour caused by the occurrence of key events, such as residential relocation and obtaining one's driving license. The technique implemented in the current research originates from the area of artificial intelligence, in particular relational reinforcement learning (RRL). The RRL approach is based on Q-learning in which the estimation of the traditional Q- function has been substituted by inductive learning. This approach aims at generalizing the triplet state, action and Q-value. The major advantage of this technique consists of the fact that the Q-function does not need to be retrained entirely whenever the environmental changes occur, and as such this technique allows visualizing short-term and long-term dynamics. Results show that in a preliminary run of this technique the agent is able to determine autonomously activity-travel sequences, taking into account temporal and spatial constraints and travel time. Moreover the agent is able to respond to environmental changes, due to the introduction of a key event, through the adaptation of the activity-travel pattern. The generated activity-travel schedules also have to be validated. The generated patterns are compared to actual data by means of the distance method SAM (Sequence Alignment Method). This method calculates the distance between the generated and the actual activity-travel schedule, reflecting as such the similarity of these patterns.

How Does a Ride Point System Differ From Fare Reduction In Ridership Of Public Transportation? an Empirical Analysis Of the Mental Accounting Theory
Authors: *Sato, Morikawa, Kurauchi*
Speaker: Takayuki Morikawa - Nagoya University
Excessive motorization has been causing the global and local environmental problems, and therefore modal shift policies from auto to mass transit are called for. Although TDM (Travel Demand Management) measures in addition to investing on transit infrastructures are implemented in Japan, significant modal shift has not been observed. Under such circumstances, we have been proposing a TDM measure of transit ride point system (called 'travel eco-point') where one can acquire points when he/she uses an environmentally friendly transportation mode such as public transportation and can exchange the accumulated points to further incentives for environmentally friendly travel behavior such as transit tickets. Social experiments on this system were carried out twice in Nagoya, Japan in 2004 and 2005 to collect behavioral data. In this paper, we investigate the effect of travel eco-point system on shifting from auto to transit focusing on the difference in the effect of fare reduction. Traditional consumer choice models that assume the instrumental rationality cannot distinguish the effect of the travel eco-point and of the fare reduction since decision makers may conduct the elaborate utility calculations toward the monetary gains. On the other hand, we often observe that FFPs (Frequent Flyer Programs) and FSPs (Frequent Shopper Programs) prevail as a very successful sales promotion, indicating that customers may feel additional psychological pleasure toward the monetary gains. This paper demonstrates a theoretical framework that reveals the differences among the effects of the measures applying the mental accounting theory (Thaler, 1985) in which the additional psychological pleasure toward the gains are explicitly formulated as the "transaction utility" while the utility derived from goods consumption in the conventional models is defined as "acquisition utility". The proposed methodology is then applied to the

empirical data collected before the 2nd travel eco-point social experiment conducted in Nagoya, 2005. The result shows that the model based on the mental accounting theory better fits to the empirical data than the traditional model, and the transaction utility is much larger than the acquisition utility in our data. Also shown is that travel eco-point seems to be most cost-effective in terms of promoting public transportation usage due to its transaction utility compared to other measures such as fare reduction and premium of pre-paid card.

New Resolution Approaches for the Sensor Location Problem

Authors: *Gentili, Bianco, Cerulli*

Speaker: Monica Gentili - University of Salerno

The problem of locating sensors on the network to optimize certain objective criteria has been object in the past few years of growing interest. In this paper we focus on the specific problem of locating the minimum number of counting sensors on the nodes of a network in order to determine the arc flow volume on all the network (the Sensor Location Problem). Such a problem was formally stated by Bianco et al. (2001), where two heuristics giving lower and upper bounds to the solution value were also presented. Successively, a combinatorial analysis of the problem was developed and the computational complexity of the problem was studied in different special cases. Moreover, some graph classes, where the problem is polynomially solvable, were presented. In Confessore et al (2005), the problem was also studied and new heuristic algorithms and approximation ones were presented. In this paper we continue the study of the problem by developing an exact branch and bound approach, based on a binary branching rule, that embeds the heuristics existing in the literature to obtain bounds to the solution value. Moreover, we develop a metaheuristic approach to solve the problem. In particular, due to the characteristics of the problem, whose solution is naturally represented by a binary vector, we applied a genetic approach whose efficiency has been showed in the literature to solve 0-1 combinatorial problems. Preliminary results are provided.

Session 18A: Traffic equilibrium and assignment III

Friday 06/15 14:30 - 16:00 Room: Kata
Chairman: Martin Ruhé

Adaptive Traffic Assignment In Stochastic Dynamic Networks
Authors: *Gao*
Speaker: Song Gao - Caliper Corporation
This paper establishes a user-equilibrium dynamic traffic assignment (DTA) model where users make adaptive routing decisions, denoted as routing policies, in a stochastic time-dependent network. A routing policy is defined as a decision rule which specifies what node to take next out of the current node based the current time and online information, essentially a mapping from network states to decisions on next nodes. A general definition of routing policy is given to allow for a wide variety of information accessibility situations, thus excluding the usually simplified assumptions such as either no information or full information. In the proposed DTA model, a routing policy is treated as an element of a traveler's route choice set. The key advantage of this approach is that online information is embedded in a traveler's route choice alternatives and, thus, systematic methods can be designed independent of online information formats. A generalization of Wardrop's First Principle is used as the equilibrium condition: each user follows a routing policy with minimum perceived disutility at his/her departure time and no user can unilaterally change routing policies to improve his/her perceived disutility. A general framework is provided and the equilibrium model is formulated as a fixed point problem with three components: the routing policy generation module, the routing policy choice model and the policy-based dynamic network loader. An MSA (method of successive averages) heuristic is designed. Computational tests are carried out in a hypothetical network, where a random incident is the source of stochasticity. The heuristic converges satisfactorily in the test network under the proposed test settings. The adaptiveness in the routing policy based model leads to shorter expected travel times at equilibrium compared to DTA models where users make non-adaptive routing choices. As a byproduct, travel time reliability is also enhanced. The value of online information is an increasing function of the incident probability. Travel time savings are high when market penetrations are low. However, the function of travel time saving against market penetration is not monotonic. This suggests that in a traveler information system or route guidance system, the information penetration needs to be chosen carefully to maximize benefits.

On the Existence and Uniqueness Of Dynamic Equilibrium In Bottleneck Models
Authors: *Ukkusuri, Ramadurai*
Speaker: Gitakrishnan Ramadurai - Rensselaer Polytechnic Institute
The time-dependent equilibrium in a single bottleneck model is, perhaps, the simplest model to explore dynamic traffic equilibrium. Hendrickson and Kocur (1981) and Arnott et al. (1993) present an 'equilibrium' solution for a variant of the bottleneck model where all travelers are homogenous and have the same preferred arrival time. Recently, Ramadurai and Ukkusuri (2006) showed that the 'equal payoff' solution obtained in Hendrickson and Kocur (1981) and Arnott et. al. (1993) is not a Nash equilibrium solution (therefore, not a user equilibrium solution). The existence and uniqueness of equilibrium in bottleneck models with heterogeneous commuters will be re-examined in the light of the results from Ramadurai and Ukkusuri (2006). In particular, the following questions will be addressed: Does the single bottleneck model have a pure-strategy Nash equilibrium solution? Does the single bottleneck model with heterogeneity in desired arrival times and cost functions have user equilibrium or Nash equilibrium solutions? What are the necessary (and sufficient) conditions for existence of equilibrium solutions? If pure strategy Nash equilibrium solutions are non-existent what alternative equilibrium strategies (for example, mixed strategy) exist and what are their uniqueness properties? Answering the above questions is critical since they can expedite the acceptance of dynamic traffic assignment models in practice.

Comparison Of Assignment Methods for Simulation-based Dynamic-equilibrium Traffic Assignment
Authors: *Mahut, Florian, Tremblay*
Speaker: Michael Mahut - INRO Consultants Inc
This paper presents an evaluation of several assignment methods for use in simulation-based dynamic equilibrium traffic assignment. The different approaches are all iterative approaches, and are used in

conjunction with a route-based traffic simulator. The simulator receives the assignment mapping and executes the network loading, while the travel times obtained from the simulator are used as inputs for the assignment method, to update the assignment for the next iteration. The assignment methods considered fall into two main categories: path-based, and splitting-rates. The method of successive averages, and variants therof, are evaluated for the path-based approach. The splitting-rate model, which is formulated in the space of a link-turn network (rather than a node-link network), is an original formulation which is based on notions from traffic flow theory.

Session 18B: Routing and scheduling

Friday 06/15 14:30 - 16:00 Room: Kamala
Chairman: Proadpran Punyabukkana

The Truckload Trip Scheduling Problem
Authors: *Savelsbergh, Archetti*
Speaker: Martin Savelsbergh - Georgia Institute of Technology
Truckload transportation represents a significant portion of all land-based freight transportation. A substantial body of literature exist on truckload transportation. Unfortunately, one essential real-life complexity is usually ignored: driver restrictions. Governments impose restrictions on truck drivers to ensure their safety as well as the safety of other drivers. People have observed that due to the presence of dispatch windows at origin locations of loads and the rules governing drivers it is not necessarily optimal for a truck to depart from its home base as early as possible in order to complete a trip as early as possible. In fact, it has been conjectured that this 'trip scheduling' problem is NP-hard. Our research disproves that conjecture and shows that this trip scheduling problem can be solved in polynomial time.

Dynamics Of the Multi-depot Pickup and Delivery Problem
Authors: *Huth, Mattfeld*
Speaker: Thomas Huth - Technical University Braunschweig
Currently emphasis in vehicle routing is put on dynamic problems. One issue are customer requests occurring dynamically over time. We present a real-world routing problem and suggest a framework to deal with dynamic aspects. The presented approach will anticipate dynamic events by model adaptation.

Truckload Continuous Move Optimization
Authors: *Lohatepanont, Adulyasak*
Speaker: Yossiri Adulyasak - Chulalongkorn University
The problem of excessive empty backhaul distances is a major challenge in the planning and operation of truckload transportation, in which goods are picked up from an origin and delivered to a destination without mid-route pickups or deliveries. Backhaul distances can be reduced by combining two or more truckload trips together to form a sequence of continuous move truckload trips. Finding optimal or effective combinations of truckload trips, however, is complicated, especially for large-scale transportation network, because the number of possible combinations increases exponentially with the number of shipments. In this paper, we propose a continuous move optimization model for large-scale transportation network, incorporating major operational complexities, namely, fleetcommodity compatibility, trip-based cost function, and time windows. We develop two solution approachesŮan exact column-generation-based branch-and-bound algorithm and a heuristic algorithm which yield significant empty haul distance reduction under relatively short runtimes, and provide a comparison study measuring the effectiveness and applicability of the two methods.

Session 18C: Models and algorithms

Friday 06/15 14:30 - 16:00 Room: Nai Harn
Chairman: Marlies Vanhulsel

A Poverty Impact Road Planning Model
Authors: *Taylor, Petersen*
Speaker: Allison Taylor - Queens University
This paper presents a methodology for directly measuring the impact of transportation projects on the poor and very poor in the context of a regional road planning model, although the methodology is generally applicable to measuring the impact of transportation plans on specific interest groups or demographic sectors. The methodology requires that the demographics of the traffic and vehicle ownership be known. For each project, the equilibrium consumer surplus is calculated by movement and vehicle type. Based on the demographics of the traffic and the vehicle ownership, the benefits to the poor and very poor is calculated. The poor's share of the project benefits (the poverty impact ratio, or PIR) can be compared to the poor's share of national or regional GDP to measure the impact of the proposal on poverty alleviation.

Assessment Of Traffic and Emissions Impacts, for Determining Future Infrastructure In a Metropolitan Street Network: a Real Application In Mexico City
Authors: *Lozano, Antun, Granados*
Speaker: Angelica Lozano - Instituto de Ingenieria, Universidad Nacional Autonoma de Mexico
We present an approach for assessing traffic and emissions impacts which are generated by large modifications to the metropolitan street network, for several current and future scenarios. We include a multicriteria analysis for determining the best set of modifications for each time period. This approach uses an User Equilibrium Model, MOBILE, Electre Method and a GIS-T, and it is based on link level. The approach was applied to the Mexico City case, and the first set of recommended large modifications to the network, were already built.

Session 19B: Tabu search approaches for routing and scheduling

Friday 06/15 16:30 - 17:30 Room: Kamala
Chairman: Henrik Andersson

Tabu Search Based Solution Methods for Scheduling Log-trucks
Authors: *Hirsch, Gronalt*
Speaker: Patrick Hirsch - University of Natural Resources and Applied Life Sciences, Vienna
We present Tabu Search based solution heuristics for the Timber Transport Vehicle Routing Problem (TTVRP) that differ with respect to solution space. The TTVRP is characterized as follows: a fleet of m log-trucks which are situated at the respective homes of the truck drivers has to fulfil n transports of round timber between different wood storage locations and industrial sites. All transports are carried out as full truck loads. Since the full truck movements are predetermined the objective is to minimize the overall distance of empty truck movements. In addition to the standard VRP we have to consider weight constraints at the network, multi-depots, and time windows. Altogether four Tabu Search variants have been developed for the TTVRP and are presented here. The first one computes with the full neighborhood of a solution in each iteration step, whereas the second variant reduces the neighborhood and therefore accelerates the search process. The third variant uses an oscillating neighborhood size depending on the number of the iteration step. The fourth variant was developed to solve big problem instances within acceptable computing times. It is based on the second variant but uses an additional technique to broaden the search process. A post-optimization heuristic was developed and can be applied to all Tabu Search variants. The presented methods were verified with extensive numerical studies.

A Tabu Search Approach for Milk Collection In Western Norway Using Trucks and Trailers
Authors: *Hoff, Lokketangen*
Speaker: Arild Hoff - Molde University College
This paper considers a real world problem for a Norwegian dairy company collecting raw milk from farmers. The problem can be classified as a special type of the Truck and Trailer Routing Problem. The routes have to be constructed so that the vehicles carry a trailer to a parking place and leave it there as a mobile depot. The milk collection from the farmers are performed with the single vehicle, which returns to the parked trailer to fill the milk over to the truck tank when necessary and move the trailer to a new parking place when favourable. In this paper we will compare different frequencies of collection, different sizes of the vehicles and the benefit of using trailers compared to driving with single trucks. We will use the tabu search metaheuristic to construct the routes for the different strategies of milk collection.

Session 19C: Discrete choice models III

Friday 06/15 16:30 - 17:30 Room: Nai Harn
Chairman: Allison Taylor

Sequential Models for Mobility Decisions: Experimentation for the Holding Vehicles Choices
Authors: *Chila, Russo*
Speaker: -
The demand models used in literature, in the field of a behavioural approach, generally simulate the user choices through a discrete choices models. The consolidated approach isn't explicitly able to simulate the variation of choice probability, in consequence of different events, that characterize the evolution of transportation system. So, in this paper we define static demand models the models that give the choice probability of the single alternative, independently by decision-maker's actual choice, relative to the actual and the previous system condition and dynamic demand models the models that give the choice probability according to the evolution system and earlier decisions. The need to introduce dynamic models, considering the state of the decision-maker, in regards to different main decisions, among which it's possible to recall: - considering the mobility choices: the holding choice and particularly the holding decision of vehicles; - considering the travel choices: the path choice, for a private transportation system user, and the run choice, for a transit system user. The models currently used in this area of research and of professional are members of the family of discrete choice models, derived from the random utility theory. These mathematical models have been applied in a way that don't gives the possibility to represent adequately the dynamic of the process choice. In particular, they don't represent the influences exercised by the past decisions on the actual choice. In literature, the known models that consider the effects of the past choices are the holding vehicles models. However, these models are based on static structures, that can be defined pseudo-dynamic. The transition matrix (Gottman and Roy, 1990), that represent the variation of user decisions over time, and the sequential model, that represent the time Ű dependencies of path choice (Russo, 1999), have suggested the automobile transition choice model. According to the sequential approach, the proposed model simulates the permanence or the transition of the actual system state. It is different from the pseudo-dynamic models, because it simulates explicitly the choice of an alternative, in a given period of time, conserving or modifying the choice set relative to the past period. The time-dependencies are considered introducing some attributes that are function of the last state. At first, the proposed model has been applied to the holding vehicle. The model has been specified, calibrated and validated using: - a database relative to the socio-economic evolution of a sample family; - a database relative to the technical classification of vehicles, defined by an Italian company of car hire; - a database relative to the technical-performances characteristics of vehicles, obtained by a specialized car review published in Italy. The results obtained by the experimentation of the model confirm the need of a dynamic sequential approach for the holding vehicles choices. They are presented in the paper and compared with the results obtained through the application of the models used in literature to the same sample. The comparison gives favourable index for the sequential model in relation to the others experimented models.

Biases In Discrete Choice Models
Authors: *Lo, Wan*
Speaker: Quentin K. Wan - The Hong Kong University of Science and Technology
In discrete choice modeling, the hypothesis is that preference for each alternative can be depicted by its utility measure and that people select the alternative with the highest utility. However, utility cannot be entirely measured; therefore it is modeled as a random variable by adding an error distribution to the measured utility. One does not, therefore, have a deterministic prediction of individuals' choices. Instead, choices are expressed in probability terms. Associated with each set of alternatives is a satisfaction function, which captures the expected utility an individual derives from this set of alternatives. The random error distribution associated with the utility function plays a key role in determining the choice probabilities as well as the satisfaction function. In deriving the choice probabilities and the satisfaction function by maximizing the expected utilities of the alternatives, the errors associated with the alternatives are always used in a positive manner. That is, the errors are always considered in such a way that they heighten the utility measures of the alternatives. The result is that the alternative with a larger error would benefit more than an alternative with a smaller error in this procedure of utility

maximization. Accordingly, for two alternatives with identical measured utility values, the alternative with a larger or more spread out error distribution would have a higher probability of being chosen. This result may or may not be consistent with actual choice behavior. All other things equal, why would people have a higher tendency of selecting the alternative that is associated with a higher error? In any case, the procedure of utility maximization places a positive bias toward the alternative with a larger error. This result, we refer to as an optimistic bias in discrete choice models. This optimistic bias will create paradoxes in choice predictions, sometimes erroneous results that are contrary to our expectations, such as under certain situation, the satisfaction function for the travel cost utility of a set of alternatives turns positive (i.e., travel cost becomes a benefit rather than a cost). In this study, we will provide a detailed discussion on these optimistic biases for a number of error term distributions and provide numerical examples for this illustration. We will also propose a set of behavioral biases to explain or avoid this phenomenon. Through this discussion, we hope that new ways will be opened up to reconsider the fundamental characteristics of discrete choice models.

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