PROGRAM

SEVENTH TRIENNIAL SYMPOSIUM ON TRANSPORTATION ANALYSIS

TROMSØ - NORWAY
JUNE 20-25 2010

TRISTANVII

	Stream 1 is held in Rica Hall I	Stream 2 is held in Rica Hall II	Stream 3 is held in Rica Panorama	Stream 4 is held in Nord-Norge salen

Sunday - June 20

19:00 – 21:00	Welcome reception

Monday - June 21

	Stream 1	Stream 2	Stream 3	Stream 4
08:30 – 09:00	Opening session			
09:00 – 10:00	Plenary 1 – Speranza			
10:00 – 10:15	Coffee			
10:15 – 11:45	Mo1.1 Routing - Heuristics	Mo1.2 Maritime Fleet Composition	Mo1.3 Public Transportation and Transit Systems	Mo1.4 Traffic Flow
11:45 – 12:00	Coffee			
12:00 – 13:00	Mo2.1 New Approaches in Vehicle Routing	Mo2.2 Workforce Management and Routing	Mo2.3 Game Theory and Transit Planning	Mo2.4 Supply Chain Design
13:00 – 14:30	Lunch			
14:30 – 16:00	Mo3.1 Railway Transportation	Mo3.2 Hub and Depot Location	Mo3.3 Routing with Column Generation	Mo3.4 State Estimation
16:00 – 16:30	Coffee			
16:30 – 18:00	Mo4.1 Routing - Exact Methods	Mo4.2 Robust Optimization	Mo4.3 Pricing	Mo4.4 Traffic Assignment
22:00 – 00:30	Midnight session			

Tuesday - June 22

	Stream 1	Stream 2	Stream 3	Stream 4
08:30 – 09:30	Tu1.1 Green Vehicle Routing	Tu1.2 Railway Transportation	Tu1.3 Airline Crew Planning	Tu1.4 Evacuation Modeling
09:30 – 10:00	Coffee			
10:00 – 11:30	Tu2.1 Routing - Exact Methods	Tu2.2 Distribution Planning	Tu2.3 Multi-objective Shortest Path	Tu2.4 Pricing
11:30 – 12:00	Coffee			
12:00 – 13:00	Plenary 2 – Möhring			
13:00 – 14:30	Lunch			
14:30 – 16:00	Tu3.1 Maritime Transportation	Tu3.2 Freight Capacity Planning	Tu3.3 Sensor Location and Calibration	Tu3.4 Traffic Control
16:00 – 16:30	Coffee			
16:30 – 18:00	Tu4.1 Routing - Heuristics	Tu4.2 Container Terminals	Tu4.3 Dynamic and Online Planning	Tu4.4 Understanding Behavior from Individual Data

Wednesday - June 23

	Stream 1	Stream 2	Stream 3	Stream 4
08:30 – 10:00	We1.1 Maritime Inventory Routing	We1.2 Team Orienteering	We1.3 Discrete Choice Models	We1.4 Traffic Flow
10:00 – 10:30	Coffee			
10:30 – 12:00	We2.1 VRP with Driver Aspects	We2.2 Inventory Routing	We2.3 Robust Scheduling and Disruption Management	We2.4 Behavioral Models
12:30 – 24:00	Excursion			

Thursday - June 24

	Stream 1	Stream 2	Stream 3	Stream 4
09:00 – 10:30	Th1.1 Inventory Routing	Th1.2 Arc Routing	Th1.3 Maritime Transportation	Th1.4 Road Pricing
10:30 – 10:45	Coffee			
10:45 – 11:45	Th2.1 Profitable Postman Problems	Th2.2 Alliances and Competition, Auctions and Winners	Th2.3 Travel Demand Models	Th2.4 Road Pricing
11:45 – 12:00	Coffee			
12:00 – 13:00	Plenary 3 – Labbé			
13:00 – 14:30	Lunch			
14:30 – 16:00	Th3.1 Multi-Period Routing	Th3.2 Railway Transportation	Th3.3 Routing and Scheduling	Th3.4 Traffic Flow
16:00 – 16:30	Coffee			
16:30 – 18:00	Th4.1 Advances in Integer Programming	Th4.2 Routing and Scheduling	Th4.3 Air Traffic Management and Airport Capacity	Th4.4 State Estimation
19:30 –	Conference dinner			

Friday - June 25

	Stream 1	Stream 2	Stream 3	Stream 4
09:00 – 10:30	Fr1.1 Routing - Exact Methods	Fr1.2 Railway Transportation	Fr1.3 Network Design and Planning	Fr1.4 Dynamic Traffic Assignment
10:30 – 11:00	Coffee			
11:00 – 12:30	Fr2.1 Rich VRP	Fr2.2 Inventory Routing	Fr2.3 Stochastic Networks	Fr2.4 Choice Modelling
12:30 – 14:00	Lunch			
14:00 – 15:30	Fr3.1 Routing - Exact Methods	Fr3.2 Maritime Transportation	Fr3.3 City Logistics	Fr3.4 Humanitarian Logistics
15:30 – 16:00	Coffee			
16:00 – 17:00		Fr4.2 Stochastic Routing	Fr4.3 City Logistics	Fr4.4 Travel Time Estimation
18:00 –	Farewell drink			

	Stream 1 is held in Rica Hall I	Stream 2 is held in Rica Hall II	Stream 3 is held in Rica Panorama	Stream 4 is held in Nord-Norge salen

Welcome to Tromsø and TRISTAN VII

We are very happy to welcome all the participants and accompanying guests to Tromsø and TRISTAN VII. As you all know, the statutes of TRISTAN require that the venue is on an island with a university. The "ø" in Tromsø means island, and the University of Tromsø is situated on the island. Tromsø lies 69° north, and has a two month period of midnight sun. Summer solstice is on the Wednesday in the conference week, which means that our excursion will take place when the sun is highest in the sky. It will of course not set.

Since its birth in 1991, TRISTAN has become one of the main forums of top researchers from academia and industry in all areas of transportation science. TRISTAN has grown since last time, 3 years ago, in Phuket, Thailand. The number of accepted talks has risen to around 200. They will be presented in four parallel sessions. Around 100 papers had to be rejected due to capacity. Still, we have more than 250 registered participants, making TRISTAN VII the biggest TRISTAN ever. Geographically, we have made a diversifying move from earlier TRISTANs. Although the physical climate will be different, we hope the warm social climate will prevail. Probably, the participants will not sneak away during sessions to go swimming!

We extend our sincere thanks to the many people and organizations that have contributed to TRISTAN VII. We wish you all a week of excellent, illuminating, informative presentations, stimulating discussions, and memorable moments from your stay in Tromsø.

The Organizing Committee

Organizing committee

Post. doc. Henrik Andersson, NTNU
Professor Michel Bierlaire, EPFL
Professor Marielle Christiansen, NTNU
Chief Scientist Geir Hasle, SINTEF (chair)
Associate Professor Arild Hoff, Høgskolen i Molde
Professor Arne Løkketangen, Høgskolen i Molde

Scientific Committee

Vinícius A. Armentano, Universidade Estadual de Campinas
Mike Ball, University of Maryland
Jaime Barcelo, Universitat Politècnica de Catalunya
Cynthia Barnhart, Massachusetts Institute of Technology
David Boyce, Northwestern University
Olli Bräysy, University of Jyväskylä
Svein Bråthen, Høgskolen i Molde
Angel Corberán, University of Valencia
Jean-Francois Cordeau, HEC Montreal
Teodor Gabriel Crainic, Université du Québec à Montréal
Andrew Daly, University of Leeds
Guy Desaulniers, Ecole Polytechnique de Montreal
Jacques Desrosiers, HEC Montreal
Richard Eglese, University of Lancaster
Kjetil Fagerholt, Norwegian University of Science and Technology
Michael Florian, Université de Montréal
Michel Gendreau, Université de Montréal
Richard Hartl, University of Vienna
Martin Hazelton, Massey University
Stephane Hess, University of Leeds
Lars Magnus Hvattum, Norwegian University of Science and Technology
Anton Kleywegt, Georgia Institute of Technology
Martine Labbé, Université Libre de Bruxelles
Gilbert Laporte, HEC Montreal
Jesper Larsen, Technical University of Denmark
Odd Larsen, Molde University College
Jean-Patrick Lebacque, Institut National de Recherche sur les Transports et leur Sécurité
Der-Horng Lee, National University of Singapore
Jean-Baptiste Lesort, Institut National de Recherche sur les Transports et leur Sécurité
Janny Leung, The Chinese University of Hong Kong
Henry Liu, University of Minnesota
Hong K. Lo, Hong Kong University of Science and Technology
Jens Lysgaard, Aarhus University
Oli B. G. Madsen, Technical University of Denmark
Pitu Mirchandani, University of Arizona
Otto Anker Nielsen, Technical University of Denmark
Bjørn Nygreen, Norwegian University of Science and Technology
Amedeo Odoni, Massachusetts Institute of Technology
Markos Papageorgiou, Technical University of Crete
Michael Patriksson, Chalmers University of Technology
Warren B. Powell, Princeton University
Christian Prins, Université de Technologie de Troyes
Harilaos Psaraftis, National Technical University of Athens
Mikael Rönnquist, Norwegian School of Economics and Business Administration
Martin Savelsbergh, Georgia Institute of Technology
Frédéric Semet, École Centrale de Lille
Marius Solomon, Northeastern University
M. Grazia Speranza, Università degli Studi di Brescia
Philippe Toint, Facultés Universitaires Notre-Dame de la Paix
Paolo Toth, Università di Bologna
Daniele Vigo, Università di Bologna
Stefan Voss, University of Hamburg
Stein Wallace, Lancaster University

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REGISTRATION

The Registration and Information Desk is located in the entrance hall of Rica Ishavshotel. The opening hours are:

Saturday, June 19	17:00-18:00		
Sunday, June 20	16:00-19:00	22:00-22:30	
Monday, June 21	08:00-10:30	14:00-14:30	16:00-16:30
Tuesday, June 22	09:30-10:00	14:00-14:30	16:00-16:30
Wednesday, June 23	10:00-10:30		
Thursday, June 24	10:30-11:00	14:00-14:30	16:00-16:30
Friday, June 25	10:30-11:00	15:30-16:00	

MAP OF RICA HOTEL
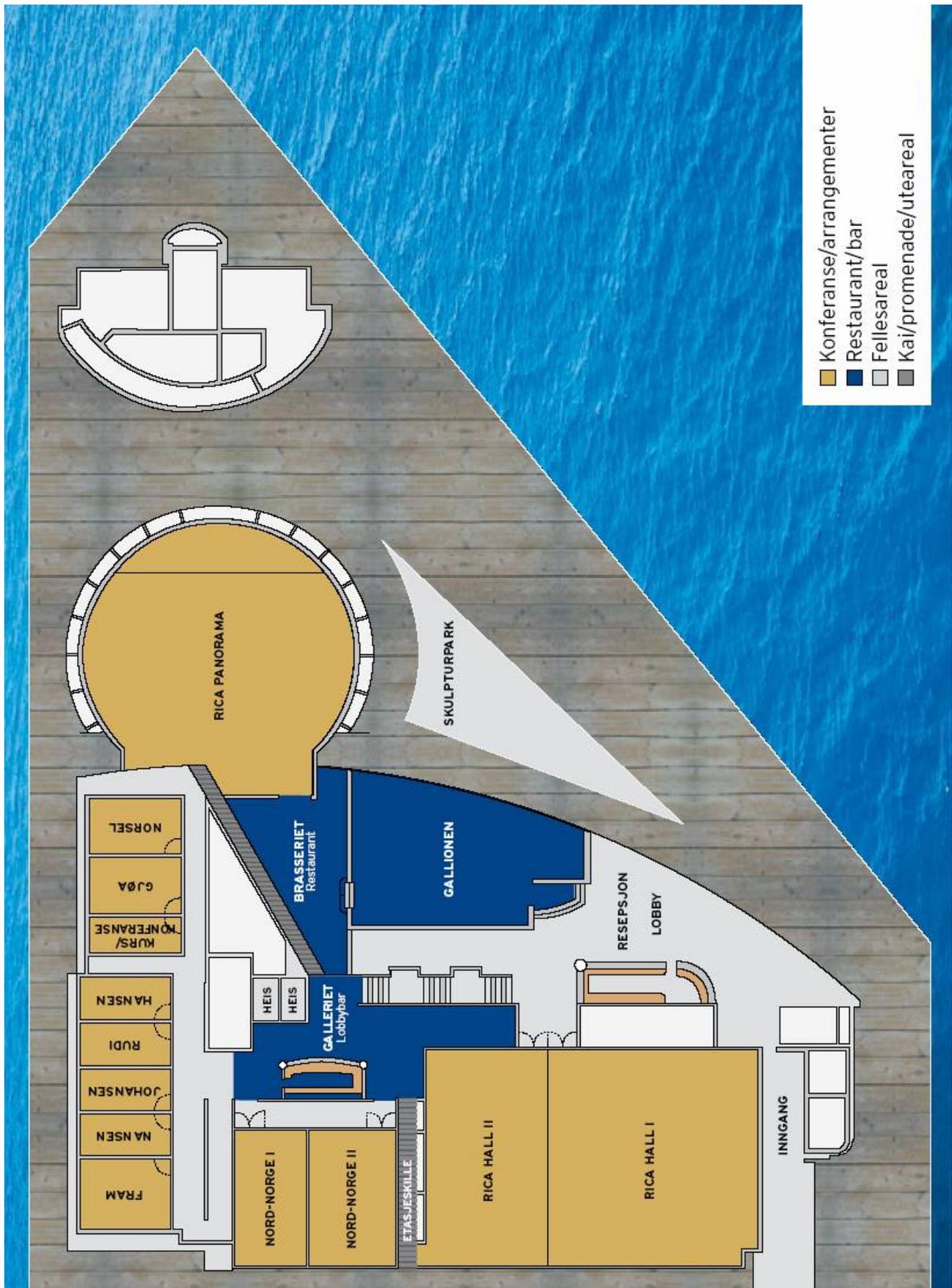
SOCIAL ACTIVITIES

Please bring your badge to all the included social activities

Welcome Reception, 19:00 – 21:00 on Sunday 20th of June

The welcome reception will be held at the Polaria museum, just a ten minute walk from Rica Ishavshotel. It is housed in a very distinctive building that represents ice floes that have been pressed up on land by the rough seas of the Arctic. The Polaria museum has an Arctic aquarium, interesting knowledge-based exhibits, a panoramic cinema, and a gift and souvenir shop. You will be served a welcome drink, and some light local snacks.

Midnight Session, 22:00 – 00:30 on Monday 21st of June

A midnight session consisting of three informal short talks will be organized on top of Mount Storsteinen in the Fjellstua restaurant, 421 m.a.s.l. The speakers will be professors Marius Solomon, Patrice Marcotte, and Gilbert Laporte. The session itself starts at 23:00 and finishes just before midnight. This gives us the possibility, weather permitting, to enjoy the panoramic views over the city and see the midnight sun. We recommend a walk on the mountain before or after the session. Each participant is responsible for transportation to and from the top of the mountain. It is possible to walk (30-45 minutes) from Rica Ishavshotel to the Cable car station or you can go by taxi. If you are in good shape, we recommend that you walk up the hiking trail to the mountain and enjoy the fantastic view on the way. This will take you some 45 minutes. The cable car is a good alternative and takes 8 minutes. The capacity is 27 persons, so make sure to queue up early if you choose this alternative. The organizing committee will distribute cable car tickets on Monday. Make sure that you are properly dressed with warm clothes in case of cold weather or wind.

Excursion, 12:30 – 24:00 on Wednesday 23rd of June

An excursion, starting around noon and finishing at midnight, will give us an insight into life outside Tromsø city. Buses will pick us up at 12:30 outside Rica Ishavshotel and drive us to Tromsø Villmarkssenter (Wilderness center) for traditional Northern Norwegian / Saami lunch in lavvus (tents). You may choose to go outside and meet the 240 huskies and pups who will provide a friendly, but loud atmosphere. Later, we will drive to a coastal community on the island of Sommarøy. Here fishing and hunting has been the livelihood since time immemorial. We will spend the rest of the afternoon and evening at and in the surroundings of Sommarøy Hotel & Conference Centre. Through a wide range of activities we will learn more about the culture and people. A barbecue will be provided for us and we will spend the Midsummer Eve together in a pleasant atmosphere. During the evening, the proposals for TRISTAN VIII will be presented. Make sure that you bring appropriate clothing and footwear. We recommend that you bring a cap, gloves, and a warm jacket. However, here you have your life chance to swim in Arctic waters, so it could be a good idea to bring a swimming costume. There will also be a hot tub available. The main group will return to Rica Ishavshotel at midnight, but there will be possibilities for earlier departure.

Conference Dinner, 19:30 on Thursday 24th of June

The conference dinner will be held at DRIV, the Student House of Tromsø; a renovated warehouse from 1902. The house is located on the quay, just a few buildings away from Rica Ishavshotel. Here, we will enjoy a Norwegian inspired dinner and good company in a nice maritime atmosphere. During the evening, we will vote for TRISTAN VIII and the winner will be announced.

Farewell Drink, 18:00 on Friday 25th of June

There will be an informal get-together and farewell drink after the conference has finished. It will be served in the Panorama room at Rica Ishavshotel, with possibilities of going outside.

SPEAKER AND CHAIR INFORMATION

The duration of each talk is 30 minutes, including 5 minutes for questions. PCs with Acrobat Reader for PDF, PowerPoint, and USB connections for memory sticks will be set up in each room. Speakers are kindly asked to upload and test their presentations before the session starts to minimize setup time. If you have special requirements, please let us know.

The speaker of the final paper in each session is the chair. The chair will open and close the session, introduce each speaker, and act as a strict timekeeper. In case of no-shows we stick to the schedule.

PLENARY SESSIONS

M Grazia Speranza - Inventory routing problems

Monday 21/06 09:00 - 10:00 Room: Rica Hall
Chair: Geir Hasle

In this talk the class of inventory routing problems (IRPs) will be presented. After a review of the literature, with motivations to study this class of problems, the focus will be on the class of discrete time IRPs that include in the objective function transportation and inventory costs. The case of a general distribution network will be considered. A product is distributed from a central facility to several customers and a maximum level of the inventory is given for each customer. The central facility monitors the inventory of each customer and decides when to serve each customer and how much to deliver, guaranteeing that no stock-out occurs. The problem is to determine for each discrete time instant of a given time period which customers to serve, the quantity to deliver to each customer and the route of the vehicles. The objective is the minimization of the sum of the cost of the routing and of the inventory. An effective hybrid heuristic and a new mixed integer linear programming formulation will be presented together with valid inequalities used to strengthen the formulation. A branch-and-price-and-cut algorithm will be proposed and computational results will be presented for a set of benchmark instances.

Rolf H Möhring - Routing in Graphs with Applications to Logistics and Public Transport

Tuesday 22/06 12:00 - 13:00 Room: Rica Hall
Chair: Michel Bierlaire

Traffic management and routing in logistic systems are optimization problem by nature. We want to utilize the available street or logistic network in such a way that the total network "load" is minimized or the "throughput" is maximized. This lecture deals with the mathematical aspects of these optimization problems from the viewpoint of network flow theory and scheduling. It leads to flow models in which - in contrast to static flows - the aspects of "time" and "congestion" play a crucial role.

Martine Labbé - Bilevel programming and network pricing

Thursday 24/06 12:00 - 13:00 Room: Rica Hall
Chair: Arne Løkketangen

Consider a general pricing model involving two levels of decision-making. The upper level (leader) imposes prices on a specified set of goods or services while the lower level (follower) optimizes its own objective function, taking into account the pricing scheme of the leader. This model belongs to the class of bilevel optimization problems where both objective functions are bilinear. In this talk, we review this class of hierarchical problems from both theoretical and algorithmic points of view and then focus on some special cases. Among others, we present complexity results, identify some polynomial cases and propose mixed integer linear formulations for those pricing problem.

MIDNIGHT SESSION

Monday 21/06 23:00 - 23:45 Fjellstua Restaurant, Mount Storsteinen
Chair: Marielle Christiansen

Marius Solomon - Those magnificent researchers and their flying benchmark problems

I will illustrate why the longevity of benchmark problems from different fields is not the same.

Patrice Marcotte - Branching, bounding, cutting, pricing, pruning, dividing and conquering mathematical programs with equilibrium constraints

Building upon the plenary talk of Martine Labbé, I will try to convince this audience that every optimization process should lead to a bilevel program. As a corollary, life itself is bilevel. Since the time allotted to this talk is limited, the elegant proof of this result, which involves the paradigms stated in the above title, will be deferred to a forthcoming Tristan conference. So will be the numerical results, based upon a parcimonious implementation of Wolfe's universal algorithm.

Gilbert Laporte - Midnight Stories

We will reexamine a number of known optimization problems in a new light. Some theoretical and empirical findings will be reported.

Session Mo 1.1 – Routing - Heuristics

Monday 21/06 10:15 - 11:45 Room: Rica Hall I

Large neighborhood search heuristics for propane delivery
Authors: *Desaulniers, Guy; Prescott-Gagnon, Eric; Rousseau, Louis-Martin*
We consider a rich vehicle routing problem arising in companies delivering propane to end users. Given a set of driver work shifts, a set of identical vehicles with a fixed capacity and housed in different depots, a set of replenishment stations, a set of mandatory customers with known demands and time windows, and a set of optional customers with known demands, time windows and bonuses for serving them, the problem consists of building feasible vehicle routes such that they can be assigned to the work shifts, all mandatory customers are serviced and total net costs (costs minus bonuses) are minimized. A route is composed of a sequence of customers interspersed by visits to replenishment stations. It is feasible if it can be assigned to a shift, it starts and ends at the corresponding depot, and it satisfies the visited customer time windows as well as vehicle capacity between the replenishments. To solve this problem, we propose two large neighborhood search heuristics: the first one uses a branch-and-price heuristic to explore the neighborhoods, whereas the second one uses a tabu search heuristic to do so. Computational results on instances derived from real-world data sets will be reported.

A parallel granular Tabu search algorithm for large scale CVRP
Authors: *Jin, Jianyong; Løkketangen, Arne; Crainic, Teodor Gabriel*
In this paper, we present a parallel granular Tabu serach metaheuristic for solving large scale capacitated vehicle routing problems. A new granular neighborhood based on getting rid of the far neighbors is implemented in the parallelization setting. Computational experiments are carried on the large scale benchmark instances of Golden et al. (1998), Li et al. (2005) and Kytojoki et al. (2007) with up to 20000 customers.

Distance-based path relinking for the vehicle routing problem
Authors: *Sörensen, Kenneth; Sevaux, Marc*
Distance-based path relinking for the vehicle routing problem

Session Mo 1.2 – Maritime Fleet Composition

Monday 21/06 10:15 - 11:45 Room: Rica Hall II

A Long-term Liner Ship Fleet Planning Problem With Container Shipment Demand Uncertainty
Authors: *Meng, Qiang; Wang, Tingsong*
A long-term containership fleet planning (LTCFP) problem for a single liner container shipping company aims at determining the number of containerships to be purchased, the number of containerships to be sold, the number of containerships to be chartered-in and the number of containerships to be chartered-out for each year within the long-term planning horizon. In this paper, we propose a multiperiod stochastic programming model for the LTCFP problem with cargo shipment demand uncertainty. For each period in the model, there are several possible containership fleet scenarios proposed based on the containership fleet owned at the beginning of the period. Given a particular containership fleet scenario, we formulate a two-stage stochastic programming model to deploy these containerships and determine liner route frequency in order to maximize the expected total profit. We also design a solution method for the two-stage stochastic programming model by the sample average approximation method. We then show that the proposed multiperiod stochastic programming model can be transformed into the longest path problem on an acyclic network. Several numerical examples are carried out to illustrate the proposed model and solution algorithm.

Robust fleet sizing and allocation in industrial ocean shipping organisations
Authors: *Tsilingiris, Panagiotis; Alvarez, José Fernando; Kakalis, Nikolaos M P*
We propose a robust approach for fleet sizing and allocation under uncertainty in industrial ocean shipping organisations. It consists of a Mixed Integer Programming (MIP) model which simultaneously decides vessel Sale & Purchase (S&P), demolition, lay-ups, and contract/market allocation/deployment. The objective is the maximisation of the Net Present Value (NPV) of the shipping unit, while accommodating the demand for transport of the parent company. In order to allow certain parameters (e.g., vessel S&P and sunset values, freight rates) to take values in an uncertainty interval, we create an equivalent MIP model using the findings of Bertsimas and Sim (2003) to control the degree of conservatism of the solution in terms of probabilistic bounds on constraint violation. The resulting MIP is parameterised to reflect the risk profile of different decision makers. Finally, we employ Monte Carlo simulation to investigate the behaviour of each optimal solution to the robust optimisation problem corresponding to a specific level of risk. After applying our approach to a realistic case, we infer that it may support fleet managers aspiring to maximise profits while being partly protected against uncertainty.

Fleet size and mix and periodic routing of offshore supply vessels
Authors: *Halvorsen-Weare, Elin Espeland; Fagerholt, Kjetil; Nonås, Lars Magne; Asbjørnslett, Bjørn Egil*
We consider a real problem faced by the Norwegian oil company Statoil, where offshore installations are serviced from an onshore supply depot by a fleet of offshore supply vessels. All installations require a given number of visits by a supply vessel each week, and each supply vessel may sail more than one voyage during the week where each voyage has a duration of two or three days. The supply vessel departures to a given installation need to be somewhat "evenly spread" to avoid departures on consecutive days followed by a number of days with no departures. The objective is to determine minimum cost fleet size and mix and corresponding weekly routes and schedules. We present a voyage based formulation for the problem, and some computational results that shows how this solution method may be used to solve real life planning problems. A planning tool based on the voyage based formulation is currently in use by Statoil and significant savings have been obtained from using it.

Session Mo 1.3 – Public Transportation and Transit Systems

Monday 21/06 10:15 - 11:45 Room: Rica Panorama

A Benders decomposition approach for the design of Demand-Adaptive transit Systems
Authors: *Errico, Fausto; Crainic, Teodor Gabriel; Malucelli, Federico; Nonato, Maddalena*
Demand Adaptive transit Systems (DAS) combine features of both traditional fixed-line bus services and purely on-demand systems, such as Dial-a-Ride. A DAS bus line serves, on the one hand, a set of compulsory stops according to a predefined schedule specified by suitable time windows. On the other hand, passengers may issue requests for transportation involving optional stops, inducing detours in vehicle routes. Similarly to most transportation systems, DASs require a complex planning process. We address a challenging issue, called the General Minimum Latency Problem (GMLP), arising in the context of the DAS line design. The GMLP is similar to the TSP except for the fact that its objective function takes into account not only the routing costs, but also a latency component related to the amount of time spent by users in the vehicles. We propose to address the GMLP by a Branch and Cut algorithm based on Benders decomposition and the exploitation of similarities between the GMLP and TSP polyhedra. We also propose general techniques to improve the convergence and the lower bounds of the Benders decomposition and we apply such ideas to the GMLP. We present computational results showing the effectiveness of the proposed methodology.

Comparison of control strategies for real-time optimization of public transport systems
Authors: *Muñoz, Juan Carlos; Giesen, Ricardo; Delgado, Felipe; Cipriano, Aldo; Cortés, Cristián; Sáez, Doris; Valencia, Francisco*
In this study we will focus at comparing the impact of different holding-only control strategies determining which buses are to be held where and for how long. The comparison study is based on two approaches: one deterministic able to optimize over the entire simulation period, but assuming that future stochasticity only depends on the mean values of demand at stops: the second approach is stochastic, based on a hybrid predictive control formulation, which assumes explicitly the stochastic behavior for future demand prediction, but only considering a finite number of steps ahead to perform the online optimization. Different scenarios regarding design frequency and demand levels (capacity being reached and not reached) will be studied to identify under which conditions each strategy outperforms the other.

Integrating routing decisions in public transportation models
Authors: *Schmidt, Marie; Schöbel, Anita*
In public transportation, concerning the passengers' demand most approaches assume a two-step procedure: First, the data about the passengers is distributed over the network using traffic assignment procedures. In a second step, the actual planning of lines, timetables, etc. takes place. This approach ignores that for most passengers there are many possible ways to reach their destination in the public transportation network, thus the actual connection the passengers will take, depends strongly on the decisions made during the actual planning phase. In our paper we investigate for which planning steps an integration of the traffic assignment procedure can be done without increasing the complexity of the problem too badly. Thus we present formulations for some of the common models in public transportation, which include the routing of the passengers in the optimization process, and analyze their computational complexities compared to the problems without routing. We concentrate on line planning, timetabling and delay management using a passenger oriented approach, more precisely the minimization of the overall travel time of the passengers in the network. We present some NP-hardness results arising from the integration of the routing decisions in the traditional models as well as polynomial algorithms for special cases.

Session Mo 1.4 – Traffic Flow

Monday 21/06 10:15 - 11:45 Room: Nord-Norge salen

Link Transmission Model: an efficient dynamic network loading algorithm with realistic node and link behaviour
Authors: *Tampère, Chris M J; Corthout, Ruben; Viti, Francesco; Cattrysse, Dirk*
Dynamic Traffic Assignment (DTA) is a set of criteria that provide a functional relationship between the demand for mobility and the network supply. It is crucial for any DTA model to dispose of a realistic model for the supply behavior: the dynamic network loading (DNL) component. The function of a dynamic network loading model is to propagate traffic from origin to destination over the links and nodes of a traffic network, assuming that the route flows are known. It then calculates as a function of time the generalized costs for traveling each route. In a DTA framework, these costs can lead to adaptation of departure time choice, route choice and/or mode choice or the choice to travel at all (elastic demand). Many different DNL models have been proposed in literature. In this paper, the Link Transmission Model (LTM) is presented. It is one of few models combining the following properties in a computationally efficient way: - link model consistent with traffic flow theory - link model accounts for delays at intersections, also in undersaturated conditions - node model consistent with all constraints imposed by the link model - node model imposing node capacity constraints.

A stochastic lane assignment scheme for macroscopic multi-lane traffic
Authors: *Lebacque, Jean-Patrick; Khoshyaran, Megan*
The object of the paper is to generalize some simple lane-assignment models introduced in the literature. The model is based on the following idea: each user chooses the fastest lane available to him, considering his user class. It is assumed that the perception of lane state by users is not exact nor are users identical. Thus the model is stochastic and results in a system of conservation laws. The properties of this model will be anlyzed, notably in relation with intersection modeling, and numerical results will be presented.

An optimizing heuristic for managing traffic flow at choke points in river transportation systems
Authors: *Smith, L Douglas; Nauss, Robert M; Mattfeld, Dirk Christian; Li, Jian*
River navigation systems with choke points can be represented as a series of unique interdependent bi-directional servers with time-varying traffic levels and operational characteristics, stochastically determined itineraries, and multiple queues with restricted queueing disciplines to impose maneuvering constraints. In this paper, we discuss the development and application of a scheduling heuristic that minimizes total waiting times of vessels at a lock while respecting a restrictive tandem queueing discipline and employing a priority shifting mechanism that prevents serious inequities (relative to a FIFO solution) in the pursuit of operational efficiency. We compare its solutions for sets of randomly generated test problems against solutions from a nonlinear integer programming model for the same problems. We then embed the heuristic (as a C++ routine) into an Arena simulation model of the UMR waterway to show the potential benefits of employing an optimizing procedure for regulating the lockage operations of commercial barge traffic.

Session Mo 2.1 – New Approaches in Vehicle Routing

Monday 21/06 12:00 - 13:00 Room: Rica Hall I

Using Heterogeneous Computing for Solving Vehicle Routing Problems
Authors: *Hasle, Geir; Kloster, Oddvar; Riise, Atle; Schulz, Christian; Smedsrud, Morten*
In the talk, we briefly explain modern PC architectures and the general principles of heterogeneous computing. We illustrate how multi-core and GPU computing may be utilized for higher performance and more robust VRP solvers, and explain the details of our solution method for the DVRP. We present the results of computational experiments on standard CVRP/DVRP benchmarks from the literature as well as industrial test instances from newspaper distribution. Perspectives and directions for future work are given.

The cost of flexible routing
Authors: *Kilby, Philip; Verden, Andrew; Zheng, Lanbo*
We outline an architecture for solving instances of the Vehicle Routing Problem that have arbitrary constraints that must be observed by solutions. In the Vehicle Routing Problem, a fleet of vehicles is used to deliver goods or services to a set of customers. A number of constraints govern the construction of routes. The system uses a Constraint Programming (CP) system to model, propagate and check these constraints. The use of the CP system allows the system to be very flexible – producing solutions for essentially arbitrary constraints that model the business practices of the companies that will use the the system. However, this flexibility comes at the price of increased execution time, and may effect solution quality. The primary contribution of the paper is to examine some facets of the trade-off between flexibility, solution quality and execution cost.

Session Mo 2.2 – Workforce Management and Routing

Monday 21/06 12:00 - 13:00 Room: Rica Hall II

Same-Day Courier Shift Scheduling with Multiple Classes of Requests
Authors: *Ghiani, Gianpaolo; Manni, Emanuele; Quaranta, Antonella*
In this talk we deal with the same-day Courier Shift Scheduling Problem, a tactical problem which amounts to minimize the staffing cost subject to service level requirements. We investigate the value of clustering the customer requests into several classes, extending the work by Ghiani et al. (2008). For this purpose, we model the problem as an integer program with probabilistic constraints on the quality of service. Given that these constraints are non linear and not known explicitly, we propose a heuristic procedure able to explore the search space efficiently through an approximated neighborhood evaluation model, relying on the estimation (via simulation) of a reduced number of parameters. Such a procedure is then embedded into a multi-start heuristic. Computational experiments aim at determining whether it is valuable to cluster the requests into classes in place of using a single class, and show that this approach can provide significant cost reductions in a typical same-day courier setting.

Workforce management in periodic delivery operations
Authors: *Smilowitz, Karen; Nowak, Maciek; Jiang, Tingting*
Service quality and driver efficiency in the delivery industry may be enhanced by increasing the regularity with which a driver visits the same set of customers. However, effectively managing a workforce of drivers may increase travel distance, a traditional metric of the vehicle routing problem (VRP). This paper evaluates the effect that workforce management has on routing costs, providing insight for managerial decision making. The analysis is presented in the context of the period vehicle routing problem (PVRP), an extension of the VRP with vehicle routes constructed to service customers according to preset visit frequencies over an established period of time. Several models are developed to apply different workforce management principles, with a general analysis comparing the models. A Tabu Search heuristic is modified for the purposes of this analysis and applied to a set of standard PVRP test cases. Several parameters associated with workforce management objectives are evaluated, including the frequency of requests and the balance between travel costs and workforce management costs. It is ultimately shown that with the proper parameters in place, workforce management principles may be successfully applied without sacrificing other operational objectives.

Session Mo 2.3 – Game Theory and Transit Planning

Monday 21/06 12:00 - 13:00 Room: Rica Panorama

A Game Theoretic Framework for the Robust Railway Transit Network Design Problem
Authors: *Laporte, Gilbert; Mesa, Juan A ; Perea, Federico*
This paper proposes a game theoretic framework for the problem of designing an uncapacitated railway transit network in the presence of link failures and a competing mode. It is assumed that when a link fails, another path or another transportation mode is provided to transport passengers between the endpoints of the affected link. The goal is to build a network that optimizes a certain utility function when failures occur. The problem is posed as a non-cooperative two-player zero-sum game with perfect information. The saddle points of the corresponding mixed enlarged game yield robust network designs.

Game-Theoretic Models for Competition in Public Transit Services
Authors: *Chan, Eddie; Leung, Janny*
Metropolitan areas account for the majority of population and economic growth in recent decades. Development of transport infrastructure and public transit services have not kept apace with the swell and sprawl of metropolitan areas, with serious congestion occurring in central business districts and insufficient coverage in peripheral areas. In this paper, we discuss some very preliminary game-theoretic models that can be used to investigate the competitive situation when several service providers offer public transit services, and study the impact on the total set of services offered to the public and the resultant level of ridership of the system. The competition among the operators can be modelled by a class of games called potential games. We discuss mathematical programmes that can be used to find the Nash equilibria for these games. By examining the equilibria solutions, we hope to examine the relative merits and tradeoffs for different structures of the transit networks, and the interplay between the services offered and the overall ridership of the system. We hope our models (albeit still rough-hewn with many simplifying assumptions) may provide some insight on the types and bundling of routes being offered by operators, and the locations for transportation interchanges and hubs.

Session Mo 2.4 – Supply Chain Design

Monday 21/06 12:00 - 13:00 Room: Nord-Norge salen

A two-stage stochastic programming model for optimal design of a biofuel supply chain from wastes to ethanol

Authors: *Fan, Yueyue*

A two-stage stochastic programming model is established to support strategic planning of biofuel supply chain system design and optimal feedstock resource allocation in an uncertain decision environment. Biowastes feedstock resources are emphasized in this paper to keep a minimal impact on global food supplies and other natural resources. This decision model can be used to evaluate the economical viability, emission impact, and infrastructure requirement of converting biowastes to ethanol, and assess the potential of waste-based biofuel as a part of sustainable future energy solution. The stochastic model is much larger in size than its deterministic counterpart. A decomposition solution algorithm based on augmented Lagrange method is implemented to overcome the computation challenges. A real-world case study based on California settings will provide modeling and computational insights and policy implications.

An MIP Reverse Logistocs Network Model for Product Returns

Authors: *Zaarour, Nizar; Melachrinoudis, Emanuel; Solomon, Marius; Min, Hokey*

Product returns are daily routines for many companies as evidenced by annual spending of \$100 billion for managing product returns in the United States. Though easily overlooked, product returns often adversely affect the company's bottom line and then divert the company's primary focus of selling and distributing its products. In addition, poor management of returned products can increase customer angst and thus hurt customer services. Considering the seriousness of return management to business success, a growing number of companies have attempted to streamline the process of collecting, handling, storing, and transporting returned products. One of those attempts include: (1) the determination of the optimal number and location of centralized return centers where returned products from customers are collected, sorted, and consolidated into a large shipment destined for manufacturer's repair facilities; (2) the estimation of the optimal holding time at the initial collection points that yields the best tradeoff between inventory carrying costs and shipping costs. To make those attempts successful, this paper proposes a mixed integer programming model that aims to manage product returns under capacity constraints and service requirements. Given the complexity of this model, we propose a linear transformation of the non-linear objective function and then obtain closed form solutions under special structures.

Session Mo 3.1 – Railway Transportation

Monday 21/06 14:30 - 16:00 Room: Rica Hall I

Optimisation of the railroad blocking problem with temporal constraint
Authors: *Housni, Djellab*
The railroad blocking problem (RBP) is formally defined as follows. We are given a set of shipments that must be routed from their origins to their respective destinations on a railroad physical network. This network comprises a set of functional yards connected by undirected links. Among the yards, some are classification yards where blocking operations (i.e., the grouping of incoming cars for connection with outgoing trains) are performed. The studied problem in this paper is railroad blocking problem with a temporal constraint. This railroad blocking problem without temporal constraint is well known as an NP-Hard problem. Our contribution is to present a combinaison of two approaches, heuristic (k-shortest path) and mixed integer programming to solve this type of industrial problem. Case studies have been carried out with real life data and the obtained results are very promising.

Railway Crew Rescheduling under Uncertainty
Authors: *Potthoff, Daniel; Huisman, Dennis; Wagelmans, Albert*
Effective disruption management is a key to a good operational performance for passenger railway companies. Within the disruption management process, the ability to reschedule the main resources rolling stock and crew is crucial. Algorithms for crew rescheduling usually assume that the duration of the disruption, and hence the adjusted timetable that will be operated, is know. In reality however, disruptions sometimes last longer than expected. This means that the timetable needs to be adjusted again and also the crews need to be rescheduled again. In this talk, we will present a quasi robust approach in order to deal with this uncertainty. The resulting set covering problem with side-constraints can be solved by a column generation based algorithm. We will present results for real-life instances from Netherlands Railways and compare our robust approach with a wait-and-see approach.

Duties Scheduling for Freight Trains Drivers: a case study at the French railways
Authors: *Housni, Djellab; Mehdi, Lamiri*
This paper deals with the problem of duties scheduling for freight train drivers at the French state railways SNCF (Societe Nationale des Chemins de Fer Français). The duties scheduling problem consists in constructing weekly shifts of driving work in order to cover all driving tasks with a minimum cost. This problem can be defined as follows. Our proposed method is based on coupling heuristic and column generation techniques and used for real data problem. Case studies have been carried out with real life data and the obtained results are very promising.

Session Mo 3.2 – Hub and Depot Location

Monday 21/06 14:30 - 16:00 Room: Rica Hall II

A single-allocation hub location problem with capacity choices
Authors: *Correia, Isabel; Nickel, Stefan; Saldanha-da-Gama, Francisco*
We propose an extension to the capacitated single-allocation hub location problem (CSAHLP) in which the capacity of the hubs is part of the decision making process. For each potential hub there is a set of possible capacities (known in advance) among which at most one can be chosen. Each capacity level available determines a limit for the incoming flow and incurs in a specific fixed set-up cost. Economies of scale are assumed for these costs. We propose two sets of mixed-integer programming formulations for the problem. The first set results from the extension to the new situation of well-known formulations for the CSAHLP. The second is obtained by indexing the allocation variables in the different capacity levels available for each potential hub. The formulations are compared in terms of the linear relaxation bounds. Some results presented are also valid for the 'classical' problem. Several valid inequalities and preprocessing tests are proposed. Computational tests performed to evaluate the models and enhancements proposed are reported.

Benders Decomposition for Large-Scale Uncapacitated Hub Location Problems
Authors: *Contreras, Ivan; Cordeau, Jean-Francois; Laporte, Gilbert*
In this paper, we propose a Benders decomposition algorithm specifically designed to approach large-scale instances of the classical Uncapacitated Hub Location Problem with Multiple Assignment (UHLPMA). Moreover, we introduce a new challenging set of benchmark instances ranging from 10 to 400 nodes to test the proposed methodology. Computational experiments assess the efficiency of the algorithm. On the one hand, it is able to speed-up by at least one order of magnitude the current best algorithm. On the other hand, it is able to solve optimally instances with up to 400 nodes within reasonable computational times.

Optimal location of one-way carsharing depots
Authors: *Correia, Gonçalo; Antunes, António*
Carsharing systems are an alternative to private vehicle ownership. Instead of owning a vehicle, a person accesses a fleet of shared-use autos, benefiting from choosing the one that best fits his/her needs for a specific objective. These systems were introduced in Europe in the 1940s, but only in the 1980s started to be adopted by cities everywhere in the world. One-way carsharing systems are widely acknowledged as the most interesting systems. However, to avoid unbalance of car stocks and long car idleness periods, they require the location of car depots to be carefully selected. In this paper, we present a mixed-integer optimization model aimed at determining the profit-maximizing location and size of the depots of a one-way carsharing system. The usefulness of the model is illustrated with an application to the Lisbon Metropolitan Area.

Session Mo 3.3 – Routing and Column Generation

Monday 21/06 14:30 - 16:00 Room: Rica Panorama

Location and Routing Problems for Drug Distribution

Authors: *Ceselli, Alberto; Righini, Giovanni; Sharma, Chetan; Tresoldi, Emanuele*

We present an exact optimization algorithm for a variation of the vehicle routing problem arising in the context of the distribution of vaccines and antiviral drugs in case of a pandemic outbreak. The problem requires a fleet of vehicles to reach the maximum number of people within a specified time limit. We present an algorithm based on column generation, where the pricing subproblem is solved through advanced dynamic programming techniques. Preliminary computational results are presented and extensions to the basic model are illustrated.

The Multiple Vehicle Travelling Purchaser Problem

Authors: *Riera, Jorge; Salazar González, Juan José*

Propose a model and an exact algorithm for solving the multiple vehicle travelling purchaser problem. See the extended abstract for more details.

A Column Generation based Approach for the Dynamic Vehicle Routing and Sceduling Problem with Soft Time Windows

Authors: *Qureshi, Ali Gul; Taniguchi, Eiichi; Yamada, Tadashi*

Transportation accounts for considerable cost in the supply chain. The Vehicle Routing and scheduling Problem with Soft Time Windows (VRPSTW) is a useful tool employed by logistics firms to optimize their operations. The classical VRPSTW is defined for static input values such as fixed customer locations and static travel time. However, the traffic conditions in urban areas change with time due to varying congestion levels and incidents resulting in varying travel time on the infrastructure links. There exists a large body of literature on the dynamic customers case of the D-VRPSTW but the dynamic travel times-related literature is really scant. Furthermore this literature have considered heuristics approaches to solve the D-VRPSTW. Therefore, this research proposes a column generation based exact solution approach for the D-VRPSTW with dynamic travel times to fill the existing research gap. The exact approach can be used for small to medium instances as well as for the evaluation and calibration of the heuristics approaches.

Session Mo 3.4 – State Estimation

Monday 21/06 14:30 - 16:00 Room: Nord-Norge salen

Calibration of structural surrogate models for simulation-based optimization

Authors: *Osorio, Carolina; Flötteröd, Gunnar; Bierlaire, Michel*

We describe a novel methodology for the simulation-based optimization of traffic signaling plans. Our framework combines a detailed traffic microsimulator with a less detailed but analytically tractable queueing model of traffic flow. We optimize the signaling plans based on the queueing model in a bilevel optimization setting, where we continuously re-estimate the queueing model from responses obtained from the simulation.

Exploring the Use of Traffic Data Collected from New ICT Based Sensors to Estimate Time Dependent OD Matrices.

Authors: *Barcelo, Jaume; Montero, Lidia; Marques, Laura; Carmona, Carlos*

Time dependent origin to destination, OD, matrices are the key input to dynamic traffic models, mainly to simulation models, microscopic as well as mesoscopic. Dynamic Traffic Models, DTM, are one of the major components of the Advanced Traffic Management Systems and Advanced Traffic Information Systems. DTM play a crucial role in estimating the current traffic state and forecasting its short term evolution and the quality of the results that they provide depends, not only on the quality of the models, but also on the accuracy and reliability of the inputs and, therefore, on the quality of the dynamic or time dependent OD matrices that are part of that input. The research reported in this paper explores two complementary issues for estimating OD matrices: the exploitation of travel time measurements provided by sensors detecting Bluetooth devices equipping vehicles (Tom-Tom, Parrot, hands free...) which define the inputs to an enhanced Kalman Filtering model; and the use of data supplied by V2I technologies (i.e. positions and speeds) that allow the estimates of direct samples which combined with a path reconstruction process provide the desired OD estimates.

The "Adaptive Smoothing Method" with Spatially Varying Kernels: ASM-svK

Authors: *Schreiter, Thomas; Yuan, Yufei; van Lint, Hans; Hoogendoorn, Serge P*

In this paper, an offline traffic state estimator which calculates the flows and speeds over space and time is proposed. The basis of this estimator is the Adaptive Smoothing Method (ASM) by Treiber and Helbing, which smooths given raw traffic data, dependent on the underlying traffic state. In the ASM, these smoothing operations do not take the underlying road geometry into account, which can lead to misestimations. Therefore, in the proposed estimator, the smoothing kernels depend on road discontinuities, like on-ramps, off-ramps or lane openings. This leads to a more accurate filter result, as simulations show.

Session Mo 4.1 – Routing - Exact Methods

Monday 21/06 16:30 - 18:00 Room: Rica Hall I

New Benchmark Results for the Capacitated Vehicle Routing Problem
Authors: *Roberti, Roberto; Baldacci, Roberto; Mingozzi, Aristide*
The Capacitated Vehicle Routing Problem (CVRP) is the problem of designing optimal delivery routes for a fleet of vehicles in order to supply a set of customers with given demands. The objective is to supply all customers minimizing the total cost of all the routes. Recently, Baldacci, Christodes, and Mingozzi (2008) proposed and exact method for the CVRP based on the Set Partitioning (SP) formulation with additional cuts that correspond to capacity and clique inequalities. In this paper, we further improve the exact method of Baldacci, Christodes, and Mingozzi (2008) using Subset-Row (SR) inequalities and a new route relaxation, called ng-route. Moreover, alternative dual solutions and new dominance rules are used to speed up the solution of the pricing subproblems and reduce the size of the nal SP model. Computational results show that the proposed method outperforms the best methods presented in the literature.

A new formulation for the 2-echelon capacitated vehicle routing problem
Authors: *Jepsen, Mads Kehlet; Ropke, Stefan; Spoorendonk, Simon*
The 2-echelon capacitated vehicle routing problem (2E-CVRP) is a transportation and distribution problem where goods are transported from a depot to a set of customers possible via optional satellite facilities. The 2E-CVRP is relevant in city-logistic applications where legal restrictions make it infeasible to use large trucks within the center of large cities. We propose a new mathematical formulation for the 2E-CVRP with much fewer variables than the previously proposed but with several constraint sets of exponential size. The strength of the model is implied by the facts that many cutting planes proposed for the previous formulations are redundant and that many model symmetries can now be avoided. A branch-and-cut algorithm is developed to solve this model to optimality.

A Branch-and-Cut algorithm for the Multi Depot Multiple TSP
Authors: *Benavent, Enrique; Martínez, Antonio*
We study the Multi Depot Multiple Traveling Salesman Problem, a variant of the very well known Traveling Salesman Problem, which consists of finding a set of routes of minimal cost, each one based in one of several available depots, that jointly visit a given set of customers. We introduce an integer formulation of the problem, the associated polyhedron, and some results that allow obtaining facet inducing inequalities for the MDMTSP from certain facet inducing inequalities for the TSP polyhedron. We also study two new families of facet inducing inequalities that are specific for multi depot problems and have shown to be very effective in a cutting plane algorithm. This partial knowledge of the polyhedron is used to implement a Branch-and-Cut algorithm, which is able to solve instances with up to 279 customers and 25 depots.

Session Mo 4.2 – Robust Optimization

Monday 21/06 16:30 - 18:00 Room: Rica Hall II

Controlling the level of robustness in timetabling and scheduling: a bicriteria approach

Authors: *Schöbel, Anita*

Finding robust solutions of an optimization problem is an important issue in practice, and in particular interesting in public transportation. A prominent application is to make timetables robust against delays. Various concepts on how to define the robustness of an algorithm or of a solution have been suggested. However, there is always a trade-off between the best possible solution and a robust solution, which is in the literature specified as price of robustness. In our paper, we analyze this trade-off using a bicriteria approach: We add the robustness of a solution as an additional goal to the optimization problem at hand. We demonstrate this approach for the aperiodic timetabling problem and for project scheduling. In both cases we are able to characterize the distribution of slack times in Pareto solutions. These results show where adding additional slack times makes sense, independent of the level of robustness considered. We furthermore show how the objective function depends on the level of robustness. This result may help planners to determine the required level of robustness beforehand. We are finally able to present polynomial solution approaches to calculate Pareto solutions and hence robust (aperiodic) timetables and schedules.

Robust Approximate Dynamic Programming for dynamic routing of a vehicle

Authors: *Meisel, Stephan; Mattfeld, Dirk Christian*

We provide and analyze a robust Approximate Dynamic Programming algorithm for a dynamic vehicle routing problem with a single vehicle and stochastic customer requests. Creation of an Approximate Dynamic Programming solution for a specific optimization problem requires both a number of design decisions and a number of decisions on the values of parameters to be set. Taking these decisions the question of the robustness of the resulting algorithm arises, where robustness is defined with respect to variations of the attributes of the problem instance considered.

Robust Optimization in Distribution Networks: The Vehicle Rescheduling Problem

Authors: *Spliet, Remy; Gabor, Adriana; Dekker, Rommert*

The capacitated vehicle routing problem is to find a routing schedule describing the order in which geographically dispersed customers are visited to satisfy demand by supplying goods stored at the depot, such that the traveling costs are minimized. In many practical applications, a long term routing schedule has to be made for operational purposes, often based on average demand estimates. When demand substantially differs, constructing a new schedule is beneficial. The vehicle rescheduling problem is to find a new schedule that not only minimizes the total traveling costs but also minimizes the costs of deviating from the original schedule. In our research project, we aim to find a robust long term schedule. The vehicle rescheduling problem is an intrinsic part of this research. A mathematical programming formulation of the rescheduling problem is presented as well as two heuristic methods, a two-phase heuristic and a modified savings heuristic. Computational and analytical results show that for sufficiently high deviation costs, the two-phase heuristic generates a schedule that is on average close to optimal or even guaranteed optimal, for all considered problem instances. The modified savings heuristic generates schedules of constant quality, however the two-phase heuristic produces schedules that are on average closer to the optimum.

Session Mo 4.3 – Pricing

Monday 21/06 16:30 - 18:00 Room: Rica Panorama

A column generation approach for a bilevel pricing problem
Authors: *Casier, Aurélie; Fortz, Bernard; Labbé, Martine*
Consider the product pricing problem (PPP) in which a company sets prices for products in order to maximize its revenue and reacting to these prices the customers buy, among all products on the market, the one providing them the biggest utility. Initially modelled as a bilevel program, PPP can be reformulated as a single level non-linear model. From this non-linear formulation, we derive a new IP formulation containing an exponential number of variables and propose a column generation solution approach.

Regulating HazMat Transportation by Toll-Setting: a Game Theory Approach
Authors: *Bianco, Lucio; Caramia, Massimiliano; Giordani, Stefano; Piccialli, Veronica*
We consider a toll-setting policy to regulate the use of roads for hazardous material transportation. We assume that the toll that a carrier has to pay to use a certain link depends on the total risk induced on that link by the routing choices of all the carriers. This implies that the latter affect the cost of each single carrier, and this leads to a Nash game. We study theoretical properties of this model, i.e., the existence and uniqueness of an equilibrium, and how a government authority could set the tolls in order to control the total risk enforcing also risk equity. The complete model is a bi-level optimization problem, where the leader (the authority) chooses the tolls on the links in order to minimize a combination of risk magnitude and carrier travel cost, and the followers (the carriers) are the players of the game, where each player aims to minimize his travelling cost. We study the properties of this model, reformulate it as a single optimization problem by using the optimality conditions for the followers' problem, and define a heuristic algorithm for solving it. We test the proposed model on some real instances.

A bilevel pricing problem with elastic demand
Authors: *Kamgaing, Aimé K; Marcotte, Patrice; Savard, Gilles*
We consider the problem of maximizing the revenue raised from tolls set on a multicommodity transportation network, taking into account that demand is assigned to cheapest paths, and is actually dependent on the total cost (initial cost of carrying the products + toll) of these paths. We propose various formulations of the problem, either arc or path flow space. In the case of a linear demand-price relationship, we propose three mixed integer (MIP) linear formulations. In the case of nonlinear demand functions, we develop one exact and two heuristic solution methods, and provide an upper bound that allows to assess the quality of the heuristic solutions.

Session Mo 4.4 – Traffic Assignment

Monday 21/06 16:30 - 18:00 Room: Nord-Norge salen

Dynamic Pricing, Heterogeneous Users and Perception Error: Bi-Criterion Dynamic Stochastic User Equilibrium Assignment
Authors: *Zhang, Kuilin; Mahmassani, Hani S; Lu, Chung-Cheng*
A probit-based bi-criterion dynamic stochastic user equilibrium (BDSUE) model is presented to capture path choice behavior of heterogeneous users with distinct value of time (VOT) and differing perception of travel costs in response to pricing and congestion in a transportation network. Across the population of travelers, the VOT is represented by a continuously distributed random variable, and path travel cost perception errors are multivariate normally distributed. The BDSUE problem is formulated as a fixed point problem in the infinite dimensional space, and solved by a column generation solution framework which embeds (i) a parametric analysis method (PAM) to transform the continuous problem to the finite dimensional space by finding breakpoints that partition the entire range of VOT into subintervals and define a multi-class dynamic stochastic user equilibrium problem (MDSUE); (ii) a column generation algorithm to augment a feasible path set for each user class; (iii) a probit-based stochastic path flow updating scheme solving a Restricted MDSUE problem defined by the set of feasible paths; and (iv) dynamic network loading using a particle-based traffic simulator to capture traffic dynamics and determine experienced travel times for a given path flow pattern. Numerical experiments on an actual network are conducted to explore convergence of the solution algorithm, and illustrate heterogeneous user responses to dynamic tolls.

Biobjective Traffic Assignment to Model Network User Behaviour in Networks with Road Tolls
Authors: *Raith, Andrea; Wang, Judith Y T; Ehrgott, Matthias*
Traffic assignment (TA) is a key component in the conventional four-stage transport planning model. It models travel behaviour in terms of route choice. Being able to model route choice decisions is essential to accurately forecast travel demand and most importantly to enable the assessment of benefits of changes in transport policies and infrastructure developments. The presence of road tolls influences the route choice of travellers. We do not make the assumption that route choice can be expressed through a generalised cost function with given VOT or VOT distribution. Instead, we explicitly distinguish time and cost as separate route choice objectives. This leads to the concept of biobjective TA. For the standard TA problem, equivalence with optimisation and variational inequality problems is exploited to develop solution algorithms. However, the equivalences do not extend to the biobjective problem. Instead we propose heuristic solution approaches. One is based on the well-known Method of Successive Averages (MSA). To replace All-or-Nothing assignment in MSA, a biobjective shortest path problem is solved and travel demand is allocated to the obtained efficient paths, for which we suggest different strategies. We also show how another TA solution algorithm, path equilibration, can be extended to solve biobjective TA.

A paradox in dynamic traffic assignment - Dynamic extension of the Braess paradox
Authors: *Knoop, Victor; Hoogendoorn, Serge P; van Arem, Bart*
The Braess paradox is well known by traffic researchers. It states that adding a link can actually increase travel time. This paper shows that if traffic dynamics are taken into account, the same effect happens at an even simpler network layout. The key principle is the delay will take place upstream of the bottleneck and not necessarily at the link of the bottleneck. Therefore, travellers will not necessarily avoid the bottleneck. Moreover, also travellers taking a route which does not pass the bottleneck are possibly delayed in the queue upstream of the bottleneck due to spillback or blocking back effects. The paper shows a two-link example network where travelers will encounter more delay if a third link is added. It is also shown that this extra delay is not bounded to a maximum. Finally, solutions are proposed consisting of measures which take care that only travellers passing the bottleneck encounter delay. This can be done by separating the traffic streams more upstream, or introducing traffic lights on one link. Both solutions cause the queue to be at the link of the bottleneck ad so to avoid spillback delays.

Session Tu 1.1 – Green Vehicle Routing

Tuesday 22/06 08:30 - 09:30 Room: Rica Hall I

GHG Emission Vehicle Routing Problem
Authors: *Figliozzi, Miguel*
Environmental, social and political pressures to limit the impacts associated with green house gas (GHG) emissions are mounting rapidly. To date there has been no or limited research which seeks to reduce emissions as the primary objective of a routing problem despite the fast growth and high impact of commercial vehicles. In the capacitated vehicle routing problem with time windows (VRPTW), it is traditionally assumed that carriers minimize the number of vehicles as a primary objective and distance travelled as a secondary objective without violating time windows, route durations, or capacity constraints. This research focuses on a different problem, the minimization of emissions and fuel consumption as the primary or secondary objective. This creates a new type of VRP which is denoted the GHG Emissions Vehicle Routing Problem or simply EVRP. This research presents two formulations and a solution approach for the EVRP where travel speeds are also decision variables. EVRP properties are stated and discussed. Results obtained under different levels of congestion are compared and analyzed. Preliminary results indicate that there may be significant emissions savings if commercial vehicles are routed taking emissions into consideration. However, savings are highly dependent on problem characteristics and binding constraints.

Green Logistics: Three Vehicle Routing and Scheduling Case Studies
Authors: *Eglese, Richard; Black, Dan*
Three vehicle routing and scheduling case studies are described based on distribution operations by road in different parts of the U.K. Traffic information on time-dependent speeds for different roads in the networks has been provided that enables shortest time paths between places to be found for different starting times. This information is used to construct a Road Timetable which is an input to LANTIME, a specially desgned vehicle routing and scheduling algorithm, to produce distribution plans. The resulting plans are compared with those produced by conventional methods that do not take the traffic information into account. Results are analysed by comparing the Greenhouse Gas emissions for the different approaches in the three case studies.

Session Tu 1.2 – Railway Transportation

Tuesday 22/06 08:30 - 09:30 Room: Rica Hall II

Service Oriented Train Timetabling

Authors: *Kaspi, Mor; Raviv, Tal*

The train planning problem can be divided into several sub-problems, mainly Line Planning, Timetabling, Platforming, Rolling Stock Circulation, and Crew Planning. In this study, we focus on quality of service aspects derived by decisions made during the line planning and timetabling phases. The quality of service is measured in terms of total time spent by the passengers in the railway system, including waiting time at the origin stations, connections and travel time. We formulate an integrated Line planning and Train Timetabling model, devise methods to encode a feasible solution and to quickly evaluate it. We then apply the Cross Entropy meta-heuristic in order to solve the problem. In order to test our algorithm we use the Israeli railway system as a test bed. The timetable created by our algorithm saves about 20% of the total travel time as compared to the one currently in use and allows better utilization of the infrastructure.

Integrated Scheduled Service Network Design for Freight Rail Transportation

Authors: *Crainic, Teodor Gabriel; Gendreau, Michel; Zhu, Endong*

We present a service network design model for freight rail carriers that simultaneously addresses the selection of services and their schedules, the classification of cars, the selection of blocks to build at each yard, and the make up of trains in terms of blocks carried. The model is based on a three-layer space-time network and we will discuss the application of this approach to the case of direct servi9ces, as well as to the case of services with intermediary stops. We will also present the meta-heuristics we developed for these cases, based on tabu search and slope scaling ideas, respectively. Numerical results on several classes of test problems, including some derived from actual applications, will also be presented and analyzed.

Session Tu 1.3 – Airline Crew Planning

Tuesday 22/06 08:30 - 09:30 Room: Rica Panorama

Integrated Crew Pairing and Crew Assignment by Dynamic Constraint Aggregation
Authors: *Soumis, Francois; Sadoune, Mohammed; El Hallaoui, Issmail; Desaulniers, Guy*
The integrated crew scheduling (ICS) problem consists of determining, for a set of available crew members, least-cost schedules that cover all flights and respect various safety and collective agreement rules. A schedule is a sequence of pairings interspersed by rest periods that may contain days off and a pairing is a sequence of flights, connexions, and rests starting and ending at the same crew base. Given its high complexity, the ICS problem has been traditionally tackled using a sequential two-stage approach, where a crew pairing problem is solved in the first stage and a crew assignment problem in the second stage. In this paper, we propose a model and a solution method for solving the crew pairing and the crew assignment problems in a single stage. The proposed solution method combines column generation and bi-dynamic constraint aggregation. The latter is a recent methodology that allows to reduce the number of constraints in the column generation master problem as well as the size of the networks in the subproblem. Computational results on real-life data show that integrating crew pairing and crew assignment can yield significant savings: on average, 4.02% on the total cost and 5.51% on the number of schedules for seven tested instances.

Integrating Medium and Short Term Decisions in Airline Crew Planning
Authors: *Römer, Michael; Mellouli, Taïeb*
Medium-term airline crew planning decisions, including part-time contracting, vacation planning and assignment of office/simulator activities affect the time-dependent availability of crew in their respective domiciles. Therefore, they have a big impact on the short-term decision of crew scheduling. In this paper, we first propose a network flow-based approach to modeling medium-term crew planning decisions. Then, to achieve an exact anticipation of crew scheduling, we integrate this model with the network flow-based model for crew pairing proposed by Mellouli which explicitly takes into account pre-planned activities. Computational results from experiments with data from a medium-sized German airline show the applicability of our approach to realistic problem instances. Furthermore, the experiments demonstrate that the possibility of making changes to pre-planned activities leads to better crew pairing solutions.

Session Tu 1.4 – Evacuation Modeling

Tuesday 22/06 08:30 - 09:30 Room: Nord-Norge salen

EVAQ: An Evacuation Model for Travel Behavior and Traffic Flow
Authors: *Pel, Adam; Bliemer, Michiel C J; Hoogendoorn, Serge P*
This contribution presents the evacuation simulation model EVAQ, dealing with several shortcomings of current evacuation models regarding travel choice behavior, compliance behavior, and network dynamics. The model framework is discussed and each of the components is described, as well as the manner in which these interact. The scalability and potential of EVAQ is illustrated by a real-life application describing the evacuation of the Dutch municipality of Rotterdam. In conclusion, the model framework and formulation, case results, discussion and conclusions presented in the paper can be used 1) to give direction to further research along this line on incorporating traveler choice behavior, compliance behavior, and network dynamics in evacuation simulation models, and 2) to understand the role of these aspects in the evacuation process and their assessment in evacuation planning studies.

Threshold Model of Social Contagion Process on Random Networks: Application to Evacuation Decision Making
Authors: *Hasan, Samiul; Ukkusuri, Satish*
In this paper, we develop a network science model to investigate the social contagion process within a network where individuals adopt alternate behaviors by following their peers. Specifically, we investigate the threshold model of social contagion on random networks with a particular mixing patterns. The threshold model follows a simple binary decision rule such as an individual agent observes the current states (either 0 or 1 i.e either evacuated or not-evacuated) of k other agents which we call its neighbors, and adopts state 1 if at least a threshold fraction of its k neighbors are in state 1, else it adopts state 0. We test the threshold model of individual decision making process assuming a distribution of threshold value for individuals. We also investigate the effects of mixing patterns of the social network to the propagation or diffusion among the population. As such this paper envisions to bring together concepts from complex networks and transportation to develop an integrated contagion propagation model. Initially, our analytical model will derive strict conditions for the information cascade to diffuse efficiently. Our simulation model will test the findings of the analytical results.

Session Tu 2.1 – Routing - Exact Methods

Tuesday 22/06 10:00 - 11:30 Room: Rica Hall I

The Dynamic Traveling Purchaser Problem with Deterministic Quantity: A Branch and Cut Approach

Authors: *Angelelli, Enrico; Gendreau, Michel; Mansini, Renata; Vindigni, Michele*

Given a set of products with a positive discrete demand and a set of markets selling subsets of the required products at given prices, the Traveling Purchaser Problem looks for a tour visiting a subset of markets such that products demand is satisfied at the minimum purchasing and traveling costs. In this paper we analyze a dynamic deterministic variant of the problem, where the quantity made available in each market for each product linearly decrease over time. We propose the model formulation and a Branch and Cut approach to solve it. New benchmark instances have been generated.

The multi-modal traveling salesman problem

Authors: *Jozefowiez, Nicolas; Laporte, Gilbert; Semet, Frédéric*

In this work, we define the Multi-Modal Traveling Salesman Problem (MMTSP). It is a variant of the Traveling Salesman Problem (TSP), where colors (representing modes of transportation for instance) are assigned to edges. Therefore the MMTSP is a bi-objective problem, where the two objectives are the minimization of the tour length and the minimization of the number of colors. We also define three single-objective problems related to the MMTSP obtained by transforming one of the objectives to a constraint or by dropping one objective. We propose mathematical models for these problems as well as ways to build valid inequalities from those existing for the TSP. First, a branch-and-cut algorithm is developed for the single-objective problems before being adapted to solve the MMTSP. Experiments are conducted on generated data and modified TSPLIB instances.

An Optimization Model for the Pick-up and Delivery of Trucks & Containers Routing with Multiple Container Loads

Authors: *Crainic, Teodor Gabriel; Di Francesco, Massimo; Zuddas, Paola*

We study the management of a heterogeneous fleet of trucks providing pick up and delivery services of containers from/to a port. In this problem some trucks can carry more than one container, whereas in the related literature the transportation capacity is assumed to be one container per truck. To address this gap, we propose an optimization model.

Session Tu 2.2 – Distribution Planning

Tuesday 22/06 10:00 - 11:30 Room: Rica Hall II

Lagrangean Decomposition for an Adaptive Location-Distribution Problem
Authors: *Gendron, Bernard; Khuong, Paul-Virak; Semet, Frédéric*
We consider a multi-echelon location problem motivated by a case study for a multi-channel retailing company, which sells a wide variety of products via Internet, mail order catalogs, and stores. Since most items to deliver are small or medium-size parcels, consolidation is a major concern which is addressed by designing a multi-echelon distribution system. The first echelon is associated with primary facilities such as central warehouses. The second echelon corresponds to facilities such as cross-docking terminals. The third echelon is associated to facilities such as small cross-docking terminals, called satellites, from which tours are issued to serve customers. This multi-echelon system is adaptive, in the sense that terminals and satellites can be opened or closed easily according to demand fluctuations. 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 terminals and the satellites. In this work, we introduce a Lagrangean decomposition approach embedded in a branch-and-bound scheme, which can deliver provably optimal solutions to large-scale instances of the problem.

Mathematical models and tabu search heuristic for two-echelon location-routing problem in freight distribution
Authors: *Sterle, Claudio; Sforza, Antonio; Crainic, Teodor Gabriel; Boccia, Maurizio*
The design of a multi-level freight distribution system is a strategical and tactical decisional problem. It has been modeled as a two-echelon location-routing problem (2E-LRP). It has been scarcely treated in literature and no exact neither heuristic solution methods have been proposed in literature for it. Several models are proposed for 2E-LRP, extending and/or adapting classical VRP formulations and a MDVRP formulation present in literature. The models can be used for small instances with a commercial solver. For medium and large instances the need arises of approaching it with a heuristic method. To this aim a Tabu Search heuristic is proposed and implemented. It is based on the decomposition of the whole problem in four subproblems, one capacitated FLP and one MDVRP for each echelon. The four sub-problems are sequentially and iteratively solved and their solutions are opportunely combined in order to determine a good global solution. Tabu Search has been experienced on three set of instances of varying dimensions and the obtained results have been compared with the available bounds. Experimental results prove that the proposed TS is effective in terms of quality of solutions and computation times in most of the solved instances.

Estimate the value of ITS information in urban freight distibution
Authors: *Flamini, Marta; Nigro, Marialisa; Pacciarelli, Dario*
This paper addresses quantitative methods for estimating the value of information from ITS in urban freight distribution. A real-life application on the retail distribution of perishable goods is considered. The problem is formulated as a vehicle routing problem with soft time windows and time-dependent travel times, and solved by using information affected by different degrees of detail and reliability. The practical performance of these solutions is then evaluated by simulation, to assess the joint benefit of using more reliable and detailed information with different solution algorithms.

Session Tu 2.3 – Multi-objective Shortest Path

Tuesday 22/06 10:00 - 11:30 Room: Rica Panorama

An Aggregate Label Setting Policy for the Multi-Objective Shortest Path Problem
Authors: *Iori, Manuel; Martello, Silvano; Pretolani, Daniele*
We consider label setting algorithms for the multi-objective shortest path problem with any number of sum and bottleneck objectives. We propose a weighted sum aggregate ordering of the labels, specifically tailored to combine sum and bottleneck objectives. We show that the aggregate order leads to a consistent reduction of solution times (up to two thirds) with respect to the classical lexicographic order.

Bi-objective Multimodal Time-Dependent Shortest Viable Path Algorithms
Authors: *Gueye, Fallou; Artigues, Christian; Huguet, Marie José*
For the passengers public transport, the development of alternatives to the individual vehicles introduces new challenges for the organization of the travels via the use of various modes of transportation. Taking into account the multimodality of urban transportation networks for individual passenger's itinerary computation introduces a number of additional constraints such as time dependent travel times, restriction and/or preferences in using some modes. The central problem considered in this work is a bi-objective shortest path on a multimodal and time-dependent network with a single source O, destination D and departure time t. The goal is to find all the non-dominated paths under the two objectives "travel time" and "number of modal transfers".

Biobjective Aircraft Route Guidance through Convective Weather
Authors: *Kuhn, Kenneth; Raith, Andrea*
Pilots flying through areas where convective weather is present select routes aiming to minimize risk and maximize efficiency. Air traffic controllers suggest routes pilots may accept or decline, while also estimating airspace capacities, scheduling aircraft landings, and performing a host of other activities all related to considerations of risk and uncertainty. The goal of this research is to provide aircraft route guidance during periods of convective weather. This work is differentiated from past work in that the problem is explicitly modelled as a bi-objective problem and solved to optimality, giving pilots flexibility to choose from a set of non-dominated routes minimizing risk and maximizing efficiency. While a similar problem has been approximately solved using heuristics, there does not seem to be a need to do so as several exact algorithms are capable of quickly identifying all efficient solutions. We use a bi-objective label setting algorithm which extends the single-objective label setting algorithm, also known as Dijkstra's algorithm. We are able to identify all efficient solutions to known sample problems involving hundreds of thousands of nodes on a standard desktop computer within 1 second without taking advantage of any speedup techniques or network pre-processing.

Session Tu 2.4 – Pricing

Tuesday 22/06 10:00 - 11:30 Room: Nord-Norge salen

Network Pricing Problem: the case of European Air Traffic Management

Authors: *Castelli, Lorenzo; Labbé, Martine; Violin, Alessia*

In Europe, every Air Navigation Service Provider (ANSP) finances its activities by charging the airlines using its airspace. These 'en route charges' usually account for around 10-20% of the cost of a flight, and they can therefore influence the route choice: airlines may decide to fly longer to avoid countries with higher charges. If ANSPs want to maximise their revenues, they must choose the optimal charge to impose on their airspace. We show that this optimal charge can be identified through a Network Pricing Problem (NPP) formulation in the form of Bilevel Programming where the leader (i.e. the ANSP) owns a set of arcs (the airways in its national airspace) and charges the commodities (i.e. the flights) passing through them. As the en route charges are proportional to a Unit Rate value fixed by the ANSP, we are able to apply a similar methodology as in the case of a single toll arc for the NPP. By exploiting the structure of the problem, we propose an exact algorithm to compute the optimal Unit Rate and apply it on a case study relying on real air traffic data and realistic flight cost figures.

Encouraging efficient usage of railway infrastructure through pricing mechanisms

Authors: *Werner, Adrian S; Lium, Arnt-Gunnar*

Efficient and reliable movement of freight and passengers is a key component for economical growth in today's society and significant resources are invested in transportation infrastructures. Railroad infrastructure is very costly to develop, yet it enables the movement of large quantities of goods and passengers. Even small improvements in its utilization affect the return on investment significantly. Consequently, it is important to remove bottlenecks and to shift traffic from peak to non-peak periods. Encouraging efficient infrastructure utilization, rail transport can be made more competitive compared to other modes of transportation. This allows for traffic migration from roads to rail, limiting the need to invest in additional road infrastructure. Moreover, it reduces emissions of CO_2, noise, or accidents associated with road transportation. We propose methods relying on differentiated tariffs/subsidies for using various infrastructure parts during the day, providing incentives to the railway operators for economically optimal usage. Such methods will help to relieve congestion as well as stimulate usage in low traffic periods. A challenge is that the incentives must be set simultaneously, taking into account each railway operator's optimal response. This is a very difficult problem which becomes increasingly complex with the network size and the number of operators.

Congestion Pricing for Airport Efficiency

Authors: *Perakis, Georgia; Sun, Wei*

Airport congestion is a serious problem in many cities around the world. One way to alleviate congestion is through tolls (congestion pricing). The main goal of this work is to determine when congestion pricing is beneficial to passengers and airlines, quantify the potential efficiency gains and explore novel ways to implement it so that both passengers and airlines can benefit. In particular, we introduce and study a congestion pricing model that applies to many airlines with different types of aircrafts. Our model allows the possibility that not all the revenue from the airport tolls will be utilized to benefit society. Furthermore, we propose an alternative way to implement congestion pricing based on welfare-sharing between airlines and passengers. Our analysis shows that when congestion is not severe, the no toll setting loses at most 25% of the total welfare compared to the setting with optimal tolls. However when congestion becomes a serious problem then the loss of welfare can be arbitrarily large and as a result, big efficiency gains can be achieved through congestion pricing.

Session Tu 3.1 – Maritime Transportation

Tuesday 22/06 14:30 - 16:00 Room: Rica Hall I

A large neighourhood search heuristic for a periodic supply vessel planning problem arising in offshore oil and gas operations
Authors: *Shyshou, Aliaksandr; Fagerholt, Kjetil; Gribkovskaia, Irina; Laporte, Gilbert*
Upstream logistics in the Norwegian oil industry includes, along with other activities, providing the offshore installations with necessary supplies. These are periodically delivered to the installations by supply vessels from onshore bases. This paper proposes a large neighbourhood heuristic for a real-world periodic supply vessel planning problem faced by StatoilHydro, the largest Norwegian offshore oil and gas operator. However, the model and the algorithm provided in the paper are of wide applicability. The problem calls for the simultaneous determination of a repetitive weekly sailing plan and of the configuration of the supply vessel fleet. Computational comparisons with an exact solution method results demonstrate the competitiveness of the heuristic.

Ship Traffic Optimization for the Kiel Canal
Authors: *Günther, Elisabeth; Möhring, Rolf H; Lübbecke, Marco*
The Kiel Canal connects the North and Baltic seas and is the busiest artificial waterway worldwide (in terms of traffic). In a billion Euro project, the German Federal Waterways and Shipping Administration plans to enlarge the canal during the coming years. This project is about contributing to a well-founded advise on how the enlargement can be optimally done. In order to evaluate the various construction possibilities it is indispensable to first provide an accurate model for the ship traffic and designing an algorithm which (ideally optimally) controls it. We present such an optimal traffic control by giving powerful heuristics which are based on successive shortest path calculations and tailored local searches. All relevant practical constraints are respected by this approach. To assess the quality of our solutions we present two integer programming formulations (and results), one of which yields a full-fledged branch-and-price algorithm with pricing subproblems which are interesting in their own right.

A Methodology to Assess Vessel Berthing and Speed Optimization Policies
Authors: *Alvarez, José Fernando; Longva, Tore; Engebrethsen, Erna*
Standard ocean shipping contracts stipulate that a chartered vessel must sail at "utmost despatch", with no consideration for the availability of berths at the destination port. The berthing policies used at many ports, which admit vessels on a first-come, first-served basis, provide an additional incentive for the master to sail at full speed. These legacy contracts and berthing policies constitute a major driver of harbor congestion and marine fuel consumption, with adverse economic, safety, and environmental consequences. We propose a methodology to evaluate the potential benefits of new berthing policies and ocean shipping contracts. Given the importance of stochasticity on the performance of maritime transport systems, and the need to represent the efficient allocation of terminal resources, we have chosen a hybrid simulation-optimization approach. Our discrete event simulation model represents vessels and their principal economic and physical characteristics, the spatial layout of the terminal, performance of the land-side equipment, contractual agreements and associated penalties, and berthing policies. The proposed optimization model – a substantial extension of the traditional berth assignment problem – represents the logic of the terminal planner. The objective of the planner is to minimize the weighted sum of fuel costs and delay penalties, while generating feasible berth-vessel-equipment assignments, and respecting the contractual agreements between all parties. The simulation program solves multiple instances of the optimization model successively in order to represent the progression of planning activities at the terminal.

Session Tu 3.2 – Freight Capacity Planning

Tuesday 22/06 14:30 - 16:00 Room: Rica Hall II

Aggregate planning in general freight intermodal transportation networks
Authors: *Anghinolfi, Davide; Paolucci, Massimo; Sacone, Simona; Siri, Silvia*
The objective of this work is to make an aggregate medium-term planning in a general freight intermodal network in which different transportation modes (road, rail and sea) are considered. The transportation demand is made of customer orders or forecasts and is given by certain quantities of goods to be moved from an origin to a destination and meeting some time requirements. The planning problem corresponds to determine how to satisfy this transportation demand in the considered network and with the available transportation resources over the considered (discretized) planning horizon, in order to minimize the overall transportation cost and the delay in delivery of orders. The proposed planning procedure is composed of two phases: the path evaluation phase and the planning phase. In the former phase, all the possible paths (and also the associated transport resources) available to serve a given order are computed. The latter phase consists in the statement and solution of an integer programming problem, in which the decision variables concern the quantities to be transported on each arc of the network by a specific transportation resource in each time step.

Modelling Commercial Vehicle Empty Trips: Theory, Novel Developments, and Applications.
Authors: *Holguin-Veras, Jose; Thorson, Ellen*
The paper reviews the modeling approaches that have been suggested to model empty trips, and proposes novel formulations that lead to improved estimation performance. The models range from simple naïve formulations to some more complex ones involving trip chains, destination choice processes, and memory components. The performance of the alternative formulations to model empty trips is assessed by applying these models to sample data sets from different countries. The formulations developed and discussed in the paper have been successfully applied in a number of different countries including Sweden, Norway, Guatemala, and Colombia. The paper starts with some background information on the subject, followed by a brief description of previous developments in the area, a description of the test cases for the model, the methodology, and finally the results and conclusions. This is not a marginal issue, all the contrary. The official statistics in the United States clearly indicate the magnitude of the problem: about 57% of the miles traveled by straight trucks, and 33% of the miles traveled by semi-trailers are empty (U.S. Census Bureau, 2004). Obviously, not properly modeling such important flow-that as said cannot be proportionally added to the loaded traffic-is bound to lead to major estimation errors. The research conducted indicated that not properly modeling empty trips lead to errors on the estimation of directional traffic that are four to seven times larger than when appropriate empty trip models are used (Holguín-Veras and Thorson, 2003).

Dynamic Capacity Control for Flexible Products: An Application to Resource Allocation in Transportation Logistics
Authors: *Schönberger, Jörn; Kopfer, Herbert*
The deregulation and harmonization of the international trade, especially within Europe, have significant impact on the business strategy and market positioning of road-based freight carrier companies. For them, the floor is prepared now to play actively on the market by adjusting their products and services as a reaction to demand changes. However, systems and decision tools for supporting a profit-oriented allocation of capacity (container, full truck loads or less-than-truckload) are hardly available because a one-to-one transfer of those technologies from other service industries is not possible. In this contribution, we investigate the dynamic acceptance/rejection decision problem that a fleet disposition manager of a freight carrier has to solve. We propose a (mixed-integer) linear program that represents the acceptance problem if a fleet of vehicles of fixed capacities is available. This model is solved with a simplex-based solver. From a solution of this model we derived least acceptable revenues (bid-prices) that must be associated with additional requests asking for transport services. In order to evaluate the proposed decision support approach, we perform extensive computational simulation experiments. Recorded indicator values are assessed and discussed.

Session Tu 3.3 – Sensor Location and Calibration

Tuesday 22/06 14:30 - 16:00 Room: Rica Panorama

Locating Sensors on Traffic Networks: A Survey
Authors: *Gentili, Monica; Mirchandani, Pitu*
Sensors are used on traffic networks to collect data for the purpose of monitoring and management of the traffic flows. Through the monitoring, travelers may be informed of the network conditions via traveler information systems. Subsequently, better information on the traffic flows, including identification of congestion and bottlenecks, allow users and managers to better control the flows on the network. Important decisions towards this end relate to where the given sensors should be located to in order to better monitor and manage flows. Many different location models have been proposed in the literature, as well as corresponding solution approaches. The proposed existing models could be classified according to two main criteria: (i) the types of sensors based on what they measure (e.g., counting sensors, image sensors, Automatic Vehicle Identification (AVI) readers, etc.), and, (ii) the objective for the optimal locations, such as, best estimation of origins and destinations, estimation of flows on arcs and routes, maximal interception of flows, and reliably measuring travel times. The purpose of this paper is review such models, including introducing new models, by classifying then with respect to characterizing parameters and objective functions.

A methodology for locating link count sensors taking into account the reliability of prior o-d matrix estimates
Authors: *Simonelli, Fulvio; Marzano, Vittorio; Papola, Andrea; Vitillo, Roberta*
The problem of selecting the optimal locations of link count sections for o-d matrix estimation has received much interest in transport engineering. Various methods have been proposed in the literature to date, following different approaches and objectives. Notably, none of those takes into account explicitly the degree of reliability of the prior o-d matrix estimate. This paper proposes a different approach, based on the availability of prior information about a space of feasible o-d matrices, i.e. the joint probability distribution of o-d demand rather than only a prior deterministic estimate. Consistently, equations represented by link counts allow for a reduction of the space of the feasible o-d matrices, in terms both of dimension and dispersion. The research aims at showing that this approach is expected to give new insight on the link count location problem. By way of an example, a toy network application is presented, in order to show how an heterogeneous level of knowledge across o-d pairs may lead to the choice of counting sections different from those resulting from the commonly adopted procedures.

A clustering approach to estimate route travel time distributions
Authors: *Charle, Wouter; Viti, Francesco; Tampère, Chris M J*
Accurate network travel time estimation is today one of the most challenging problems in traffic theory. The mainstream research on travel time estimation concentrates on the estimation of mean route travel time or some measures of travel time reliability (i.e. 10th and 90th percentiles). However, given the growing detail in travel time measurements it is also possible to estimate route travel time distributions. This serves a broader spectrum of applications and provides more useful information. For this goal, this research presents a method to calculate the travel time histogram of a route, based on link travel time observations. The central problem in the development of the method is the distinction between (cheap) on-line storage and computations and (expensive) on-line computations. For that it is important to minimize the on-line computational effort of calculating a route travel time histogram. The method described in this study is able to significantly reduce the on-line computational effort by making use of a new clustering algorithm.

Session Tu 3.4 – Traffic Control

Tuesday 22/06 14:30 - 16:00 Room: Nord-Norge salen

A simulation-based optimization approach to perform urban traffic control
Authors: *Osorio, Carolina; Bierlaire, Michel*
In this paper, we present a metamodel to perform simulation-based optimization of congested urban networks. The metamodel is a combination of a polynomial with an analytical traffic model. It is integrated within a derivative-free trust region algorithm. The framework is used to solve a fixed-time signal control problem for a subnetwork of the Lausanne city center. The performance of the signal plans derived by this approach are compared to that of signal plans derived by other approaches, and to the performance of an existing plan for the city of Lausanne. The results indicate that this framework is an attractive approach for derivative-free applications with a limited computation budget, where short-term performance is of main interest.

Signal optimisation using the cross entropy method
Authors: *Ngoduy, Dong; Maher, Mike; Ronghui Liu*
The paper investigates the application of the cross entropy method (CEM) to the problem of signal optimisation in urban networks. The CEM is a relatively new approach to the solution of complex combinatorial optimisation problems, and has been shown in previous work by the authors to work well when applied to the optimisation of fixed-time signal timings on a six-arm signalised roundabout, with a cell transmission model used to model the traffic flow and evaluate the performance index $z(x)$ for any solution x. The present research extends this to the case where there is re-routeing through the network. In the first version, a UE assignment model is used to describe the route choice and flows, and to calculate the value of $z(x)$. The principal objective is to compare the performance of the CEM with that from a genetic algorithm approach. In the second version a Monte Carlo SUE assignment model is used, the outputs from which contain random error. Therefore the returned value $z(x)$ is noisy, with $z(x) = z0(x) + e$, where the variance of e is a decreasing function of the number of assignment iterations.

A Strategy for Adaptive Traffic Signal Control with Emphasis on Offset Optimization
Authors: *Pohlmann, Tobias; Friedrich, Bernhard*
The paper presents the conceptual design of a newly developed Adaptive Traffic Control Strategy (ATCS) for traffic signal control in urban meshed sub-networks with several signalized intersections. The strategy optimizes signal plans for consecutive time intervals of 15 minutes based on a forecasted estimated traffic demand. While the method optimizes cycle length, phase splits and offsets, the focus of the paper is on the latter. Three different algorithms for offset optimization are proposed: Parallel Genetic Algorithm, Serial Genetic Algorithm and Sequential Enumeration. An extended version of the Cell Transmission Model is used to calculate the fitness of possible solutions (i.e. specific offset combinations) in terms of total delay. The effects of necessary transitions from the previous to the new coordination pattern are considered as well during optimization. The paper also contains some results of a comprehensive microsimulation study with Aimsun NG assessing the performance of the strategy in comparison with a fixed time control optimized with Transyt 7F.

Session Tu 4.1 – Routing - Heuristics

Tuesday 22/06 16:30 - 18:00 Room: Rica Hall I

A Path Relinking based Evolutionary Algorithm for Vehicle Routing Problems with Time Windows and Return Products

Authors: *Anagnostopoulou, Afroditi; Repoussis, Panagiotis; Tarantilis, Christos*

This paper presents a novel Path-Relinking based Evolutionary Algorithm for solving Vehicle Routing Problems with Time Windows and Return Products. In particular, the main focus is given on problems settings where the same vehicle can be used for both deliveries and collection services. To this end, three different time restricted problem variants are considered with mixed and simultaneous pickups and deliveries. The proposed solution method adopts an (m,l)-evolution strategy equipped with a Path Relinking recombination mechanism and memory-based trajectory local search algorithms for route elimination and distance traveled minimization. Computational experiments on benchmark data sets of the literature demonstrate the efficiency and effectiveness of the proposed solution method compared to other methods of the literature.

Multi-Vehicle One-to-One Pickup and Delivery Problem with Split Loads

Authors: *Tuzun, Dilek; Cavuslar, Gizem; Sahin, Guvenc; Sahin, Mustafa; Oncan, Temel*

The one-to-one pick-up and delivery problem with split loads has not received much attention in the literature although Nowak et al. (2008) has shown that splitting loads may lead to significant reduction in costs. We study the multiple vehicle version of this problem. The problem is NP-hard; therefore, we propose heuristic algorithms to solve instances of practical size in reasonable time. Our heuristic algorithm adapts the well-known Clark and Wright savings heuristic to the pick-up and delivery case to find an initial solution. The tabu search component of the algorithm improves the solution by searching splits that will improve the total route length and decrease the number of vehicles used. The tabu search component also makes use of the optimality conditions on the splits. We perform computational experiments to test the performance of the heuristic algorithm as well as to understand the effect of different splitting strategies and tabu search parameters.

Heuristics for special instances of the Double TSP With Multiple Stacks

Authors: *Felipe, Angel; Ortuño, M Teresa; Tirado, Gregorio*

The Double Traveling Salesman Problem with Multiple Stacks (DTSPMS) is a pickup and delivery problem in which some precedence and loading constraints induced by the use of multiple compartments in the containers of the vehicles must be respected. It is an interesting vehicle routing that comes from a real application in the field of logistics and that has been receiving increasing attention during the last years. In this paper different heuristic approaches are proposed and their performance is tested on different kinds of instances. We have generated several sets of instances with different sizes, but we also propose the use of special instances with different characteristics concerning the distribution of orders, the magnitude of distances, the number of stacks, etc., to better evaluate the performance of heuristics. This study, that is still being developed, provides more information about the heuristics and may allow to determine which algorithms behave better for each kind of instances.

Session Tu 4.2 – Container Terminals

Tuesday 22/06 16:30 - 18:00 Room: Rica Hall II

Analysis and Simulation of a Port Container Terminal
Authors: *Averaimo, Pietro; Bruno, Giuseppe; Gargano, Francesco; Genovese, Andrea; Improta, Gennaro; Vinti, Cinzia*
A port container terminal, as known, is a complex logistic system in which several, material and immaterial, flows interact. In this context, operations management requires an appropriate use of Information and Communication Technologies as well as Decisions Support Systems. This problem becomes more and more crucial for container terminals using limited resources in terms of yards, quays and equipments. This is the case of the port container terminal located in Naples harbor (Italy) that we analyzed and whose operations and processes we reproduced through a discrete event simulation model built on the base of real data, on the field, collected. The performed experiments indicated the suitability of the simulation model to effectively represent the current scenario. On this basis, we have implemented and compared different management and optimization policies in order to evaluate how they could affect the overall terminal performances.

Train load planning in seaport container terminals
Authors: *Ambrosino, Daniela; Sacone, Simona; Siri, Silvia*
In this work we deal with the train load planning problem in seaport container terminals. We consider the case in which the loading plan (indicating on which wagon containers have to be placed) is performed by the terminal operator with the aim of optimizing both the pick-up operations in the storage area where containers are waiting for being loaded on trains and the loading operations on the train. We assume to plan the train loading operations of import containers over a given planning horizon (e.g. one or more days) in case there is only one track in the railway yard and the overhead travelling crane loads containers sequentially, i.e. from the first wagon to the last one. We have stated a mathematical programming problem in which specific costs are paid if rehandling operations are realized and containers are not loaded on trains. The decisions concern the assignment of containers to wagons of different trains, taking into account length and weight limitations of wagons, the weight capacity of trains and the position of each container in the stocking area (given by the relevant slot and tier).

Container storage assignment in an automatic maritime terminal.
Authors: *Dejax, Pierre; Sun, Xiaoming; Bostel, Nathalie; Lu, Zhiqiang; Xi, Lifeng*
This research is concerned with the planning of container allocation of storage in a new automatic handling system using optimization technologies. The objective of the research is to determine an optimized allocation and storage plan for arriving/departing containers in this new configuration of automatic container terminal in order to equilibrate the workload of handling equipments and thus achieve a high performance in the time necessary to execute the loading and unloading import/export operations of vessels over a sliding planning horizon. We propose to solve the problem by a hierarchical approach in two stages: first, elaboration of a global allocation plan in order to determine a storage area for each incoming container from export customers or arriving vessels at imports; this problem is modelled and solved as a MILP; second, determination of a detailed allocation plan, with the goal of minimizing the makespan under the constraints generated by the global plan; this problem is formulated and solved as an allocation problem on a bipartite graph, to minimize a cost expressing the travel distance of the handling equipments between the quay side and the storage blocks. Experimentations on real data from the Port of Shanghaï show the effectiveness of our approach.

Session Tu 4.3 – Dynamic and Online Planning

Tuesday 22/06 16:30 - 18:00 Room: Rica Panorama

Solution methods for the dynamic dial-a-ride problem with stochastic requests and expected return trips

Authors: *Schilde, Michael; Doerner, Karl F; Hartl, Richard F*

In its daily operation, the Austrian Red Cross faces the problem of designing vehicle routes to serve dynamically arising transportation requests from patients' home locations to hospitals using a fixed vehicle fleet. Additionally, each such transportation request may cause a return transport in the opposite direction to happen on the same day. Based on the fact that some stochastic information about these return transports is available, our work aims to verify the hypothesis that including this kind of information while designing the vehicle routes is beneficial to solution quality. Therefore, different modifications of the variable neighborhood search metaheuristic were tested using 40 different sets of real world inspired test instances.

Dynamic Ride-Sharing in Metro Atlanta

Authors: *Agatz, Niels; Erera, Alan; Savelsbergh, Martin; Wang, Xing*

While ride-sharing is not new, the ubiquity of GPS-enabled cell phones has enabled practical dynamic ride-sharing. To exploit hardware capabilities, ride-sharing systems are needed to match up people for rides in ways that achieve both user and system objectives. In this research we develop a set of alternative control algorithms for such systems and study the characteristics of environments within which dynamic ride-sharing offers the greatest potential for emission and congestion reduction.

Online TSP and Hamiltonian Path Problems with Acceptance/Rejection Decisions

Authors: *Jaillet, Patrick; Lu, Xin*

The Traveling Salesman Problem and Hamiltonian Path Problem are well-known combinatorial optimization problems. We are concerned here with online versions of the generalizations of these problems on metric spaces where the server doesn't have to accept all requests. Associated with each request (to visit a point in the metric space) is a penalty (incurred if the request is rejected) and a weight (collected if the request is accepted and the point visited). Requests are revealed over time to a server, initially at a given origin, who must decide which requests to serve in order to minimize the time to serve all accepted requests plus the sum of the penalties associated with the rejected requests while collecting enough weights to exceed a given quota. In the first online version of these problems, we assume that the server's decision to accept or reject a request can be made any time after its release date. In the second online version of these problems, we assume that the server's decision to accept or reject a request must be made exactly at its release date. For all these variations we present bounds on competitive ratios, and in some cases obtain optimal online algorithms.

Session Tu 4.4 – Understanding Behavior from Individual Data

Tuesday 22/06 16:30 - 18:00 Room: Nord-Norge salen

Modeling the dynamics of all-day activity plans
Authors: *Himpe, Willem; Flötteröd, Gunnar; Hurtubia, Ricardo; Bierlaire, Michel*
The modeling effort described in this text is motivated by the problem of identifying a smart-phone user's current activity (we currently consider work, shopping, leisure, home, education, and service) from sensor data obtained by the phone. This data comprises the current position, nearby wireless devices and networks, and phone inputs of the user. We build on a previous article, where a Bayesian activity estimation framework is presented, which consists of two components: The behavioral prior model provides a first distributional estimate about the activity based on socioeconomic attributes and land use data. This information is then updated using a likelihood function that relates the detection of nearby Bluetooth devices of known activity partners to the according activities. Preliminary experimental results with this system were obtained based on a likelihood function that was modeled from survey data in that the actually conducted activities of the respondent were known. In a real application, such a survey is infeasible and supplementary information from which the activities can be inferred in hindsight is needed. This problem is tackled in this work, which proposes an additional behavioral model that is evaluated at the end of each day, generates an improved estimate of the missing activities, and updates the relation between encountered Bluetooth devices and presumably conducted activities accordingly in the likelihood, which allows for improved real-time activity estimates in the following day. This text describes the specification and estimation of this additional model.

A Combined GPS/Stated Choice Experiment to Estimate Values of Crash-Risk Reduction
Authors: *Fifer, Simon; Greaves, Stephen; Ellison, Richard*
This paper reports on a study into the hypothetical/stated response of motorists to a kilometre-based charging regime that incorporates elements of risk, specifically nighttime driving and speeding. Hypothetical responses are gathered through a Stated Choice (SC)experiment that pivots off actual driving behaviour collected using an in-vehicle Global Positioning System (GPS) device over five weeks. This provision of greater reality using revealed preference (RP) information ensures that the alternatives in the SC experiment are embedded in reality, providing motorists with (in theory) a more realistic context for their choices. In the SC experiment, participants are asked to trade-off financial rewards against reductions in kilometres driven, night-time driving and speeding for different trip purposes. In turn, this information is used to estimate values of crash-risk reduction and help guide a proposed charging regime that will be used to empirically assess changes in driving behaviour later in the year.

Development of Stated-Preference Survey System on the Combined WEB and GPS Mobile Phones
Authors: *Kusakabe, Takahiko; Sadakane, Kenichiro; Yamanaka, Ippei; Asakura, Yasuo*
The purpose of this study is to develop the system for the travel mode choice survey using web based stated-preference (SP) questionnaire based on probe person (PP) system. The system is designed to observe the mode choice behaviour in various actual situations in urban activities. This paper introduces the system that consists of the PP survey system, Web-diary system, and Web-questionnaire system. As an empirical survey, we conducted the survey aiming to obtain the SP data of the mode choice between walking and the newly introduced travel mode"Personal Mobility". The abbreviated analysis shows that the system can obtain the SP data considering the various situations of the travellers' urban activities.

Session We 1.1 – Maritime Inventory Routing

Wednesday 23/06 08:30 - 10:00 Room: Rica Hall I

Mixed integer models for a short sea fuel oil distribution problem
Authors: *Agra, Agostinho; Christiansen, Marielle; Delgado, Alexandrino*
We consider a short-sea fuel oil distribution problem occurring in the archipelago at Cape Verde. Here, an oil company is responsible for the routing and scheduling of ships between the islands such that the demand for various products is satisfied during the planning horizon. Inventory management considerations are taken into account at the demand side, but not at the supply side. The ports have restricted opening hours each day, so multiple time windows are considered. In contrast to many other studies within ship routing and scheduling, considerable time is spent in the ports compared to at sea. This means that both a variable (un)loading/unloading time and set up time for (un)loading different products in the same ports are incorporated. A mathematical model of the problem is presented and it includes both a continuous and discrete planning horizon due to the multiple time windows and a daily varying consumption rate of the various products in the different ports. We discuss different strategies to improve the proposed model, such as the use of an extended formulation and the inclusion of valid inequalities. Finally, a computational study based on real data is reported in order to compare different ways of combining those strategies.

Branch-and-Price for creating an Annual Delivery Program of Multi-Product Liquefied Natural Gas
Authors: *Rakke, Jørgen Glomvik; Christiansen, Marielle; Andersson, Henrik; Desaulniers, Guy*
We consider a combined ship routing and inventory management problem for one of the world's largest producers of LNG. The problem is how to manage the producer's inventory and fleet of ships to create an Annual Delivery Program (ADP) that respects the long-term contracts at lowest possible cost, while maximizing the expected revenue from spot contracts. First, a MIP formulation of the ADP planning problem will be presented. This model, called the Basic Voyage Model (BVM), is based on pre-generation of all possible scheduled voyages within the planning horizon. The LP-relaxation of the BVM is weak, mainly because it is always possible to deliver fractional combination of ships in order to avoid penalties. We know that this is not possible in the MIP solution, and hence it introduces a large gap between the LP-solution and the MIP-solution. In order to reduce this gap, the BVM is reformulated using delivery patterns. However, the number of possible patterns is far too large to be generated a priori, making it necessary to generate the patterns dynamically using column generation. Since the subproblems do not possess the integrality property, it also opens up the possibility to raise the bound and, thus, reduce the gap.

A New Decomposition Approach for a Liquefied Natural Gas Inventory Routing Problem
Authors: *Andersson, Henrik; Christiansen, Marielle; Desaulniers, Guy*
The problem analyzed in this paper is a combined inventory management, ship routing and scheduling problem describing the distribution of LNG from liquefaction plants where the natural gas is cooled down to its liquid state, via the LNG carriers to regasification terminals where the LNG is stored, reheated, and fed into pipeline systems to serve the market. The purpose is to describe a new decomposition approach for an LNG-IRP. Instead of describing the movements and operations through schedules, duties are used. A duty covers a smaller part of the planning horizon, and a sequence of duties now represents the movements and operations. A branch-and-price-and-cut algorithm has been developed for the problem. The subproblems are fairly easy compared to formulations where the movements and operations of the ships are described by schedules covering the whole planning horizon, and are solved using an enumeration algorithm. Many different branching entities are used, and the connection between the branching entities and the possibility to generate strong valid inequalities is utilized. Known valid inequalities have been generalized to better exploit the structure of the problem and are added during the branch-and-bound search. Computational results comparing this decomposition approach to earlier formulations will be presented.

Session We 1.2 – Team Orienteering

Wednesday 23/06 08:30 - 10:00 Room: Rica Hall II

The Split Delivery Capacitated Team Orienteering Problem
Authors: *Bianchessi, Nicola; Archetti, Claudia; Hertz, Alain; Speranza, M Grazia*
In this work, we consider the Capacitated Team Orienteering Problem (CTOP). In particular, we investigate a relaxation of the problem arising when split deliveries, that is possible multiple visits to customers, are allowed. We formally prove a tight bound on the gain that can be achieved. An exact approach is then devised to solve the problem and also to experimentally evaluate the impact of allowing split deliveries. The algorithm is tested on a new set of instances derived from some VRP benchmark instances. Preliminary computational results show the effectiveness of the solution approach and give an empirically evidence that splitting the deliveries can yield substantial gain.

The Multi-Constraint Team Orienteering Problem with Multiple Time Windows
Authors: *Souffriau, Wouter; Vansteenwegen, Pieter; Vanden Berghe, Greet; Van Oudheusden, Dirk*
This abstract introduces the Multi–Constraint Team Orienteering Problem with Multiple Time Windows (MC-TOPMTW) as an extension of the Orienteering Problem, which is a combinatorial routing problem of which the goal is to find a tour that maximises the total score earned by visiting vertices. The MCTOPMTW is defined mathematically. A fast GRASP - Iterated Local Search hybrid metaheuristic algorithm is proposed. Computational experiments presents promising results.

An Enhanced Ant Colony System for two Transportation Problems
Authors: *Gambardella, Luca Maria; Montemanni, Roberto*
Ant Colony System is a well-known metaheuristic metaphore, and has been succesfully applied to many combinatorial optimization problems. In this work some weaknesses of the method are identified, and some changes to the original idea are introduced, in order to enhance the performance of the method. Experimental results on the Sequential Ordering Problem and on the Team Orienteering Problem with Time Windows are discussed.

Session We 1.3 – Discrete Choice Models

Wednesday 23/06 08:30 - 10:00 Room: Rica Panorama

A discrete choice approach to simulating airline passenger itinerary flows
Authors: *Fearing, Douglas; Vaze, Vikrant; Barnhart, Cynthia*
Passenger delays are estimated to cost the U.S. economy billions annually due to time lost. Analysis performed by Bratu and Barhnart (2005) on one month of passenger booking data for a legacy carrier suggests that delays due to itinerary disruptions, which generally go unmeasured, could significantly add to these costs. The challenge in extending their analysis systemwide is that publicly available data sources do not contain passenger itinerary flows. The passenger demand data that the Bureau of Transportation Statistics (BTS) provides is aggregated either monthly or quarterly. The methodology we develop in this work is precisely to address this limitation. That is, we use a discrete choice model trained on a small set of proprietary passenger booking data to simulate disaggregate passenger itinerary flows for all airlines. Subsequently, we estimate the magnitude and distribution of U.S. domestic passengers delays for 2007 based on the simulated passenger itinerary flows. Beyond the analysis of historical passenger delays, we expect our approach to be valuable in extending passenger analyses to other contexts where previously only flight information has been available.

Evaluation of an Auction Protocol in on-demand mobility services based on a response dynamics and heterogeneity
Authors: *Hara, Yusuke; Hato, Eiji*
This paper presents an individual choice behavior model as trade behavior model. It is expressed by discrete choice model and we consider the state dependence and serial correlation in the trade behavior from day to day. In a case study, we implemented bicycle sharing system, bicycle sharing tradable permits auction system, and probe person system. Sharing permits trade auction is a double auction mechanism and all tradable permits are allocated to all users at random and users can trade them freely on the internet. Probe person system is a method to get travel diary data and positioning data in detail by GPS mobile phone. We collected travel behavior data and trade behavior data in these systems. We have taken a close look at the evidence on the influence of spatial relevance and uncertainty of schedule in mobility permits auction. What we are modeling from the data is trade behavior considering serial correlation and state dependence, and we clarified the elements having effect on trade behavior.

User equilibrium under reference-dependent route choice in a two-link network
Authors: *Delle Site, Paolo; Filippi, Francesco*
Experimental evidence supports choice theories which assume that carriers of utility are gains and losses relative to a reference point and that losses are valued more highly than gains. Reference-dependent theory adopts these hypotheses to explain risk-less choices, prospect theory risky choices. When route choices are considered, application of reference-dependent theory is of interest because it can represent loss aversion effects in the trade-off between travel time and money. However, in the literature application of reference-dependent theory has received relatively less attention than application of prospect theory. Given this context, the paper considers stochastic user equilibrium under reference-dependent route choice (RDSUE) in a two link network. The paper has two aims. One is theoretical. The paper proves that the properties of existence and uniqueness of equilibrium hold under the usual conditions that apply to conventional SUE. The idea of reflexive RDSUE is introduced and it is proved that this desirable property holds under loss aversion for time and money. The other aim is practical. The paper applies RDSUE to the classical town bypass case and analyses the policy implications for tolling on the bypass of loss aversion embodied in route choice.

Session We 1.4 – Traffic Flow

Wednesday 23/06 08:30 - 10:00 Room: Nord-Norge salen

Anisotropic second order models and associated fundamental diagrams
Authors: *Schnetzler, Bernard; Louis, Xavier*
Some anisotropic hyperbolic second-order models enter within the frame of a general formulation expressed by the Generalized Second-Order Model. Within such a frame, assuming that I is the second Riemann invariant, the second equation comes from the nullity of its total derivative. (The first equation expresses the vehicle conservation.) Then a second variable y = d I carried by the traffic is defined - the speed is deduced from the couple (d, y) -, where d is the density and I depends on either a vehicle characteristics or a driver's attribute. Of course this characteristics or this attribute must be invariant. To sum up a traffic which carries different values of invariant is a mixture. This formalization means that each driver or vehicle carries the value of one parameter (the value of the invariant) of a generic fundamental diagram which is described by the analytical expression of the invariant. Now a practical use of such models must ensure that the diagrams match real data; generally speaking, some combination of parameters and invariant values are not admissible. In what follows three anisotropic second-order models are investigated with regard to an invariant value depending on the vehicle length.

Short-Term Traffic Flow Forecasting by means of Wavepack Analysis and Multi-population Genetic Programming
Authors: *Tsakonas, Athanasios; Karlaftis, Matthew*
Accurate short-term predictions of traffic variables such as volume and occupancy is of outmost importance in transportation research because of the increased demand for reliable Advanced Traffic Management and Traveler Information Systems in urban areas. Literature indicates that real-time short-term prediction models of traffic variables have to be accurate and effective for a given forecasting horizon. Empirical evidence has shown that prediction accuracy is best accomplished by data-driven approaches that construct the underlying rules of complex traffic datasets rather than working based on pre-determined mathematical rules; these models can be parametric (such as ARIMA models) or non-parametric (such as non-parametric regression and neural networks). The present paper proposes a flexible and adaptive real-time system for short-term traffic flow prediction. The system is based on the principles of computational intelligence and wavelet packet analysis and is able to develop the proper model for prediction based on prevailing traffic flow conditions. The proposed methodology is proven to be competitive to previous research. Also, the system automatically selected the input variables that contributed the most to the output, potentially offering knowledge discovery. Finally, the solution form is a practical expression, containing only the elementary mathematical operations, a property that contributes to its portability.

Traffic breakdowns and freeway capacity as extreme value statistics
Authors: *Kühne, Reinhart; Lüdtke, Axel*
Instabilities of traffic flow influence maximum traffic volume (=capacity) in a stochastic manner. The appropriate mathematical framework uses the terms of extreme value statistics starting with a queuing theoretical traffic dynamics description and a probabilistic approach for freeway capacity identification. The investigation are compared with empirical observations and lead to an excellent accordance between mathematical ideas, traffic engineering basics and data from real freeways.

Session We 2.1 – VRP with Driver Aspects

Wednesday 23/06 10:30 - 12:00 Room: Rica Hall I

A Vehicle Routing Problem with Time Windows and Driver Familiarity
Authors: *Schneider, Michael; Doppstadt, Christian; Sand, Bastian; Stenger, Andreas; Schwind, Michael*
Motivated by an industry project, we consider the influence of driver familiarity with routes and customers
on the routing operations of small package shipping companies. Driver familiarity can be achieved by means
of fixed delivery districts for each driver, but this approach forfeits routing flexibility. Thus, if the value of
routing flexibility increases, the solution quality of any approach based on such fixed delivery areas is likely to
suffer. In today's small package shipping, flexibility is of particular importance due to a very high percentage of
time-definite deliveries. Therefore, our routing method forgoes any fixing of delivery areas. Instead, our vehicle
routing model explicitly considers individual driver knowledge by means of driver specific travel and service
times. Thus, drivers have an incentive to stay in familiar areas due to shorter driving and service times while
maintaining their flexibility. In this way, we can find an optimal trade-off between driver familiarity and routing
flexibility. We develop an ant colony optimization method specifically tailored to the described routing problem
and investigate its performance in numerical studies.

The vehicle routing problem with driver assignment
Authors: *Wen, Min; Krapper, Emil; Larsen, Jesper; Stidsen, Thomas K*
In this presentation, we will talk about a real-life vehicle routing problem with driver assignment arising at
the largest fresh meat producer in Denmark. This problem consists of a one-week planning horizon, heteroge-
neous vehicles, and drivers with predefined work regulations. These regulations include, among other things,
predefined workdays, fixed starting time, maximum weekly working duration, break rule. The objective is to
minimize the total delivery cost. We proposed a multi-level variable neighborhood search heuristic to solve the
problem. At the first level, the problem size is reduced through an aggregation procedure. At the second level,
the aggregated weekly planning problem is decomposed into daily planning problems, each of which is solved by
means of a variable neighborhood search. At the last level, the solution of the aggregated problem is expanded
to that of the original problem. The method is implemented and tested on real-life data consisting of up to 2000
orders per week. Computational results show that the aggregation procedure and the decomposition strategy
are very effective in solving this large scale problem, and our method is able to produce quality solution within
reasonable computational time.

Solving a real-world service technician routing and scheduling problem
Authors: *Parragh, Sophie N*
In this talk we address a service technician routing and scheduling problem: a given number of technicians have
to be scheduled in order to fulfill a given number of service tasks within a given planning horizon. Each task
demands a technician that disposes of the appropriate skills of at least the demanded level. Time windows,
validity periods, and maximum shift lengths have to be respected and lunch breaks have to be scheduled. In
addition, two technicians' tours may have to be synchronized at certain points in time in order to complete
those tasks that demand two technicians. We present an exact and a heuristic method for this problem, namely
a branch-and-cut algorithm, a greedy solution construction method and an improvement heuristic that uses the
branch-and-cut algorithm to solve the individual scheduling subproblems.

Session We 2.2 – Inventory Routing

Wednesday 23/06 10:30 - 12:00 Room: Rica Hall II

A customer-centric solution approach to cyclic inventory routing
Authors: *Raa, Birger; Dullaert, Wout*
This paper presents two new solution methods for the cyclic inventory routing problem, in which the long-term trade-off between distribution and inventory costs has to be made. The first solution method generalizes the route-centric approach of Raa and Aghezzaf (2009) by introducing the 'nestedness' concept of Viswanathan and Mathur (1997). The second solution method steps away from the route-centric approach and takes a customer-centric approach by first determining customer cycle times, then assigning customers to days, and only building routes for each day afterwards. Computational results will be reported from a wide range of computational experiments on both cyclic inventory routing datasets and periodic vehicle routing benchmark instances from the literature, to assess the performance of both proposed solution approaches, and to determine the value of the additional flexibility that these two methods offer, i.e. their potential for further cost savings.

The Static Repositioning Problem in a Bike-Sharing System
Authors: *Forma, Iris; Raviv, Tal; Tzur, Michal*
Bike-sharing systems allow people to rent a bicycle at one of many automatic rental stations scattered in the city, use them for a short journey and return them at any other station in the city. Recently many cities around the world deployed such systems in order to encourage their citizens to use bicycles as an environmentally sustainable, socially equitable mode of transportation, and as a good complementary to other modes of mass transit transportation systems. A crucial factor for the success of a bike sharing system is its ability to meet the fluctuating demand for bicycles and for vacant lockers at each station. This is performed through a repositioning operation which consists of removing bicycles from stations with high return rates and transferring them to stations with higher demand rates, using a dedicated fleet of trucks. Operating such a fleet in a large bike sharing system is an intricate problem consisting of decisions on routes that the trucks should follow, and the number of bicycles that should be removed or placed in each station at each visit of the truck. In this research we model the repositioning problem, formulate a MILP, and develop methods to solve problems of realistic size.

The Free Newspaper Delivery Problem
Authors: *Archetti, Claudia; Doerner, Karl F; Tricoire, Fabien*
In this talk we present hybrid solution approaches for the Free Newspaper Delivery Problem. The problem is related to the inventory routing problem with additional constraints concerning production rate.

Session We 2.3 – Airlines - Robust Scheduling and Disruption Management

Wednesday 23/06 10:30 - 12:00 Room: Rica Panorama

Robust and Recoverable Maintenance Routing Schedules
Authors: *Eggenberg, Niklaus; Salani, Matteo; Bierlaire, Michel*
We present a methodology to compute more efficient airline schedules that are less sensitive to delay and can be recovered at lower cost in case of severe disruptions. We modify an original schedule by flight re-timing with the intent of improving some structural properties of the schedule. We then apply the new schedules on different disruption scenarios and then recover the disrupted schedule with the same recovery algorithm. We show that solutions with improved structural properties such as ncreased slack better absorb delays and are therefore more efficiently recoverable than the original schedule. We provide computational evidence using the public data provided by the ROADEF Challenge 2009 (http://challenge.roadef.org/2009/index.en.htm)

Cluster Based Fleet Assignment Problem
Authors: *Boudia, Mourad; Gabteni, Semi*
This paper proposes a new approach to solve a fleet assignment problem based on itinerary demand clustering. The demand clustering was introduced to improve the reliability of the forcast. The proposed approach model was compared with the itinerary based fleet assignment model on basis of several instances. The cluster based results are better and mors robust compared to the results obtained using the itinerary based approach.

Passenger Improver - A Second Phase Method for Integrated Aircraft-Passenger Recovery Systems
Authors: *Acuna-Agost, Rodrigo; Boudia, Mourad; Jozefowiez, Nicolas; Mancel, Catherine; Mora-Camino, Felix*
Airlines are permanently confronted to disruptions caused by external or internal factors like extreme weather conditions, unavailability of crew members, unexpected breakdowns of aircraft, or airport capacity shortages. These disruptions prevent the planned execution of the schedule, which either becomes suboptimal or infeasible. This article deals with the problem of generating a new provisional schedule that minimizes the impact of disruptions by taking into consideration the flight schedule, the fleet and maintenance management requirements and the impact on passengers, all simultaneously. A post-optimization method that improves the solutions obtained by current approaches is developed. The method, called Passenger Improver (PI), permits to obtain an optimal reaccommodation for the still disrupted passengers. This approach was tested on the ROADEF challenge 2009 instances obtaining important improvements of the current solutions.

Session We 2.4 – Behavioral Models

Wednesday 23/06 10:30 - 12:00 Room: Nord-Norge salen

A Mixed-Nested Logit Model for the Residential Location Choice in Land Use-Transport interactions.
Authors: *Carrese, Stefano; Saracchi, Stefano*
In this paper, in the land use and transport interaction framework, the type of link (a correlation or causality) between the built environment and the travel behavior has been investigated: the relationship between neighborhood characteristics and travel behavior is taken into account to understand if attitudes and neighborhood preferences influence the residential location choices and travel behavior. It could be useful to examine, whether neighborhood design influences travel behavior or whether travel preferences influence the choice of neighborhood. This could lead to better understand the effect of the transport policies in the residential location choice (R.L.C.). To investigate if there is a casuality or an effect between the two choices (R.L.C. and Travel choice) a survey in order to calibrate a nested logit model in the Rome metropolitan region has been conducted. For the parameters calibration even the normal, log-normal and Johnson distribution for the latent classes will be taken into account, in order to view the differences between the outputs and to underline which distribution better represents the real R.L.C., even trying to built a Mixed Nested Logit Model.

Households' multiple vehicle ownership and their car usage - An analysis with the nationwide interview survey in Japan
Authors: *Fukuda, Daisuke; Kobayashi, Michiko; Hyodo, Tetsuro*
The motor vehicle is an essential transport measure in peoples' daily life and their commercial activities (e.g. logistics). In the past, the total number of vehicles, the total number of licensed drivers and the total mileage were steadily increasing together with the economic growth in Japan. In addition, the government has expected that the growth would continue for the future. Recently, however, with the various structural changes (e.g. falling birthrate, change in peoples' life style, aging population, change in the gasoline price and global warming), the structure of car market has been dramatically changed. Especially, there are two big changes: is a decrease in total mileage and the increase in small-sized vehicles (SV) while the number of middle-sized vehicles (MV) is not constantly increasing in Japan. Generally, when households own a single SV or more than 2 any vehicles, regardless of the car type, the average mileage per household becomes lesser. Thus, it is possible that there is a relation between the decrease in the total mileage in Japan and the increase in the number of SVs. With this motivation, the purpose of this study is to analyze the structural relationship between the multiple-vehicle ownership and their usage at the household level using a large dataset.

Comparative evaluation of Logit and Fuzzy Logic models of gap-acceptance behavior
Authors: *Rossi, Riccardo; Meneguzzer, Claudio; Gastaldi, Massimiliano; Gecchele, Gregorio*
In this study two alternative models of gap-acceptance behavior at unsignalized intersections with priority control are compared based on their ability to predict actual diver choices. The first is a probabilistic model of the Logit type, while the second is a model based on Fuzzy Logic. The explanatory variables included in both models are the size of the time interval evaluated by drivers in their acceptance/rejection process, the total (queuing plus stop-line) delay experienced on the controlled approach, and the type of interval being evaluated (gap or lag). Both models are estimated/identified based on field observations of actual gap-acceptance behaviour. The predictive power of the two models is compared using a technique known as ROC (Receiver Operating Characteristic) curve analysis, which apparently has never been applied before in the area of transport modeling. Our preliminary results are that the ROC curves suggest a slight superiority of the Logit model over the Fuzzy Logic model; however, other statistics, computed in order to provide a more complete comparative analysis of the two models, reveal no clear dominance of either model over the other.

Session Th 1.1 – Inventory Routing

Thursday 24/06 09:00 - 10:30 Room: Rica Hall I

Optimization of an Order-Up-To Level Policy in an Inventory Routing Problem with Stock-Outs
Authors: *Bertazzi, Luca; Bosco, Adamo; Guerriero, Francesca; Laganà, Demetrio*
We study an inventory routing problem in which each retailer defines a maximum inventory level and has a either a deterministic or a stochastic demand to be satisfied over a given time horizon. An order-up-to level policy is applied, i.e. the quantity sent to each retailer is such that its inventory level reaches the maximum level, whenever the retailer is served. An inventory cost is charged if the inventory level is positive. A penalty cost is charged and the excess demand is not backlogged if the inventory level is negative. Shipments from the supplier to the retailers can be performed by one vehicle of given capacity at each discrete time instant. The problem is to determine a shipping policy that minimizes the total cost, given by the sum of the total inventory and penalty cost at the retailers and of the total routing cost. We first study the deterministic version of this problem. For this problem, we formulate a mixed-integer linear programming model and implement a branch-and-cut algorithm. Then, we design a rollout algorithm for the solution of the stochastic inventory routing problem. The performance of these algorithms is evaluated on randomly generated problem instances.

Robust Optimization of Bulk Gas Distribution
Authors: *Dubedout, Hugues; Neagu, Nicoleta*
The goal of this research work was to increase the robustness of optimization solutions for bulk gas distribution relatively to uncertain events such as unexpected plant outages. Thus, in this work we investigate new optimization models and methods to build robust routing and scheduling plan. The optimized methods include in a proactive manner assumptions about unexpected plant outages while searching for solutions. The proposed methods are applied on real life test cases of very large scale (e.g., several hundreds of customers). The obtained results are compared to manual dispatching as well as to optimization models which do not consider pro-actively plant outages while constructing solutions.

A Decision Tree Approach for a Stochastic Inventory Routing Problem
Authors: *Esbensen, Eystein; Fagerholt, Kjetil; Hvattum, Lars Magnus; Nygreen, Bjørn*
A real-world shipping company faces a dynamic and highly stochastic inventory routing problem for its dry bulk operations. There are two kinds of shipping contracts. The first has a fixed starting time, and a late arrival will result in severe penalties. The second can be performed at any time, as long as inventory levels are within specified limits. The main stochastic element is port congestions, such that for tight schedules, there is a substantial risk of arriving late for a fixed time contract. The structure and conditions of this problem make it practical to use a brute-force approach: a decision tree. A simulator is used to build decision trees, evaluate solutions, and to compare alternative solution methods. Preliminary tests indicate that the proposed method works well and can provide good decision support.

Session Th 1.2 – Arc Routing

Thursday 24/06 09:00 - 10:30 Room: Rica Hall II

The windy clustered prize-collecting problem

Authors: *Corberán, Angel; Fernández, Elena; Franquesa, Carles; Sanchis, José M*

Prize-collecting Arc Routing Problems are arc routing problems where a profit is associated with each demand edge. It is assumed that if a demand edge is serviced, its profit is collected once, independently of the number of times it is traversed. A decision must be made to jointly determine a subset of demand edges to be served and a route to serve them. The Clustered Prize-collecting Arc Routing Problem considers the connected components defined by the demand edges, and it is further required that if a demand edge is serviced, then all demand edges of its component are also serviced. This work introduces the Windy Clustered Prize-collecting Arc Routing Problem where, in addition, two non-negative values are associated with each edge, representing the costs of traversing the edge in each direction. A mathematical programming formulation is presented and some polyhedral results, including some families of valid and facet defining inequalities are also given.

Compact Models for the Mixed Capacitated Arc Routing Problem

Authors: *Gouveia, Luis; Mourão, M Cândida; Pinto, Leonor S*

Capacitated Arc Routing (CARP) models are widely used in distribution or collection problems where vehicles with limited capacity, perform certain activities that are continuously distributed along some pre-defined links (routes, streets) of an associated network. The CARP is defined either as an undirected problem or as a directed problem depending on whether the required links are undirected or directed. The Mixed Capacitated Arc Routing Problem (MCARP) models a more realistic scenario since it accommodates both directed and undirected required links in the associated network, allowing then to consider simultaneously narrow and large streets. We present a compact flow based model for the MCARP. Due to its large number of variables and constraints, we have created an aggregated version of the original model. Although this model is no longer valid, we show that it provides the same linear programming bound than the original model. Different sets of valid inequalities are also derived. The quality of the models is tested on benchmark instances with quite promising results. We discuss and compare it with the best known method from the MCARP literature used for medium and large sized instances.

The undirected capacitated arc routing problem with profits

Authors: *Archetti, Claudia; Feillet, Dominique; Hertz, Alain; Speranza, M Grazia*

A profit and a demand are associated with each edge of a set of profitable edges of a given graph. A travel time is associated with each edge of the graph. A fleet of capacitated vehicles is given to serve the profitable edges. A maximum duration of the route of each vehicle is also given. The profit of an edge can be collected by one vehicle only that also serves the demand of the edge. The objective of this problem, that is called the Undirected Capacitated Arc Routing Problem with Profits (UCARPP), is to find a set of routes that satisfy the constraints on the duration of the route and on the capacity of the vehicle and maximize the total collected profit. We propose a branch-and-price algorithm and several heuristics. We can solve exactly instances with up to 97 profitable edges. The best heuristics find the optimal solution on most of instances where it is available.

Session Th 1.3 – Maritime Transportation

Thursday 24/06 09:00 - 10:30 Room: Rica Panorama

Improving the logistics of moving empty containers - Can new concepts avoid a collapse in container transportation?

Authors: *Voss, Stefan; Stahlbock, Robert*

Since the introduction of the maritime container in the mid 1950's, liner shipping groups have migrated from inefficient traditional cargo handling techniques to large cellular vessels which can be seen at any of the world's major ports today. The use of the container improved intermodal productivity and allows for shorter point to point transit times. In addition, cargo damage is reduced. On one hand, shippers and carriers have benefited enormously. On the other hand, they are faced with increased operational complexity as well as a multitude of variable and fixed costs. Managing these costs is important in particular in situations with intense competition in turbulent financial times. Total seaborne trade has quadrupled over the past four decades. Billions of dollars are spent each year to deal with inefficiencies caused by repositioning of empty containers. An increase of the container population as well as an increasing global trade imbalance resulted in accumulation of empty containers in some major port areas and container shortage in other regions. In this paper we consider the problem of empty container transportation. We briefly describe the global chain of maritime container transport and related costs for different actors. We provide an analysis of data emphasizing the imbalance of loaded and empty container transportation between various origins and destinations. Most importantly, we provide a review of literature regarding empty container management and discuss some approaches including promising decision support systems for reducing empty container transportation. Moreover, we discuss solution concepts to overcome parts of this situation which are not popular in practice (like, e.g., the use of foldable containers). Economical and technical conditions for promising usage are considered together with ideas for improving them. Ecological issues related to reverse logistics (e.g., scrap, waste paper/recycle) are taken into account and we propose the idea of pooling (i.e., interchange of containers on different scales, between shipping companies, owners etc.). Finally, we discuss entry and exit of containers with respect to the transport chain.

Recursive column generation for the Tactical Berth Allocation Problem

Authors: *Vacca, Ilaria; Salani, Matteo; Bierlaire, Michel*

Seaport container terminals are source of many interesting large-scale optimization problems, that arise in the management of operations at several decision levels. In this work we study exact methods to solve the Tactical Berth Allocation Problem with Quay Crane Assignment, an integrated decision problem that occurs in the management of the quayside resources. We reformulate the problem via Dantzig-Wolfe and present an exact solution approach based on column generation that exploits the problem's structure. In particular, the computational complexity of the pricing problem is tackled by developing a recursive column generation algorithm that starts taking into account only a meaningful subset of compact formulation's variables. Computational results on instances based on real-world data are presented and discussed.

A greedy construction heuristic for the Liner Service Network Design Problem

Authors: *Løfstedt, Berit*

The Liner Service Network Design Problem (LSN-DP) is the problem of constructing a set of routes for a heterogeneous vessel fleet of a global liner shipping operator. Routes in the liner shipping context are non-simple, cyclic routes constructed for a specific vessel type. The problem is challenging due to the size of a global liner shipping operation and due to the hub-and-spoke network design, where a high percentage of the total cargo is transshipped. We present the first construction heuristic for large scale instances of the LSN-DP. The heuristic is based on the multiple quadratic knapsack problem. The problem is solved using a greedy algorithm. The heuristic is able to find a solution for a real life case with 234 unique ports and 14000 demands in 33 seconds.

Session Th 1.4 – Road Pricing

Thursday 24/06 09:00 - 10:30 Room: Nord-Norge salen

Second Best Congestion Pricing for Transit Networks
Authors: *Hamdouch, Younes; Marcotte, Patrice*
In this paper, we address second-best congestion pricing of a transit system, with the aim to encourage passengers to select travel strategies that lead to the least travel delay under some constraints on the fares. Similar to the one used to reduce congestion on vehicular traffic networks, we formulate the second-best problem as a mathematical program with equilibrium constraint and propose a cutting constraint algorithm for its solution. We will then discuss the extension of the model to the situation where both private and transit modes are considered.

Nonlinear Road Pricing
Authors: *Lawphongpanich, Siriphong; Yin, Yafeng*
Nonlinear pricing refers to a case in which the price or tariff is not strictly proportional to the quantity purchased. While it is prevalent in many industries and has been studied by economists for over 80 years, nonlinear pricing has been largely overlooked in the road pricing literature even though road pricing in practice is often nonlinear. In this presentation, we consider nonlinear pricing in the context of managing travel demand, reducing congestion, and environmental impact in a given area. When toll prices are nonlinear, the user equilibrium conditions are generally not linkwise additive and the associated generalized travel cost function may not be differentiable. From these two observations, many mistakenly conclude that no link-based user equilibrium conditions exist. Thus, our objective for this presentation is to show that, for many common forms of nonlinear pricing, link-based user equilibrium conditions do exist. For those forms with no link-based equilibrium conditions, it is possible to slightly modify standard algorithms such as Frank-Wolfe and its variants to find a tolled user equilibrium flow distribution.

The Min-Toll-Booth Problem: Complexity, Algorithms and Experimental Findings
Authors: *Harks, Tobias; Sieg, Martin; Schaefer, Guido*
We consider the problem of computing tolls in non-atomic network routing games such that a predetermined flow is realized as Nash flow. It is a well-known fact that marginal cost tolls give rise to a Nash flow that minimizes the total travel time. In this paper, we study the problem of computing such tolls such that the number of tolled arcs is minimized. We prove that this problem is NP-hard and APX-hard, even for very restricted single-commodity networks, and give first approximation results. Finally, we empirically evaluate the performance of our approximation algorithm on a set of real-world test instances.

Session Th 2.1 – Profitable Postman Problems

Thursday 24/06 10:45 - 11:45 Room: Rica Hall I

The Profitable Capacitated Rural Postman Problem

Authors: *Irnich, Stefan*

The talk presents a non-standard extensions of classical postman problems, i.e., the Profitable Capacitated Rural Postman Problem (PCRPP). The PCRPP can be characterized by non-connected (postal) delivery regions, where it is possible to select the street segments that are serviced. Moreover, the overall duration of the postman tour is bounded. Up to now, exact methods for the Capacitated Arc Routing Problem (CARP) either rely on branch-and-cut or on the transformation into the corresponding node-routing problem, the well-known VRP. An alternative exact approach that has not been analyzed before (as far we know) is the solution of the CARP by column generation or Lagrangian-relaxation, where the subproblem is directly treated as a postman problem. In fact, the subproblem is the PCRPP and we propose its solution by branch-and-cut, instead of transforming it into a node-routing problem and applying corresponding node-routing methods. The talk at TRISTAN 7 will present results on a branch-and-cut implementation for the PCRPP and give answers the following research questions: What is a good separation strategy when solving the PCRPP via branch-and-cut? What characterizes CARP instances to be well-suited for being solved with a column-generation or Lagrangian-relaxation approach?

A new approach to the Maximum Benefit Chinese Postman Problem

Authors: *Corberán, Angel; Plana, Isaac; Rodriguez-Chia, Antonio; Sanchis, José M*

The Maximum Benefit Chinese Postman Problem (MBCPP) is a generalization of the CPP in which not all the edges have to be traversed, and, associated with each edge of the graph, a cost for its traversal with service, a deadhead cost for its traversal with no service and a set of benefits are considered. A benefit is derived from every traversal with service of an edge. The objective is to find a closed walk (tour) starting and ending at the depot with maximum net benefit. In this work we study the MBCPP defined on an undirected graph. An ILP formulation is given, as well as a partial description of its associated polyhedron. A branch-and-cut algorithm for its resolution has been designed and computational results are presented.

Session Th 2.2 – Alliances and Competition, Auctions and Winners

Thursday 24/06 10:45 - 11:45 Room: Rica Hall II

A Model of Alliances between Competing Carriers

Authors: *Kleywegt, Anton*

We consider an alliance between two carriers in which the carriers exchange capacity. In the structuring of the alliance, each carrier should take into account that after the exchange, the other carrier becomes a competitor offering similar services. We propose a model to study the behavior of such an alliance, and to give guidance regarding the initial capacity to exchange.

Exact and Metaheuristic Approaches for Bi-Objective Winner Determination in Transportation Procurement Auctions

Authors: *Buer, Tobias; Pankratz, Giselher*

This contribution proposes a model and a solution method to support the allocation stage of a combinatorial transportation procurement auction. First, a bi-objective winner determination problem is described which is based on the well-known set covering problem. The model supports bundle-bidding to account for valuation interdependencies between transportation orders. Furthermore, it jointly considers the objectives of minimizing the total procurement costs and maximizing the quality of the procured services. The model helps a shipper to decide which subset of the submitted bids he should accept. To solve the bi-objective winner determination problem, a solution method based on GRASP and the Pareto dominance principle is considered. Accordingly, the proposed procedure does not aim at identifying a best solution depending on the shippers preferences (which anyway are often hard to elicit); instead it heuristically searches for the whole set of preference-independent non-dominated solutions. The performance of the proposed Pareto solver is assessed by means of numerical benchmark tests. These artificial test instances reflect some major economic features of the scenario, which are not guaranteed by known instances for similar problems in the literature. The proposed GRASP Pareto solver is compared to a genetic algorithm and for smaller instances, to an exact branch-and-bound approach.

Session Th 2.3 – Travel Demand Models

Thursday 24/06 10:45 - 11:45 Room: Rica Panorama

Risk Taking and Strategic Thinking in Route Choice: A Stated-Preference Experiment
Authors: *Razo, Michael; Gao, Song*
This research investigates route choice behavior in networks with risky travel times and real-time information. A stated preference survey is conducted in which subjects use a PC-based interactive map to choose routes link-by-link in various scenarios. The scenarios include two types of maps: the first presenting a choice between one stochastic route and one deterministic route, and the second with real-time information and an available detour. The first type measures the basic risk attitude of the subject. The second type allows for strategic planning, and measures the effect of this opportunity on subjects' choice behavior. Results from each subject are analyzed to determine whether the subject planned strategically for the en route information or simply selected fixed paths from origin to destination. The full data set is used to estimate several choice models, using expected travel times and standard deviations as explanatory variables. Estimation results are used to assess whether models that incorporate strategic behavior more accurately reflect route choice than do simpler path-based models.

On Negative Correlations and the Consistency of GEV-based Discrete Choice Models
Authors: *Ben-Elia, Eran; Prashker, Joseph N; Toledo, Tomer*
GEV type discrete choice models like Nested Logit and Cross Nested Logit have gained considerable popularity with modelers for their tractability and easiness of estimation. However, a key assumption in the estimation process is that any correlation, between the error terms of alternatives' utilities, is necessarily non-negative. This paper's focus is on the case where this assumption fails i.e. when choices exhibit negative correlation. By using a simple synthetic database which creates artificially correlated errors we estimated GEV models and compared them to the 'known' true values imputed in the data and to an MNP model which can accommodate almost any correlation structure. Our results reveal that in the simple case of three alternatives, NL can still compensate for non-positive correlations. However, in the case of four alternatives (or more) the model fails and the estimated correlations are biased. CNL, estimated with a Paired Combinatorial Logit specification failed in the presence of negative correlations and even in cases of positive correlations MNP was significantly more accurate. Surprisingly, this bias was not found for the utility functions' coefficients and alternative specific constants. These results show that the modeler must take great care in considering which model is appropriate when estimating discrete choice models. Moreover, the case for using more flexible models like MNP or Mixed Logit is put forward when knowledge about the data content is limited and levels of uncertainty are high.

Session Th 2.4 – Road Pricing

Thursday 24/06 10:45 - 11:45 Room: Nord-Norge salen

Finding optimal toll locations and levels in elastic demand networks -A MILP approximation approach

Authors: *Ekström, Joakim; Rydergren, Clas; Sumalee, Agachai*

This paper proposes a heuristic solution algorithm for solving the non-convex toll design problem for elastic demand networks in which the road users are distributed according to a user equilibrium. In the toll design problem we search for the toll locations and the corresponding toll levels that will maximize the social surplus. The toll design problem is converted by a linearization scheme to a mixed integer linear program (MILP) which approximates the objective function and constraints in the original problem. The MILP has the property of global optimum, and gives a lower bound estimation of the original non-linear problem. The user equilibrium condition is represented by the variational inequality (VI) constraints, and the MILP approximation is solved by applying a cutting constraint algorithm (to deal with the VI-constraints) together with a commercial MILP-solver. Numerical results are presented for a small network, and the results are encouraging.

Invariance principle in regional tax/toll competition

Authors: *Khoshyaran, Megan; Lebacque, Jean-Patrick*

The object of this paper is to study inter-regional tax and toll competition. Reaction curves are calculated explicitly in the framework of a semi-analytic two-regions model. This model takes into account heterogeneous travel costs, population clusters, and can take into account the demand functions and congestion effects. The reactions functions are multi-valued, precluding the formation of Nash equilibriums. This result can be extended to multiple regions. For many regions, assignment and distribution must be taken into account. The invariance principle statess that when regions compete, each trying in turn to optimize its revenue, the process will not converge, with some regions loosing out and others gaining.

Session Th 3.1 – Multi-Period Routing

Thursday 24/06 14:30 - 16:00 Room: Rica Hall I

Template-based Tabu Search Algorithms for the Multi-Period Vehicle Routing Problem with Consistent Service Constraints

Authors: *Stavropoulou, Foteini; Repoussis, Panagiotis; Tarantilis, Christos*

This paper presents template-based Tabu Search algorithms for solving the Consistent Vehicle Routing Problem (ConVRP). The ConVRP has been first introduced by Groër et al. (2008) and involves the design of a set of least cost vehicle routes to service a set of customers with known demand over multiple days. The objective is to minimize the total distance traveled while satisfying operational constraints, such as vehicle capacities, route duration, visit requirements and consistent service. The proposed solution approaches operate on a dual-mode basis within a multi-start solution framework. Based on the consistent service constraint, the ConVRP is decomposed into a master and a slave sub-problem. The master sub-problem seeks to design a template schedule in order to determine the visiting sequence of frequent customers. On the other hand, the slave sub-problem seeks to find the actual daily service schedules for both frequent and non-frequent customers on the basis of the master template schedule. Computational experiments on benchmark data sets of the literature yield high quality solutions, illustrating the effectiveness and efficiency of the proposed solution approaches.

Models and Algorithms for Bin Allocation and Vehicle Routing in Waste Collection Applications

Authors: *Hemmelmayr, Vera; Doerner, Karl F; Hartl, Richard F; Vigo, Daniele*

We consider a problem encountered in the waste collection industry. For a number of waste collection sites we have to determine the service frequency over a given planning period as well as the number of bins to place there. The problem consists of a routing and an allocation aspect. More precisely, if a site has a higher service frequency, the routing cost will increase, since we have to visit this site more often, but at the same time the allocation cost is less, because we use a smaller number of bins. The bins used have different types and different cost and there is a limit on space at each collection site as well as a limit on the total number of bins of each type that can be used. We present solution methods based on a combination of a metaheuristic for the routing part and a MILP for the allocation part.

Multi-Period Street Scheduling and Sweeping

Authors: *Dussault, Benjamin; Cerrone, Carmine; Golden, Bruce; Wasil, Edward*

We consider a city, which seeks to sweep a subset of its streets over two days. However, some streets require that parking be readily available on some streets. To enforce this, the city places parking signs that indicate which side of these streets are to be swept on "even" days and which sides of these streets are to be swept on "odd" days. What closed path should the street sweeper take on each day to minimize total distance traveled while satisfying all the constraints? We ask the following more general question: How should the city redo the signs to minimize the required travel distance of the street sweeper while still satisfying the parking constraints? We further extend the problem by asking: How can the city minimally change existing street signs to allow for a schedule with a maximum decrease in distance traveled by the street sweeper? To solve these problems we employ a genetic algorithm heuristic to generate good solutions in a short amount of time.

Session Th 3.2 – Railway Transportation

Thursday 24/06 14:30 - 16:00 Room: Rica Hall II

Bi-objective conflict detection and resolution in railway traffic management

Authors: *Corman, Francesco; D'Ariano, Andrea; Pacciarelli, Dario; Pranzo, Marco*

Railway conflict detection and resolution is the daily task faced by railway managers that consists of adjusting train schedules whenever disturbances make the timetable infeasible. The main objective pursued by the infrastructure managers is minimization of train delays, while train operating companies are also interested in other indicators of passengers dissatisfaction. The two objectives are conflicting whenever delay reduction requires cancellation of some connections between train services, which hampers passengers transfer. The infrastructure company and the train operating companies discuss on which connection to keep or drop in order to reach a compromise solution. In this paper we face the bi-objective problem of minimizing delays and missed connections to provide a set of feasible non-dominated schedules to support this decisional process. We use a detailed alternative graph model to ensure schedule feasibility and develop two heuristic algorithms to compute the Pareto front of non-dominated schedules. Our computational study, based on a complex and densely occupied Dutch railway network, shows that good coordination of connected train services is important to achieve real-time efficiency of railway services since the management of connections may heavily affect train punctuality. The two algorithms approximate accurately the Pareto front within a limited computational time.

Strategic Gang Scheduling in the Railway Industry

Authors: *Klabjan, Diego; Yang, Dengfeng*

The gang scheduling problem is to schedule jobs throughout a year for a set of gangs. We proposed a two-phase optimization strategy. First, by using shortest path we construct an initial solution. Then we improve it by means of a math-heuristic.

Railway Crew Rescheduling with Retiming

Authors: *Veelenturf, Lucas P; Potthoff, Daniel; Huisman, Dennis; Kroon, Leo G*

Railway operations are disrupted frequently. For example the Dutch railway network experiences about three large disruptions per day on average. In such a disrupted situation railway operators need to quickly adjust their resource schedules. In practice, the timetable, the rolling stock schedule and the crew schedule are recovered in a sequential way. In this paper, we model and solve the crew rescheduling problem with retiming. This problem extends the crew rescheduling problem by the possibility of delaying the departure of some trains. In this way we partially integrate timetable adjustment and crew rescheduling. The algorithm is based on column generation techniques combined with Lagrangian heuristics. In order to keep the computational times low, retiming is allowed only for those trains where it seems promising. Computational experiments with real-life disruption data show that, compared to the approach without retiming, it is possible to find better solutions by using crew rescheduling with retiming.

Session Th 3.3 – Routing and Scheduling

Thursday 24/06 14:30 - 16:00 Room: Rica Panorama

Solving the Weekly Log-Truck Scheduling Problem by Integer Programming
Authors: *El Hachemi, Nizar; El Hallaoui, Issmail; Gendreau, Michel; Rousseau, Louis-Martin*
We address a routing and scheduling problem encountered in a forestry application: the Weekly Log-Truck Scheduling Problem, in which a fleet of homegeneous trucks must transport full truckloads from forest areas to woodmills over a full week. This problem includes aspects such as synchronization between trucks and log-loaders (both in forest areas and at woodmills), multiple products, inventory stocks, and a lunch breaks for drivers. The objective is to minimize the overall cost including waiting times, loaded travel and empty driven distance. Our solution approach is based on two phases. In the first phase, an integer linear program determines the destinations of full truckloads for each day of the week. In the second phase, another integer program, based on a time-space network representation of truck activities, is used to route and schedule trucks at a minimum cost for any given day. Computational experiments were performed using CPLEX 11 as a solver for the integer programs. Almost all instances were solved within thirty minutes with a reasonable gap.

A Routing Problem for the Science-on-Wheels Project
Authors: *Ozdemir, Emrah; Sural, Haldun*
In this study, we introduce a new selective and time windows constrained routing problem, called the science-on-wheels routing problem (SWRP), which is motivated by a project of ILKYAR, a non-governmental organization. The project is based on on-site activities performed in the selected junior boarding schools and is applied once a year. The SWRP plays an important role for the success of the project and involves two main decisions partitioned into two levels. In the first level, a set of schools is selected according to a given criterion subject to the special time windows constraints in a given project period. In the second level, a selected school is assigned to a project day. The problem is modeled using bi-level programming methods. The solution approach is implemented on the test instances that are compiled from the real-life data. Computational results show that our approach generates good solutions in short times.

An integrated solution method for order batching and picking
Authors: *Raa, Birger; Dullaert, Wout*
This paper investigates the optimization of order picking efficiency in picker-to-part warehouses with multiple blocks by integrating decision making on batch sizing, batch composition and order picker routing. Although there is an extensive literature on each of these three individual aspects, this paper is, to the best of our knowledge, the first to provide integrated approaches. Eleven integrated approaches are suggested by combining existing solution procedures for the three subproblems in various ways and augmenting these with local search improvement heuristics. Computational experiments on an extensive collection of benchmark datasets show that (i) both the capacity of the picker and the number of blocks in the warehouse have a significant impact on the performance of the proposed algorithms, (ii) batching procedures should consider both travel distance and capacity utilization, and (iii) the improvement heuristics have a significant impact on solution quality. It is also shown that allowing order splitting across batches has a significant potential for further travel distances reductions.

Session Th 3.4 – Traffic Flow

Thursday 24/06 14:30 - 16:00 Room: Nord-Norge salen

A third order highway multilane model
Authors: *Louis, Xavier; Schnetzler, Bernard; Lebacque, Jean-Patrick*
A macroscopic hyperbolic model is presented to simulate multilane highways dynamics. This one is analytically solved and integrated in a finite volume simulation code.

Sensitivity analysis of velocity and fundamental traffic flow diagrams from modelling of vehicle driver behaviors
Authors: *Mussone, Lorenzo; Bonzani, Ida*
This paper deals with the sensitivity analysis of the velocity and fundamental diagrams derived in steady uniform flow conditions and based on a detailed analysis of the individual behavior of the driver-vehicle subsystem.

Joint Problem of Traffic Signal Synchronization and Bus Priority
Authors: *Colombaroni, Chiara; Gemma, Andrea; Fusco, Gaetano*
Several methods have been developed to allow bus priority with respect to general traffic in urban areas. Among these, signal priority strategies attempt to reduce delay in two ways: by reducing the probability of a transit vehicle encountering a red signal, and, if this does occur, by reducing the wait time until the green signal. The objective of this study is modeling and simulating a mathematical procedure to provide bus priority along a synchronization arterial, through the combination of passive and active bus priority strategies.

Session Th 4.1 – Advances in Integer Programming

Thursday 24/06 16:30 - 18:00 Room: Rica Hall I

Advances in Linear Programming and Column Generation
Authors: *Desrosiers, Jacques*
Dantzig-Wolfe decomposition and column generation embedded into a branch-and-bound scheme are established as leading solution methodologies for many large-scale integer programming problems, especially in the areas of vehicle routing and crew scheduling applications. The proposed talk is an extension of two recent researches in the solution of set partitioning problems by column generation and of linear programs by the primal simplex method. The classical column generation method works with a restricted master problem, that is, a subset of the columns. The proposed improved column generation method works with a reduced restricted master problem, that is, it additionally reduces the size of the current basis. As already shown for the constraints aggregation on set partitioning problems where CPU times are reduced by a factor of 50 to 100 for some vehicle routing and crew scheduling applications, this additional row reduction of the master problem should have a large impact on the solution time of degenerate linear and integer programs solved by column generation.

Solving periodic timetabling: Improving the Modulo Network Simplex method
Authors: *Goerigk, Marc; Schöbel, Anita*
The problem of finding a suitable timetable that allows customers to travel without unnecessary delay from one station to another is as economically important as difficult to handle mathematically. Especially the case of periodic timetables, in which events occur repeatedly over a given period, is known to be NP-hard - in fact, even finding a feasible solution is so. Thus even heuristics are rare. On the other hand there are recent achievements like the newly introduced timetable of the dutch railway system that impressively demonstrate the applicability and practicability of the mathematical model. Karl Nachtigall and Jens Opitz presented a new heuristic approach to the periodic timetabling problem based on the classical network simplex method. Besides the drawback that a feasible starting solution still has to be provided, it suffers under relatively high running times and solutions mediocre in quality. This presentation proposes different approaches we explored to improve the modulo simplex algorithm with respect to its running time and the quality of the solution which result in an algorithm that is able to handle problems of the size of the German intercity rail network.

Using Branch-and-Price to Find High-Quality Solutions Quickly
Authors: *Hewitt, Mike; Nemhauser, George; Savelsbergh, Martin*
Our research presents a new approach for solving integer programs that possesses the primal-side capabilities of heuristic procedures and the dual-side capabilities of branch-and-bound-based techniques. In addition, we present examples of how the approach can be applied to a challenging transportation-related problem, the Multi-commodity Fixed Charge Network Flow problem, to yield an algorithm that produces high-quality solutions much more quickly than a state-of-the-art mixed integer programming solver.

Session Th 4.2 – Routing and Scheduling

Thursday 24/06 16:30 - 18:00 Room: Rica Hall II

A quadratic time algorithm for the U.S. Truck Driver Scheduling Problem
Authors: *Goel, Asvin; Kok, Leendert*
In the United States of America driving and working hours of truck drivers must comply with the hours of service regulations imposed by the U.S. Department of Transportation. It is known that whenever a truck driver schedule complying with these regulations exists for a sequence of n locations which shall be visited within given time windows, such a schedule can be found in $O(n^3)$ time. This paper shows that by carefully traversing the search space this complexity can be reduced. A tree search algorithm is presented which generates feasible truck driver schedules in $O(n^2)$ time.

GRASP/VND with Path Relinking for the Truck and Trailer Routing Problem
Authors: *Villegas, Juan; Prins, Christian; Prodhon, Caroline; Medaglia, Andrés L; Velasco, Nubia*
The Truck and Trailer Routing Problem (TTRP) is an extension of the well known vehicle routing problem. In the TTRP a limited fleet of trucks and trailers is used to serve a set of customers from a main depot. Due to the existence of accessibility constraints there are two types of customers: truck customers accessible only by truck; and vehicle customers accessible either by truck or by a complete vehicle (i.e., a truck pulling a trailer). The objective of the TTRP is to find a set of routes of minimum total distance such that: each customer is visited by a compatible vehicle exactly once; the total demand of the customers visited in a route or subtour does not exceed its capacity; and the availability of the fleet is met. In this work we solve the Truck and Trailer Routing Problem using a route-first, cluster-second procedure embedded within a hybrid metaheuristic based on Greedy Randomized Adaptive Search Procedure (GRASP), Variable Neighbourhood Descent (VND) and Path Relinking (PR). We test PR: as post-optimization procedure; as intensification mechanism; and in Evolutionary Path Relinking. The computational experiments show that all the variants of GRASP/VND with PR outperform the previous competing methods.

The Simultaneous Vehicle Scheduling and Passenger Service Problem
Authors: *Petersen, Hanne; Larsen, Allan; Madsen, Oli; Ropke, Stefan*
Passengers using public transport systems often experience waiting times when transferring between two scheduled services. We propose a planning approach which seeks to obtain a favorable trade-off between the conflicting objectives passenger service and operating cost, by allowing some moderate modifications of the timetable during the vehicle scheduling phase. This planning approach is referred to as the Simultaneous Vehicle Scheduling and Passenger Service Problem (SVSPSP). The SVSPSP is solved using a large neighbourhood search metaheuristic. The proposed framework is tested on data inspired by the express-bus network in the Greater Copenhagen Area. The results are encouraging and indicate a potential decrease of passenger waiting times in the network of 10-20%, with the vehicle scheduling costs remaining largely unaffected.

Session Th 4.3 – Air Traffic Management and Airport Capacity

Thursday 24/06 16:30 - 18:00 Room: Rica Panorama

Stochastic Integer Programming Models for Air Traffic Flow Management Problems

Authors: *Ball, Michael; Ganji, Moein; Glover, Charles; Lovell, David*

In this paper we address a stochastic air traffic flow management problem. Our problem arises when airspace congestion is predicted, usually because of a weather disturbance, so that the number of flights passing through a volume of airspace (flow constrained area - FCA) must be reduced. We formulate an optimization model for the assignment of dispositions to flights whose preferred flight plans pass through an FCA. For each flight, the disposition can be either to depart as scheduled but via a secondary route, or to use the originally intended route but to depart with a controlled (adjusted) departure time and accompanying ground delay. We model the possibility that the capacity of the FCA may increase at some future time once the weather activity clears. The model is a two-stage stochastic integer program that represents the time of this capacity windfall as a random variable. Our model allows the initial reroutes to vary from pessimistic (initial trajectory avoids weather entirely) to optimistic (initial trajectory assumes weather not present). We conduct experiments allowing a range of such trajectories and draw conclusions regarding appropriate strategies.

On the optimum expansion of airport networks

Authors: *Santos, Miguel; Antunes, António*

Air transport has been growing at a fast pace for several decades. This has led to severe airport congestion problems everywhere in the world and, particularly, in the largest airports. In the short term, these problems can be dealt with through demand management measures. However, in the long run, they will be difficult to address without building new airports and/or expanding the capacity of existing airports. In this article, we introduce an optimization model aimed at helping air transport authorities in making these types of decisions. The model assists in determining the expansion actions to apply to a network of airports, while complying with a given budget. The objective is to maximize the total revenue passenger kilometers traveled within the airport network, taking into account the capacity of the airports and the impact of travel costs upon demand. The type of results that can be obtained through the application of the model is illustrated for a small size network.

Airline Network Design under Congestion

Authors: *Pita, João; Antunes, António*

Airport congestion and flight delays are among the main problems faced today by the air transportation industry, being at the origin of important losses for the airlines and for the economy as a whole. In this article, we present a mixed-integer optimization model for airline network design where the implications of airport congestion and flight delays are taken into account. The model defines the flight schedule and fleet assignment decisions that maximize the profit of an airline operating in slot-constrained airports. Tests made for randomly-generated instances and for (a simplified version of) the TAP Air Portugal network indicate that the model can provide very useful results within reasonable computation effort.

Session Th 4.4 – State Estimation

Thursday 24/06 16:30 - 18:00 Room: Nord-Norge salen

Estimation and Prediction of Traffic Parameters using Spatio-Temporal Data Mining

Authors: *Leonhardt, Axel; Busch, Fritz*

Sound knowledge of the actual und near future traffic state, expressed through appropriate traffic parameters such as the travel time, is fundamental for many dynamic traffic management systems. The paper presents an instance based learning model to estimate and predict relevant traffic parameters using spatio-temporal pattern recognition. Observations, e.g. occasionally observed travel times from probe vehicles, are stored together with data patterns (explanatory variables). These data patterns are derived from continuously available data, generally collected from local detectors scattered in the road network, in combination with calendar variables (day of week and time of day). Data patterns are compared using a spatio-temporally weighted distance metric, and the observations corresponding to the k nearest patterns are used to fit a local function using a Gaussian kernel. The method has been compared to other approaches and successfully tested for several routes in the city of Graz, Austria (using local occupancy data as explanatory variables and taxis as probe vehicles to collect travel times) and in the city of Munich, Germany (using local traffic flow data as explanatory variables and vehicle re-identification to collect travel times).

Online estimation of Kalman Filter parameters for traffic state estimation

Authors: *van Hinsbergen, Chris; Schreiter, Thomas; van Lint, Hans; Hoogendoorn, Serge P; van Zuylen, Henk*

The Extended Kalman Filter (EKF) has been applied successfully to optimally combine data with online traffic simulation models. However, one of the great difficulties in applying the EKF is that its parameters describing the measurement and process noise distributions need to be estimated, while these distributions are seldomly known or even observable. Until now, the EKF parameters are usually chosen based on trial and error. In this paper is a consistent methodology is proposed to continuously adapt the EKF parameters in an online traffic state estimation system. The methodology follows from Bayesian inference, the same method with which the EKF can be derived itself. In a case study it is shown that these continuously adapted parameters lead to good state estimates, independent of their initial values, while taking constant values is shown to be very sensitive to the initial values.

Real-Time Traffic Estimation Using Data Expansion

Authors: *Lederman, Roger; Wynter, Laura*

This paper summarizes a method for estimating traffic volumes on a road network using historical and real-time traffic data when a non-negligeable subset of the network links do not have data. The approach involves both an offline phase and a real-time phase. In the offline phase, a bilevel program must be solved, thereby generating a new set of parameters for the real-time phase. The real-time phase is efficient enough to be scalable to full city-wide deployments. Simulations on several test networks show excellent results

Session Fr 1.1 – Routing - Exact Methods

Friday 25/06 09:00 - 10:30 Room: Rica Hall I

Exact Methods for the Multi-Trip Vehicle Routing Problem
Authors: *Toth, Paolo; Mingozzi, Aristide; Roberti, Roberto*
The "Multi-Trip Vehicle Routing Problem" (MTVRP) is an extension of the Capacitated Vehicle Routing Problem where each vehicle is allowed to perform more routes during its working period. MTVRP is defined on an undirected graph, where each edge has a "travel cost" and a "travel time", and each customer has a given "demand". A fleet of m identical vehicles is available, each vehicle having a "capacity" Q and a "maximum working time" T. A "route" is a simple circuit visiting the depot and a subset of customers and such that the total demand of the customers does not exceed Q. A "schedule" for a vehicle is a subset of routes having total working time not exceeding T, and visiting each customer at most once. The objective of MTVRP is to design a set of m schedules, one for each vehicle, of minimum total cost and such that all the customers are visited exactly once. In this work, we present two exact methods for the MTVRP using two different set-partitioning based formulations. The computational results show that benchmark instances with up to 100 customers can be consistently solved to optimality within acceptable computing times.

The Uncapacitated Dial-a-Ride Problem on a Tree
Authors: *Anily, Shoshana; Pfeffer, Aharona*
The uncapacitated Dial-a-Ride Problem (DARP) on a tree, is defined by a single vehicle of unlimited capacity, a set of object types and a null object, and a tree T=(V,E), where V is a set of n vertices and E is the set of edges. Each vertex v is associated with a pair of object types (s(v),d(v)), where s(v) is the object type supplied by v, and d(v) is the object type required by v. The total supply (demand) of each object type is one unit. Each edge of T is associated with a non-negative cost. The objective is to design a minimum cost feasible route that starts and ends at the root of the tree, so that the vehicle while following the route satisfies the requirements of all the vertices. This problem is known to be NP-hard. In this talk we prove some structural properties that any optimal solution for the problem satisfies. Tight lower and upper bounds on the optimal solution are provided, as well as necessary and sufficient conditions under which the optimal solution coincides with the lower bound. We also present a heuristic whose effectiveness is tested via a computational study.

New lower bounds and exact method for the m-PVRP
Authors: *Ngueveu, Sandra Ulrich; Prins, Christian; Calvo, Roberto Wolfler*
The m-Peripatetic Vehicle Routing Problem (m-PVRP) consists in finding a set of routes of minimum total cost over m periods so that two customers are never sequenced consecutively during two different periods. It models for example money transports or cash machines supply where for security reasons the sequence of customer must vary, and the aim is to minimize the total cost of the routes chosen. New lower bounding procedures and an exact method are presented in this paper, comprising a column generation approach and a polyhedral approach. The former consists in two dual heuristics that identify good dual feasible solutions for the linear relaxation of the aggregated set partitioning formulation, based upon three key ideas: the approximation of routes with non-elementary routes called q-routes, the use of a column generation approach to handle the exponential number of variables and the use of dual ascent to estimate the best dual variables values. The polyhedral approach consists in two branch-and-cut algorithms for the edge-based m-PVRP formulation and the aggregated edge-based m-PVRP formulation. Computational results show that the algorithms developped are both fast and efficient.

Session Fr 1.2 – Railway Transportation

Friday 25/06 09:00 - 10:30 Room: Rica Hall II

Heuristic column generation for railroad track inspection scheduling

Authors: *Lannez, Sebastien; Artigues, Christian; Damay, Jean; Gendreau, Michel*

In this paper we address a real world optimisation problem which occurs at the French National Railway Company (SNCF), the Rail Track Inspection Scheduling Problem (RTISP). It can be viewed as an arc routing problem with limited vehicle capacity (CARP), time windows on arc (CARP-TW), an heterogeneous fleet (H-CARP) and intermediate facilities (IF-CARP). The proposed model is a generalization of these arc routing problems because it contains them all as a special case. Our contributions are the mixed integer program formulation of the problem, the presentation of a two phases heuristic build upon column generation, dynamic programming and constraint programming and its computational analysis. The originality and strength of our algorithm is its ability to tackle a yearly scheduling on a sparse graph with thousand nodes and arcs.

Passenger Oriented Rolling Stock Rescheduling

Authors: *Nielsen, Lars; Kroon, Leo G; Maroti, Gabor*

In this paper we address the rescheduling of rolling stock in a passenger railway system. The problem is to adapt the rolling stock schedule to a change in environment such as an infrastructure blockage. Part of the problem is to deal with the dynamics of the passenger flow. The goal is to minimize the passenger delay by providing sufficient capacity while limiting the changes to the processes at the stations. These processes concern the adjustment of train lengths by removing units from or adding units to train. In a disrupted situation, the passengers respond to the change in environment by re-computing their shortest route to their destination in the time expanded network, and greedily compete for the available capacity. We propose a model for the problem and solve it with an iterative heuristic. Each iteration involves the application of a MIP model for the rolling stock rescheduling, and the evaluation of the passenger flow through simulation. The quality of a passenger flow is then fed back to the objective function for the rolling stock rescheduling in the next iteration. We apply our approach to a number of instances derived from cases from a major Dutch railway operator.

Delay Management with Passenger Re-Routing: Solving Practical Instances

Authors: *Dollevoet, Twan; Huisman, Dennis*

Missing a connection in a railway system can have a large impact on the travel time of passengers. In case of a small delay, railway operators might therefore decide to delay connecting trains slightly. Deciding which trains should wait for the passengers in a delayed feeder train is the field of Delay Management. In the first delay management models, the delay of a passenger that misses a connection is assumed to be equal to the cycle time. However, passengers will often adjust their route when a connection is missed. In our view, determining a route for every passenger should be part of delay management. Passenger Re-Routing can straightforwardly be incorporated into the delay management models. However, the size of the problems becomes too large for realistic instances, especially because in practice a solution should be available on a short notice. We therefore suggest an alternative formulation of the delay management problem that still captures the behavior of the passengers but with a size that is much smaller. Furthermore, we present a solution procedure that adjusts the possible re-routings for passengers dynamically.

Session Fr 1.3 – Network Design and Planning

Friday 25/06 09:00 - 10:30 Room: Rica Panorama

On the solution of robust traffic network design and pricing problems
Authors: *Patriksson, Michael; Cromvik, Christoffer*
We investigate the optimization of tolls and other control measures in a traffic network, taking into account several sources of uncertainty. The goal is to produce controls that are robust to changes in the uncertain parameters. Since such hierarchical problems are modelled as mathematical programs with equilibrium constraints (MPEC), we are here considering their stochastic extension, the stochastic mathematical program with equilibrium constraints (SMPEC), as introduced in Patriksson and Wynter (1999). The talk will present some of the fundamental theory regarding the existence and stability of optimal solutions to such problems, as applied to the setting where networks flows are governed by the Wardrop conditions. We present extensions to this theory to stationary solutions, and to the inclusion of risk objectives as well as to multiple objectives. Apart from detailed illustrations from small-scale examples, we hope to be able to show test results on larger networks from implementations of MPEC algorithms in tandem with sample average approximation (SAA) methods.

Integrated Urban Hierarchy and Transportation Network Planning
Authors: *Bigotte, João; Antunes, António*
Regional development plans typically aim at improving the accessibility to facilities where services such as education, health care, public safety, and justice are offered to the population. This can be achieved both by redefining the level of hierarchy to assign to the urban centers of the region under study (with a class of facilities associated with each level of hierarchy) and by redesigning the region's transportation network. Traditionally, these two subjects - urban hierarchy and transportation network planning - have been addressed separately in the optimization literature. This article presents an optimization model that simultaneously determines which urban centers and which network links should be promoted to a new level of hierarchy so as to maximize accessibility to all classes of facilities. The usefulness of the model for solving real-world problems of integrated urban hierarchy and transportation network planning is illustrated through an application to the Centro Region of Portugal.

Multi-objective Network Design Problem: minimizing externalities using dynamic traffic management measures
Authors: *Wismans, Luc; van Berkum, Eric; Bliemer, Michiel C J*
The optimization of transport systems by expanding or improving an existing network is often referred to as a Network Design Problem (NDP). This paper describes the results of research on optimization of accessibility, air quality, climate, traffic safety and noise using dynamic traffic management (DTM) measures. Within this research the NDP problem is formulated as a bi-level optimization problem. The formulation of the objective functions and calculation methods developed are based on using a dynamic traffic assignment (DTA) model. A DTA model is used to solve the Dynamic User Equilibrium problem at the lower level, because it is best suited to assess the effects of DTM measures at externalities while traffic dynamics are important explanatory variables. However, using a DTA model results in large computational efforts. Therefore three solution approaches, using metaheuristics, are tested for solving the upper level trying to accelerate the search. Within these metaheuristics we applied genetic programming methods in which specific attention was paid to the determination of the initial set of solutions and restriction of the solution space. This framework is tested in a case study and the results analysed to determine if objectives were opposite or aligned and to compare the solution approaches.

Session Fr 1.4 – Dynamic Traffic Assignment

Friday 25/06 09:00 - 10:30 Room: Nord-Norge salen

Network Contraction for Rapid Equilibrium Assessment
Authors: *Boyles, Stephen*
Many transportation planning applications require repeated application of a static user equilibrium traffic assignment model. This paper presents a method for contracting a network, reducing its size to allow faster computation. Analytical formulae for series, parallel, delta-wye, and wye-delta transformations are provided; under certain assumptions, efficient algorithms exist to reduce any planar network to a single link using these transformations. Interesting parallels arise with the study of resistive electrical circuits. A brief demonstration on the well-known Braess network illustrates this procedure.

Risk-averse Traffic Assignment in a Dynamic Traffic Simulator
Authors: *Knoop, Victor; Bell, Michael; van Zuylen, Henk*
It is known that users are to a certain extent risk-averse in choosing their routes. Several articles show how this can be applied practice. However, up to now, game-theoretical risk-averse traffic assignment has only been applied for static traffic assignment. This paper extends this concept and describes how risk-averse traffic assignment can be integrated with any dynamic simulator capturing all queuing dynamics. We propose a methodology in which all incident scenarios are simulated in a dynamic traffic simulator. The travellers anticipate the worst of these scenarios (or a mixture thereof), and change their route based on this anticipation. That, in turn, changes the traffic situation and the delays for the incident scenarios, changing which scenario is worst. To come to the final traffic assignment, the above steps are integrated in a loop, adapting the traffic assignment using the method of successive averages. The method is shown on a test-case which shows that risk-averseness changes the results of the traffic assignment in a way that travellers avoid the busy roads where possible incidents have a large effect.

Quantifying variability due to incidents including en-route rerouting
Authors: *Corthout, Ruben; Tampère, Chris M J; Immers, Lambertus H*
In dynamic traffic assignment (DTA) problems, reliability is increasingly acknowledged as an important factor influencing the decisions of travellers. One of several problems that need to be overcome before variability itself and the respons of drivers can be adequately modelled by DTA models, is the development of stochastic dynamic network loading (DNL) that produce probability distributions of traffic states and travel times. In a previous paper, we introduced the Marginal Incident Computation (MIC) model, a highly efficient algorithm that approximately quantifies congestion spillback due to incidents. Since only the additional incident congestion is calculated, computation time can be reduced to less than 0.1% compared to a full, explicit simulation. The MIC model can thus be used as a component in a stochastic DNL, quantifying variability due to incidents. In this paper, the MIC model is extended with an en-route route choice model that allows drivers to re-evaluate their initial route. Thus, the effect of rerouting drivers on the spillback of the incident congestion can be accounted for. The extended MIC model is calibrated and validated based on two separate data sets from the Dutch primary road network with incident congestion.

Session Fr 2.1 – Rich VRP

Friday 25/06 11:00 - 12:30 Room: Rica Hall I

A heuristic based on clustering for the vehicle routing problem: a case study on spare parts distribution

Authors: *Sharifyazdi, Mehdi; Bagherpour, Matin*

The problem studied in this paper is categorized as Vehicle Routing Problem. The problem is defined in a distribution center which receives orders from its customers regularly and distributes collected and packed items between the customers. The problem aims to determine the orders which should be transmitted together, as well as the vehicles to carry the orders, and finally the routes to reach the customers. These decisions must be made in such a way to minimize transportation costs, while keeping lead time between receiving customers' orders by distribution center and delivering prepared orders to customers in appropriate levels. In this paper, an event-oriented heuristic algorithm is proposed for the mentioned problem.

Solving a Rich Vehicle Routing Problem in a cooperative real-world scenario

Authors: *Nagel, Andrea; Pankratz, Giselher; Gehring, Hermann*

In this contribution, we consider a cooperation of four distributors in the food and beverages industry, each of them offering high-quality products that are complementary to the products offered by the other companies. The producers have decided to coordinate their distribution activities by inter-organisational transportation planning. Acting in the same market segment but all the same not being competitors allows us to use a centralized planning approach for modelling the cooperation. The setting is characterized by several standard VRP constraints such as time windows, capacities and backhauls and the non-standard extensions of dynamics and simultaneous planning of own-name transport and subcontracting. Two algorithmic approaches that deal with this situation have been developed. One by using a Large Neighbourhood Search (LNS) strategy in combination with a Threshold Accepting procedure, another by adapting the Greedy Randomized Accepting Procedure (GRASP) which itself applies a LNS instead of a simple Neighbourhood search. These two approaches are currently under intensive testing. The test results will be presented.

Approximate Hill Climbing Approach for the Fleet Size and Mix Vehicle Routing Problem with Time Windows

Authors: *Bräysy, Olli*

We present a new approximate search strategy that is combined with a hybrid threshold accepting and tabu search metaheuristic. The basic idea is to skip the objective function evaluations during hill-climbing phases and pick from memory previously calculated values instead. The suggested method is applied to the Fleet Size and Mix Vehicle Routing Problem with Time Windows. Computational testing on the 768 benchmarks show that the new solution method is competitive to previous best approaches with respect to both time and solution quality.

Session Fr 2.2 – Inventory Routing

Friday 25/06 11:00 - 12:30 Room: Rica Hall II

Discrete time model for an Inventory Ship Routing Problem
Authors: *Agra, Agostinho; Andersson, Henrik; Christiansen, Marielle*
We consider a maritime inventory routing problem that combines routing and inventory management at all ports of a single product. The product is produced and stored at production (loading) ports and transported by a heterogeneous fleet of ships to the consumption ports (unloading ports). Inventory capacities and inventory safety stocks are considered on the production and consumption ports. We present a mathematical formulation of the problem where the time is discretized to easily take the varying production and consumption rates into account. Then we discuss different approaches to strengthen that formulation. These approaches include the study of extended formulations and the inclusion of valid inequalities. Since the ISRP is a general problem that incorporates characteristics from other well-know intensively studied problems, such as, the Vehicle Routing Problem, Capacitated Lot-sizing Problem, etc., the approaches followed explore also the connections between the ISRP and these other related problems. Computational results based on real data will be reported.

A heuristic for rich maritime inventory routing problems
Authors: *Kloster, Oddvar; Flatberg, Truls*
In maritime inventory routing, a fleet of vessels is employed to transport products that are produced and consumed in different ports with limited storage capacity. The tight coupling between inventory management and routing, and diverse constraints make this a challenging problem. We generate a routing plan using an iterative construction algorithm, starting from an empty plan. In each iteration, a constraint violation, e.g. a stockout, is identified. We generate a number of different journeys that can fix the violation and add the best one. This continues until the plan is feasible or no remaining violation can be fixed. The construction algorithm is reused in the optimization phase, where each iteration consists of removing and then rebuilding a part of the plan. We present results on real world cases.

Tabu Search for Coordinating Production and Distribution Routing Problems
Authors: *Armentano, Vinícius; Shiguemoto, André*
This work addresses the problem of optimally coordinating a production-distribution system over a multi-period finite horizon, where a facility production produces several items which are distributed to a set of customers by a fleet of homogeneous vehicles. The demand of each item at each customer is known over the horizon. The production planning determines how much to produce of each item in every period, while the distribution planning defines when customers should be visited, the amount of each item that should be delivered to customers and the vehicle routes. The objective is to minimize the sum of production and inventory costs at the facility, inventory costs at the customers and distribution costs. We also consider a related problem of inventory-routing, where a supplier receives or produces known quantities of items in each period and has to solve the distribution problem. We propose a tabu search procedure for solving such problems, and this approach is compared with Vendor Managed Policies proposed in the literature, in which the facility knows the inventory levels of the customers and determines the replenishment policies.

Session Fr 2.3 – Stochastic Networks

Friday 25/06 11:00 - 12:30 Room: Rica Panorama

A Stochastic and Dynamic Policy-Oriented Model of a Large Network of Airports
Authors: *Odoni, Amedeo; Pyrgiotis, Nikolas*
As more airports in the United States and in Europe become congested, it also becomes increasingly likely that delays at one or more airports will spread to other parts of the network. We describe an analytical model, Airport Network Delays (AND), developed to study this complex phenomenon. It computes delays due to local congestion at individual airports and, more important, captures the "ripple effect" that leads to the propagation of local delays throughout the network. The model operates by iterating between a stochastic and dynamic queuing engine (QE) that computes delays at individual airports and a delay propagation algorithm that updates flight schedules at all the airports in the model in response to the local delays computed by the QE. The AND model is fast computationally, making possible the exploration of the impacts of a large number of scenarios and policies on system-wide delays. It has been fully implemented for the network of the 34 busiest airports in the continental United States. An implementation for the network of the 34 busiest airports in Europe is in progress. The model provides insights into the complex interactions through which delays propagate through the network and the often-counterintuitive consequences of these interactions.

Single-commodity stochastic network design
Authors: *Wallace, Stein W; Crainic, Teodor Gabriel; Kaut, Michal; Thapalia, Biju K*
This paper investigates the structures of optimal designs coming from stochastic integer programs, and compares them to their deterministic counterparts. Random demand as well as random arc capacities are studied. The goal is to understand what is lost in terms of flexibility by solving deterministic design models.

Real Option Models for Network Design Under Uncertainty
Authors: *Chow, Joseph Y J; Regan, Amelia*
The goals of a transportation agency have changed over the last few decades. The evolution of systems analysis has shifted from systems optimization to dynamic strategic planning which focuses on the need to account for uncertainties, and to account for decision-makers who are not perfectly rational or have conflicting interests. Our research examines the value of real options as a tool for hedging risk under uncertainty in future demand for transportation systems. We propose the first real options based solution for multi-period urban network design problems with uncertainty. We present three new models and show how they can incorporate flexibility into network design. These models show the range of strategies available to a decision-maker. Numerical tests are conducted with the classic Sioux Falls test network. The first model is tested for sensitivity to demand volatility, time horizon while the second model is solved for the option value directly as a function of the network design variables. Finally the last model obtains an optimal staging for each individual link design solution, and the option value is compared with the other two models. We discuss the performance of each of these models and examine their potential for solving problems of realistic size.

Session Fr 2.4 – Choice Modelling

Friday 25/06 11:00 - 12:30 Room: Nord-Norge salen

Distance to the city centre and travel behaviour: A Case of Ahmedabad City

Authors: *Munshi, Talat; Zuidgeest, Mark*

Travel behavior is often linked to urban form of a city. It has been observed in literature that Mono-centricity or poly-centricity of an urban form affects travel characteristics like in trip lengths and mode choice; there are theoretical arguments which favor both concentration and dispersion. The purpose of this research is to identify employment centers in the city of Ahmedabad for years 1985 and 2007 and relate it with change in travel behavior over the period. It was found that over the years jobs have decentralized from the core area to newer part and this has resulted in negligible increase in observed trip lengths as compared to increase in cities agglomeration areas. The shift in modal share is towards private modes of transport. The traditional city is still the preferred destination choice for work and shopping trips, but as distance travelled increases more individual prefer newer centers as shopping and work destination mainly for individuals using private modes of transport. This also indicates that the new center's have activities of higher utility value mainly for owners for private motorized vehicles.

Route choice behavior based on license plate observations in the Dutch city of Enschede

Authors: *Thomas, Tom; Tutert, Bas*

Route choice is an important component of traffic assignment. Assignment models are however seldom validated by observed choices. In this study, we use license plate observations from the Dutch city of Enschede to analyze empirical route choice behavior. We generate a route set of many alternative routes and show how the observed distribution of chosen routes depends on the travel times along these routes. The frequency ratio between two routes can be described by a negative exponential-to-the-power-law as function of absolute travel time difference. We find that in 25% of the cases a longer route is chosen, and that this leads to an average relative detour factor of 8% with respect to the shortest route. Thus, loads on the network are underestimated in user equilibrium assignments where users choose the shortest route. Our results can be used to improve traffic assignment. Without explicitly modeling other attributes or individual preferences, which are often hard to measure anyway, we implicitly take them into account.

Sensitivity Analysis Method for Trip Mode Choice Behavior of Expo 2010 Shanghai

Authors: *Du, Yuchuan; Jiang, Shengchuan; Sun, Lijun*

This research paper is directed toward obtaining a better understanding of trip mode choice behavior of Expo 2010 Shanghai visitors and the effectiveness of traffic management policies in reducing private transport traveling. Considering the diversity of survey respondents, a two-stage gradual stated preference survey method is provided. Based on a large-scale stated preference survey for tourists in an airport, a train station and highway service stations in Shanghai, three versions of multinomial logit model for local and out-of-town visitors were developed. The sensitivity analysis results show that that travel time, walking time and travel cost are all effective influencing factors but differ in utility among the various groups. Local visitors are more sensitive to walking time and total expenses, out-of-town one-day-trip visitors are more concerned about total travel time and out-of-town lodging visitors are highly sensitive to walking time and total travel time. The combination policies were suggested to be taken to achieve the aim of reducing private transport less than 10%. Meanwhile, a negative influence on subway use is an issue that needs to be addressed.

Session Fr 3.1 – Routing - Exact Methods

Friday 25/06 14:00 - 15:30 Room: Rica Hall I

An exact method to solve the Multi-Trip Vehicle Routing Problem with Time Windows and Limited Duration
Authors: *Hernandez, Florent; Feillet, Dominique; Giroudeau, Rodolphe; Naud, Olivier*
The Multi-Trip Vehicle Routing Problem with Time Windows (MTVRPTW) is a variant of the classic Vehicle Routing Problem with Time Windows (VRPTW) where vehicles can be scheduled more than one trip within a workday or planning time horizon. In this study, we consider a special case of the MTVRPTW, called MTVRPTW-LD, where duration of trips (routes) are limited. This problem was addressed in 2007 and 2009 by N. Azi et al. They designed exact methods for the single-vehicle case, then for the multi-vehicle case. Based on these investigations and on previous works, we developed a new exact method, also based on column generation, allowing large improvements in terms of computing times. A main advantage of our approach lies in the efficiency of the column generation subproblem, solved with a fast pseudo-polynomial algorithm.

Hop-indexed Circuit-based formulations for the Travelling Salesman Problem
Authors: *Godinho, Maria Teresa; Gouveia, Luis; Pesneau, Pierre*
We introduce a new Hop-indexed Circuit-based formulation for the TSP in which we consider the non necessarily simple circuit associated to each node as a subproblem. We discuss model enhancements based on some proprieties that relate the circuits associated to different nodes and contextualize the linear programming relaxation of the new enhanced model with the linear programming relaxation of some of the strongest formulations know from the literature. We will show that among known compact formulations from the literature, the proposed formulation is the one with the tightest linear programming bound. Finally, we will show that the proposed formulation is quite interesting for the related and so-called cumulative travelling salesman problem. Computational results taken from instances with up to 40 nodes show that the proposed formulation provides linear programming gaps that are within 1% per cent of the optimum. This is a huge improvement to previously know formulations.

VRP Solved by Bounding and Enumeration of Partial Paths
Authors: *Petersen, Bjørn; Jepsen, Mads Kehlet*
A column generation based algorithm for the Capacitated Vehicle Routing Problem (CVRP) and the Vehicle Routing Problem with Time Windows (VRPTW) is presented. The algorithm is inspired by the enumeration strategy of Baldacci et. al, where columns with potentially negative reduced cost is enumerated after good upper and lower bounds are found. The enumeration have memory issues which are handled with a reduction of the solution space by relaxing the columns from elementary routes to partial paths.

Session Fr 3.2 – Maritime Transportation

Friday 25/06 14:00 - 15:30 Room: Rica Hall II

Nested Column Generation for a Ship Routing and Scheduling Problem with Split Pickup and Split Delivery

Authors: *Hennig, Frank; Nygreen, Bjørn; Lübbecke, Marco*

Our split pickup split delivery routing and scheduling problem is a hard optimization problem to solve. However, it exploits a large amount of freedom to save transportation cost. In this paper we explore the capabilities of a nested column generation approach for this problem. We decompose the problem of transporting multiple products from production ports to consumption ports by a heterogeneous fleet of ships in a level 1 master problem, and, for each ship, a level 2 master problem with route generation subproblem. The first level ensures meeting all pickup and delivery requirements. The second level takes care of all cargo related constraints to be enforced on feasible ship routes. Routes are supplied by the route generation subproblem. We implement the algorithm in SCIP and solve realistic test instances using SCIP with Cplex. Results show that feasible schedules can be generated for realistic test instances. Schedules can be improved compared to previous studies. However, there is little hope to find proven optimal results in reasonable time.

Routing and Scheduling of Roll-on/Roll-off Ships with Simultaneous Cargo Selection and Stowage Decisions

Authors: *Hvattum, Lars Magnus; Øvstebø, Bernt Olav; Fagerholt, Kjetil*

Roll-on/Roll-off (RoRo) ships transport cargo on wheels such as cars, trucks, farming equipment, and military equipment. Almost all intercontinental and regional trade of vehicles is made with RoRo ships, transporting tens of millions of vehicles every year. We consider problems on an operational level of planning. A ship becomes available in a region at a given point in time and must complete its voyage in another region at a given point in time. During this interval it can pick up cargoes from the first region, sail to the second region, and deliver the cargoes. Some cargoes are mandatory to carry, while others are optional. The quantity carried from each cargo may be flexible. In addition to the routing and scheduling of the ship, decisions must be made regarding stowage: a given ship route may be infeasible due to ship capacity or stability. The problem is modeled as a mixed integer program and solved using Xpress MP and a tailor made heuristic procedure.

A Branch-and-Price-and-Cut Method for Tramp Ship Routing and Scheduling

Authors: *Stålhane, Magnus; Andersson, Henrik; Christiansen, Marielle; Cordeau, Jean-Francois; Desaulniers, Guy*

We present a branch-and-price-and-cut method for solving a tramp ship routing and scheduling problem. The problem is a maritime version of a pickup and delivery problem with time windows and capacity constraints. The fleet of ships is heterogeneous, and each ship has a different initial position. The cargoes comprise of both optional and mandatory cargoes, each with a given size and corresponding profit. The objective is to create a portfolio of cargoes that maximizes the shipping company's profit. We present three possible maritime extensions to this problem - split loads, coupled cargoes, and an option of chartering in ships. The problem is decomposed into a master problem, and one subproblem for each ship. The subproblems are solved as shortest path problems with resource constraints, using dynamic programming. The master problem is solved as a set packing problem using the simplex algorithm. Cuts are added to the master problem in order to strengthen the formulation. For each of the three extensions mentioned above we present the modifications needed in the solution method. Computational results based on test cases from the tramp shipping industry will be presented. The effect of different branching-rules, node selection policies, and cuts will also be tested and compared.

Session Fr 3.3 – City Logistics

Friday 25/06 14:00 - 15:30 Room: Rica Panorama

Optimization of multi-modal transportation chains in city logistics

Authors: *Huart, Alexandre; Brotcorne, Luce; Semet, Frédéric*

The growing congestion of road infrastructure, particularly in urban areas, is alarming and requires solutions to increase the logistics productivity. Based on this observation and to improve profitability, service companies managing a fixed capacity aim to increase their occupancy rates. To achieve this goal, we propose a pooling strategy among all actors in the logistics chain.

New Fast Heuristics for the Two-Echelon Vehicle Routing Problem

Authors: *Crainic, Teodor Gabriel; Mancini, Simona; Perboli, Guido; Tadei, Roberto*

In this paper we study the single depot Two-Echelon Vehicle Routing Problem (2E-VRP), the variant of Multi-Echelon VRP made up of two levels of routing activities. At the first level, goods are delivered by a first-level fleet, from the depot to a set of intermediate depots, named satellites, where they are consolidated into second-level vehicles for delivery to customers. These two routing problems are strongly interdependent and are connected by the customer-satellite assignment problem. Service at each level is provided by an homogeneous fleet. We consider constraints on the maximum number of available vehicles for both levels, and on the satellites capacity, which is expressed as number of vehicles starting from a satellite. Satellites capacity may vary among the satellite. The goal is to serve customers minimizing the total transportation cost of the two-echelon system, without violating the capacity constraints of the vehicles. We consider a single depot and a fixed number of capacitated satellites. All customer demands, fixed and known in advance, must be satisfied. We present two fast and accurate heuristics based on separating the depot-to-satellite transfer and the satellite-to customer delivery by solving iteratively the two resulting routing subproblems, while adjusting the satellite workloads linking them. The first one is a clustering based heuristics, the second one is based on a path-relinking procedure. Computational results on a wide set of instances up to 50 customers and 5 satellites and their comparison with with results from literature show how our methods outperform the existing methods, both in efficiency and effectiveness.

Efficient and reliable vehicle routing in urban areas

Authors: *Ehmke, Jan Fabian; Mattfeld, Dirk Christian*

Efficient and reliable vehicle routing in urban areas is based on empirical traffic data that can be utilized in time-dependent problem formulations. In this paper, we consider telematics based data collection, data processing and data utilization in order to provide information models as input for time-dependent vehicle routing in city logistics. Therefore, the key issues of traffic data collection are reported and the transformation from raw traffic data into efficient time-dependent information models is described in detail. The information models are utilized in time-dependent routing approaches, considering the FIFO condition. The applicability and the benefit of the information models are demonstrated by computational experiments concerning a case study for Stuttgart, Germany. In particular, we solve the corresponding time-dependent travelling salesman problem by several heuristics. Results are compared regarding computational efforts for data provision, route calculation and precision in travel time estimation.

Session Fr 3.4 – Humanitarian Logistics

Friday 25/06 14:00 - 15:30 Room: Nord-Norge salen

Risk Approaches for Delivering Disaster Relief Supplies
Authors: *Nolz, Pamela; Doerner, Karl F; Semet, Frédéric*
In this paper we focus on the aspect of risk on delivery tours for disaster relief supplies. The contribution of this investigation is threefold. First of all, we develop and apply five approaches in order to evaluate the risk of delivery tours for disaster relief supplies to become impassable, regarding correlated as well as uncorrelated measures. The different risk approaches are included in a multi-objective Covering Tour Problem (CTP) as a third objective function in addition to a combination of the minisum facility location criterion and the maximal covering location criterion on the one hand and the minimization of travel time on the other. Secondly, an extension of a Memetic Algorithm (MA) is developed. While a straightforward adaptation of the MA is applied to three of the five risk measures, the algorithm is extended by an enrichment phase for the remaining two risk approaches. At last, it is shown that the potentially Pareto-optimal front can be enriched by the developed solution method.

Managing Debris Collection and Disposal Operations
Authors: *Carbajal, Antonio; Stilp, Kael; Villarreal, Monica; Ergun, Ozlem; Keskinocak, Pinar*
Debris is the waste generated by a hazardous event such as a natural disaster or a terrorist attack. The amount of debris generated by some large-scale disasters is equivalent in volume to years of normal solid waste production in the affected areas. Debris removal after a disaster is costly and it is often a long and complicated process requiring the careful consideration of both short term and long term effects on people's health and safety, and the environment. Although there exists a set of federal and local guidelines for what should be done in debris clearance operations, systematic methods and analytical studies are lacking on how these operations must be conducted. Debris operations are categorized into three phases: Debris Clearance, Debris Collection and Debris Disposal. In this research, we develop mathematical models that capture the important characteristics of the debris related operations in each stage along with methodologies for solving these mathematical models efficiently. Our ultimate goal is the development of an integrated model that considers the interactions between the decision problems in all three phases simultaneously.

Optimization Method for Evacuation Instructions - Influence of the Parameter Settings
Authors: *Huibregtse, Olga L; Hoogendoorn, Serge P; Hegyi, Andreas; Bliemer, Michiel C J*
In this paper, the influence of the parameter settings of an optimization method for evacuation instructions on the effectiveness of the optimized instructions and the speed of convergence is analyzed. In the evacuation problem, both the effectiveness and the speed of convergence are important. When instructions are created beforehand, the effectiveness of the instructions is the most important criterion, but when there is a time limit, a balance between the effectiveness and the speed of convergence has to be found because of the computational time of the optimization method. The first results show this influence, which is different for different levels (related to the number of possible solutions) of the evacuation problem. In the complete paper, the influence of all parameters is analyzed to discover for which parameters the values have to be carefully chosen and to propose suitable parameter settings when applying the method in new case studies.

Session Fr 4.2 – Stochastic Routing

Friday 25/06 16:00 - 17:00 Room: Rica Hall II

An Enhanced Exact Algorithm for the Multi-Vehicle Routing Problem with Stochastic Demands
Authors: *Rei, Walter; Gendreau, Michel*
We describe an enhanced branch and cut algorithm that is based on the principles of the well known 0-1 integer L-Shaped procedure to solve the general variant of the Vehicle Routing Problem with Stochastic Demands. A new separation algorithm to find partial route cuts, as well as new cuts derived from the application of the Local Branching heuristic will be presented. Computational results will show the effectiveness of the new algorithm.

Trajectory-Adaptive Routing in Dynamic Networks with Dependent Random Link Travel Times
Authors: *Huang, He; Gao, Song*
This paper studies the problem of finding the optimal trajectory-adaptive routing policies with minimum expected travel time (METT) in a stochastic time-dependent network. The case of complete network dependency is studied, where all link travel times at all times are jointly distributed random variables. In order to circumvent the curse of dimensionality in state space, a recursive definition of trajectory-adaptive routing policy without the trajectory information in the state variable is given. Based on that definition, Bellman's principle of optimality won't hold, i.e., a sub-policy of an optimal trajectory-adaptive routing policy is not necessarily optimal. Non-dominated routing policy and pure routing policy are further defined, and it is shown that, for any origin node and departure time, there must exist an optimal routing policy which is pure. An exact algorithm is designed based on the concept of decreasing order of time (DOT) to find the pure trajectory-adaptive routing policies with METT.

Session Fr 4.3 – City Logistics

Friday 25/06 16:00 - 17:00 Room: Rica Panorama

Uncertainty in Planning City Logistics Operations

Authors: *Ricciardi, Nicoletta; Crainic, Teodor Gabriel; Errico, Fausto; Rei, Walter*

City Logistics systems aim to reduce the impact of freight transportation on the city traffic, environment, and living conditions. A major instrument in achieving this goal is the consolidation of loads of different shippers, consignees and carriers into the same vehicles and the coordination of the movements of these vehicles. We focus on City Logistics systems appropriate for large urban areas, where consolidation and coordination activities are performed at facilities organized into a hierarchical,two tired structure. Similarly to any complex transportation system, City Logistics systems require planning at strategic, tactic and operational levels. In the literature very little attention has been paid to uncertainty and its possible impact on the planning of City Logistics activities. Similar to most of the City Logistics literature, the authors did not address uncertainty issues, nor did they study in any detail the broader issue of defining a tactical plan for regular operations. Our goal is to start filling this gap and present processes and models to build tactical plans for two-tiered City Logistics systems that account for the uncertainty in transportation demand.

Session Fr 4.4 – Travel Time Estimation

Friday 25/06 16:00 - 17:00 Room: Nord-Norge salen

Improving the prediction of the travel time by using the real-time floating car data
Authors: *Dembczynski, Krzysztof; Gawel, Przemyslaw; Jaszkiewicz, Andrzej; Kotlowski, Wojciech; Szarecki, Adam*
In this paper we consider the problem of travel time prediction for a car navigation system. Given a static black box prediction model based on historical data, the aim of the research is to improve the performance of this model by a dynamic counterpart utilizing real-time GPS floating car data generated by the users of the car navigation system. The prediction is computed for each single segment of the road network by using the Gaussian process model or the exponential smoothing. We consider also two extensions that take into account the dependencies between different segments. In the first one, the prediction of the travel time is additionally based on data from the most correlated segments. In the second one, the travel times are smoothed over segments constituting the longer paths of the main roads. Exhaustive experiments on real data were conducted that show high accuracy of the proposed models and significant improvement over the static black-box model.

TRISTAN VII – Author index

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