VeRoLog

NANTES 2016

ANNUAL WORKSHOP

of the EURO working group on Vehicle Routing and Logistics optimization

at Mines Nantes

6-8 June 2016

verolog2016.sciencesconf.org

Conception and production: Ecole des Mines de Nantes - Communication Department

BOOK OF ABSTRACTS

Annual workshop of the EURO working group on Vehicle Routing and Logistics optimization (VeRoLog)

VeRoLog

NANTES 2016

BOOK OF ABSTRACTS

Nantes (France) – June 6-8, 2016

The fifth meeting of the EURO Working Group on Vehicle Routing and Logistics optimization (VeRoLog 2016) was held in Nantes (France) from June 6 to June 8, 2016. The VeRoLog conference is an annual meeting bringing together the large community of researchers and practitioners interested in vehicle routing optimization and its relationship with logistics. The conference is open to high quality methodological contributions, relevant real-world applications, and case studies from industry and the service sector.

The program for the 5th edition was made up of 142 presentations covering a broad range of topics related to routing (e.g., dynamic vehicle routing, routing with synchronization, technician routing) and logistics (e.g. facility location, network design, supply chain management). A landmark for this edition is the notable body of research involving environmental issues (e.g. bike and vehicle sharing, electric vehicle routing, green vehicle routing and logistics). The conference also welcomed 2 invited speakers: Stefan Røpke (Technical University of Denmark), who presented « 10 years of Adaptive Large Neighborhood Search (ALNS) », and Mike Hewitt (Loyola University Chicago) who talked about « recent advances in service network design ». As the perfect complement to the technical sessions and plenary talks, the program also included 4 special slots devoted to more industry-oriented talks: two tutorials by LocalSolver and PTV Group and two brainstorming sessions by ORTEC and and GTS Systems. In the latter, a novelty in VeRoLog conferences, the companies shared a problem with the community and brainstormed with the participants on ways to solve it.

This book contains the abstracts of the 142 talks given in the technical sessions.

Christelle, Fabien, Jorge, Olivier, and Marc

Table of contents

A multi-objective optimization for relocating electric vehicles in car-sharing services

Ornella Pisacane * [1], Maurizio Bruglieri [2], Ferdinando Pezzella [3]

[1] Facoltà di Ingegneria, Università degli Studi E-Campus (E-Campus) – Via Isimbardi, 10 - 22060 Novedrate (COMO), Italy
[2] Dipartimento di Design, Politecnico di Milano (POLIMI) – Via Durando, 38/a, 20158 Milano, Italy
[3] Dipartimento di Ingegneria dell'Informazione, Università Politecnica delle Marche (UNIVPM) – Via Brecce Bianche 12, 60131 Ancona, Italy

Nowadays, also thanks to the Information and Communication Technology, the sharing mobility represents a significant part of the sharing economy. In particular, the Car Sharing Services (CSSs), in which the user rents a car for short time, paying according to the time of use, support the sustainable mobility, reducing the number of parked vehicles and consequently, the traffic congestion, noise and air pollution. These two last advantages are more guaranteed in CSSs with Electric Vehicles (EVs). In fact, the EVs guarantee zero local CO2 emissions and are less noisy than the traditional combustion engine vehicles.
In particular, in One-way CSSs (OCSS), a user can drop off a vehicle in a parking station different from the pickup one. However, the OCSSs suffer of possible imbalances between the demand and the supply of vehicles, leading to a Vehicle RElocation Problem (VREP). We address a VREP in OCSSs with EVs in which the relocation is operator-based: the CSS operators relocate the EVs by directly driving them from a station of pickup to one of delivery and move from a station of delivery to one of pickup by folding bikes.
To balance the good quality of service assured to the users (maximizing the number of EV requests satisfied), the cost reduction and the load balancing among the operators, a multi-objective VREP is solved. Firstly, a set of feasible solutions is heuristically generated and then, through the epsilon-constraint method, a three-objective non-overlapping model is solved. Numerical results are carried out on some benchmark instances.

*Speaker

Setting Inventory Levels in a Bike Sharing Network

Sharon Datner [1], Tal Raviv * [1], Michal Tzur [1], Daniel Chemla [2,3]

[1] Department of Industrial Engineering, Tel Aviv University – Israel
[2] Université Paris Est – Université Paris Est (UPE) – France
[3] Universite Paris 13, Paris – université Paris 13 – France

A major issue that Bike Sharing Systems operators must address is the non-homogeneous asymmetric demand processes. These demand processes create an inherent imbalance, thus leading to shortages either of bicycles when users are attempting to rent them or of vacant lockers when users are attempting to return them. The predominant approach taken by operators to cope with this difficulty is to reposition bicycles to rebalance the inventory levels at the different stations. Most repositioning studies assume that a target inventory level or range of inventory level is known for each station. In this paper, we focus on determining the correct target level for repositioning according to a well-defined objective. This is a challenging task because of the intricate nature of the user behaviour in the system. For example, if bicycles are not available at the desired origin of a user's journey, the user may either abandon the system, use other means of transportation, or look for available bicycles at a neighbouring station. If in another case, a locker is not available at a user's destination, then that user is obliged to find a station with available space to return the bicycle to the system. Thus, an empty/full station can create a spill over of demand to nearby stations. In addition, stations are related by origin-destination pairing. We take this effect into consideration when setting target inventory levels and develop a robust guided local search algorithm for that purpose. We show that neglecting the interactions among stations leads to inferior decision-making.

*Speaker

On finding optimal charging station locations in an electric car sharing system

Georg Brandstätter * [1], Markus Leitner [1], Ivana Ljubic [2]

[1] University of Vienna – Vienna, Austria
[2] ESSEC Business School – ESSEC Business School – France

Recent technological advancements have made electric vehicles a more reasonable choice in many applications where conventionally powered vehicles have been used previously. One such application is urban car sharing, where customers rent cars for short periods of time to move around within a city.
However, the range of most electric cars is still fairly limited, and recharging them takes longer than refueling cars with an internal combustion engine. Therefore, a network of charging stations must be built within system's operational area, where the cars can be recharged between trips. Since building these stations is very costly, their locations must be chosen carefully to optimize the system's operational efficiency.
We present several integer linear programming formulations for solving the problem of optimally placing charging stations within the network's operational area, as well as finding their optimal size. Given a limited budget, our objective is to maximize the profit gained from the estimated customer demand that can be satisfied by the constructed stations. To improve flexibility, customers can pick up a car at any sufficiently close station, as well as return it to any station near their destination (subject to the availability of a car and free charging slot, respectively).
The empirical performance of these models is compared on a set of benchmark instances that are based on artificial as well as real-world data.

*Speaker

Solving the time-and-load dependent green vehicle routing and scheduling problem on real road networks

Ramin Raeesi *† [1], Konstantinos Zografos [1]

[1] Lancaster University Management School, Centre for Transport and Logistics (CENTRAL) – United Kingdom

The Green Vehicle Routing and Scheduling Problem (GVRSP) has drawn considerable research attention, due to its capability to address the trade-off between traditional business and environmental objectives. Most of the existing models consider the problem on a complete graph composed of the depot and the customers. However, time and load dependent problems are not always possible to be modeled over a complete graph, since the departure times and carried loads between nodes are not known in advance. This paper formulates the GVRSP as a bi-objective time-and-load-dependent optimization model and proposes an algorithm for solving it on a real road network. A network reduction technique to reduce the number of eligible paths between the network nodes, and an algorithm for departure time optimization that can be embedded into different local search-based metaheuristics are proposed. We are presenting results of computational experiments to demonstrate the efficiency of the proposed methodology.

*Speaker

†Corresponding author: r.raeesi@lancaster.ac.uk

Strategic Fleet Planning for City Logistics

Anna Franceschetti *† [1], Dorothée Honhon [2], Gilbert Laporte [1], Tom Van Woensel [3], Jan Fransoo [3]

[1] HEC Montréal – Canada
[2] Naveen Jindal School of Management, University of Texas at Dallas – United States
[3] Eindhoven University of Technology – Netherlands

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

*Speaker
†Corresponding author: anna.franceschetti@cirrelt.net

From Floating Car Data to Time-Dependent Route Scheduling: a Holistic Methodology

Franziska Heinicke * [1], Axel Simroth [1]

[1] Fraunhofer Institute for Transportation and Infrastructure Systems IVI (Fraunhofer IVI) – Germany

Punctuality is a great challenge in transportation and logistic management to comply with given time restrictions like delivery time windows. But travel times can only be roughly approximated by assuming average speed depending on the road type. In doing so, the changes in traffic volume over the day are disregarded although they have a high influence in speed and travel time.

In the past, many logistic service providers have implemented GPS receivers to collect floating car data from the transportation process. This data contains also information about traffic volume - or rather reflects their influence on driving speed. At rush hour the collected speeds will be slower than at low-traffic times (e.g. during the night).

In this talk, a methodology to proceed from floating car data to time-dependent route scheduling will be presented. This includes the analysis of floating car data to derive time-dependent speeds, called speed profiles; the clustering of road sections according speed profiles to reduce storage effort; an algorithm to calculate time-dependent travel times; and finally a route scheduling approach using time-dependent travel times. Because of the planned real-world application, computational time and storage effort is of importanance in all steps of the methodology.

*Speaker

An Integrated Location-Inventory-Routing Problem

Mehdi Amiri-Aref * [1], Walid Klibi [2,1], Zied Babai [1]

[1] Operations Management and Information Systems Department, KEDGE Business School – KEDGE BUSINESS SCHOOL – 680 cours de la Libération, 33405 Talence Cedex, Bordeaux, France, France
[2] Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT) – Canada

A location-inventory-routing optimization problem characterized by an uncertain customer demand and supply lead-time is studied in this work. It considers a supply network which consists of a set of suppliers, multiple potential distribution centers and a set of demand zones. A daily reorder point (r, Q) inventory control policy is used at the distribution centers to be opened. From these distribution centers, delivery routes must be decided to ship the demand zones in time and to avoid backorders. A scenario-based approach is used to model the demand and lead-time uncertainty. Hence, a stochastic two-stage mathematical model maximizing the total expected supply network profit is obtained, which is solved using the sample average approximation method. Based on an illustrative case, we show the impact of inventory and routing costs on the strategic location-allocation decisions. However, it is found out that solving this problem is very difficult and time consuming. Therefore, a heuristic solution approach is under development to deal with realistic-size instances.

*Speaker

A column generation approach for multi modal operational transportation planning

David Wolfinger *† [1], Fabien Tricoire [1], Karl Doerner [1]

[1] University of Vienna – Vienna, Austria

We address the problem of operational transportation planning in a multi modal context. In this problem customer requests have to be transported from a set of pickup locations to a set of delivery locations, whereby the pickup and delivery locations are paired. Along their trip, customer requests can either be transported completely by truck, or use the truck just for the first- and last-mile and use another (or several other) mode of transportation for the long haul. We consider rail and water transport for the long haul, and thus the transshipments can take place either at a port or a train station. Furthermore, we consider time windows at the pickup and delivery locations, and allow for split loads. The fleet of long haul vehicles (i.e. ships and trains) is fixed for the planning horizon, whereas an unlimited supply of trucks is assumed. The objective is to minimize the sum of transportation cost (fixed and variable cost of all vehicles) and transshipment cost. We solve this problem with a column generation approach, where the pricing problem is solved in a heuristic fashion.

*Speaker

†Corresponding author: david.wolfinger@univie.ac.at

A Multi-Resource Routing Problem: Container Delivery in Urban Area

Ulrike Ritzinger * [1], Bin Hu [1], Aleksandar Sibincic [2]

[1] AIT Austrian Institute of Technology – Austria
[2] Technical University of Vienna (TU WIEN) – Austria

A real-world container drayage problem, were containers are transported between an intermodal terminal, a container terminal and customer locations is considered. We model the problem as a Multi-Resource Routing Problem (MRRP) including trucks, drivers, trailers and containers. Given a fleet of trucks and drivers, and a fleet of trailers, the goal is to utilize these resources most efficiently to complete a number of given orders. Orders consist of several tasks with time windows, such as picking up a container at the terminal, delivering it to a customer, and bringing the processed container back.
A novel aspect of this problem, usually neglected in the literature, is the management of trailers, which are required to transport the containers. Here, the compatibility between container types and trailer types must be considered. Thus, the decision which trailer should be attached to which truck depends on the containers which must be transported on the day, the availability of trailers, and the toll costs of the truck and trail combination on the highways.
To model the problem formally, we present a Mixed Integer Program using a multi-commodity flow formulation on a constructed graph. Resources and tasks are represented by nodes and the daily plan of each truck is a path. We also propose a metaheuristic approach based on variable neighborhood search which also utilizes the same graph in order to reduce the search space. Classic neighborhood structures, as well as, problem specific ones are used in combination and contribute to the overall success.

*Speaker

Mixed integer formulations for the Green Location Routing Problem

David Cortés-Murcia *† [1], William J. Guerrero‡ [1], Jairo R. Montoya-Torres [2]

[1] Escuela Colombiana de Ingeniería Julio Garavito – AK.45 No.205-59, Bogotá., Colombia
[2] Universidad de La Sabana – Campus del Puente del Común, Km. 7, Autopista Norte de Bogotá. Chía, Cundinamarca., Colombia

In this paper, the design of a two-echelon supply chain is studied combining location and routing decisions taking into account the CO2 emissions generated by the transportation decisions and the number of depots to open. The model aims to minimize the CO2 emissions, which are correlated to the energy consumed by vehicles, assuming it depends on the distance traveled and the load carried by the vehicle on each arc. The following constraints are considered: a single vehicle and a single depot must serve each costumer; each route must begin and end at the same depot; and demand must be fully satisfied without exceeding depot and vehicle capacities. We propose two mathematical formulations based on mixed-integer programming. The first model is inspired by the traditional formulation of the Location-Routing Problem, often presented in the literature, and it was adapted for the new objective function. The second model modifies the definition of the routing variables excluding the index associated to vehicles, and replacing it by an index for depots. A computational study is performed using adapted benchmark instances. Preliminary results show significant differences in the performance of the mathematical models when solving the problem to optimality. On average, the proposed model solved the instances 96.72 % faster than the adapted traditional formulation. Further, an analysis of the impacts of using the proposed objective function is presented. On average, the new objective function may reduce up to 35% the amount of CO2 emissions compared to the solutions considering a cost minimization objective function.

*Speaker
†Corresponding author: david.cortes@escuelaing.edu.co
‡Corresponding author: william.guerrero@escuelaing.edu.co

Large Neighborhood Search for the Clustered Vehicle Routing Problem

Timo Hintsch * [1], Stefan Irnich [1]

[1] Johannes Gutenberg Universität Mainz – Germany

This presentation considers the Clustered Vehicle Routing Problem (CluVRP) which is a variant of the classical Capacitated Vehicle Routing Problem. Customers are partitioned into clusters and it is assumed that each cluster must have been served in total before the next cluster can be served. This decomposes the problem into three subproblems, the assignment of clusters to tours, the routing inside a cluster, and the routing of the clusters in the tour. The second task requires the solution of several Hamiltonion path problems, one for each possibility to start and end the route through the cluster. These Hamiltonion paths are pre-computed for every pair of customers inside each cluster. The chosen start-end-pair of the clusters also affects the routing of clusters. We present a Large Neighborhood Search which makes use of the Balas-Simonetti neighborhood. Computional results are compared to existing exact and heuristic approaches from the literature. In addition a second variant, the CluVRP with soft constraints, is considered. Customers of same clusters must still be part of same routes, but do not need to be served contiguously any more. Adaptions of our approach are discussed.

*Speaker

Heuristic Solutions for a Bicriteria Evacuation Scheduling and Transportation Problem

Kaouthar Deghdak *† [1], Vincent T'kindt * [1]

[1] Univeristé de Tours, Laboratoire d'Informatique (EA 6300), ERL CNRS OC 6305 – Polytech'Tours – 64 avenue Jean Portalis, 37200 Tours, France

We consider the problem of evacuating an urban area to a set of shelter locations after an important disaster. In such a case, many sub-problems arise: when should people be evacuated? What are the best shelters' locations to accommodate evacuees? When and where to transport the evacuees? We consider a multicriteria problem where the bus routing for public transport, the routing for individual traffic, as well as shelter location decisions, have to be decided. The objective is to minimize both the evacuation time and the evacuation risk. This problem was introduced Goerigk, Deghdak and Hessler in 2014 and has been solved by using a multicriteria genetic algorithm. In this contribution, we propose an heuristic based on a decomposition of the evacuation problem into sub-problems. Exact or heuristic algorithms are set up to solve these sub-problems.
The genetic algorithm and the decomposition heuristic have been evaluated on real-world instances modeling Nice city (France) and Kaiserslautern city (Germany). Computational results show that the decomposition heuristic is capable of finding non-dominated solutions that are not calculated by the genetic algorithm. During the conference, we will present detailed comparisons between the two methods in terms of running times and solutions' quality for several instances of Nice city and Kaiserslautern city. Besides, we will present how we can couple the two methods to obtain improved results.

*Speaker
†Corresponding author: deghdak.kaouthar@gmail.com

Minimizing the logistic ratio in the inventory routing problem

Claudia Archetti *† [1], Guy Desaulniers [2], M. Grazia Speranza [1]

[1] Department of Economics and Management, University of Brescia – Italy
[2] Ecole Polytechnique de Montréal and GERAD – Canada

The inventory routing problem combines two well-known problems, namely, vehicle routing and inventory management. We consider a single product and a single depot where the vehicles start and end their routes. The depot is located at the product supplier for which the quantity to be produced in each period of a planning horizon is known. The product is consumed by a set of customers and the quantity consumed in each period is known for each customer. Each customer has an inventory capacity that must be respected. At the supplier and at each customer, there might be an initial inventory. The inventory routing problem consists of determining in which period(s) each customer must be visited, the quantity delivered at each visit, and the delivery routes to perform in each period. Typically, the objective of the IRP consists of minimizing the sum of the routing costs and the holding costs. However, with this objective, there is no incentive to leave inventory at the customers where the unit holding cost is higher than at the supplier. In this paper, we consider a different objective that is also used in practice, namely, to minimize the so-called logistics ratio which is given by the total routing costs divided by the total delivered quantity. In this case, no holding costs are considered. The resulting problem is denoted inventory-routing problem with logistics ratio. We propose an exact algorithm to solve the problem and show computational results which provide some insights in the problem characteristics.

*Speaker
†Corresponding author: claudia.archetti@unibs.it

A Column Generation Framework for Industrial Gas Inventory Routing

Rodrigue Fokouop *† [1], Jean André [1], Emiliano Traversi [2], Roberto Wolfler Calvo [2], Lucas Létocart [3], Roberto Baldacci [4]

[1] Applied Mathematics - Operational Research & data sciences team , Paris Saclay Research Center - Air Liquide R&D – L'AIR LIQUIDE – France
[2] LIPN - Université Paris Nord – université Paris 13 – France
[3] LIPN UMR CNRS 7030, Institut Galilée - Université Paris 13 – université Paris 13 – France
[4] DEI, University of Bologna – Italy

In this work we propose a column generation approach for solving the Inventory Routing Problem with Replenishment Facilities (IRPRF). The IRP concerns the distribution of industrial gases from a set of production plants to a set of customers under Vendor Managed Inventory (VMI) distribution policy. Industrial gases are stored at the production plants. The supplier knows the future demand such that no product run-out is allowed.
We consider a multi-period IRP problem with a discrete short-term planning horizon. The considered IRP is a multi-product problem with a heterogeneous fleet of capacitated vehicles, and time windows for customers and production plants. The problem also includes a rich set of business constraints.

Two versions of the IRP problem are considered in this work. The first version minimizes the total distribution cost. The second version minimizes the logistic ratio (the ratio between the total distribution cost and the total delivered quantity). To the best of our knowledge, very few papers deal with the non-linear (rational) objective function.
We propose a unified column generation approach that can solve both versions of the problem. To deal with non linear objective function, we introduce a suitable variables substitution, which leads to a linear formulation that can be used for computing valid lower bound for the problem. The paper provides computational results concerning heuristics and valid dual bounds for the problem, based on real on the field instances.

*Speaker
†Corresponding author: rodrigue.fokouop-w@airliquide.com

A Hybrid Local Search Algorithm for Production Routing Problem

Mustafa Avci * [1], Seyda Topaloglu [1]

[1] Dokuz Eylül University – Turkey

In many supply chain systems, the decision problems of production, inventory, distribution and routing operations are generally optimized independently. In this usual approach, the decisions taken for a particular operation are used as input data for its successor operations. On the other hand, the integration of these decision problems has attracted research interest due to the benefits provided by the coordination of these operations. The production routing problem (PRP) is an integrated operational planning problem that combines the two well-known optimization problems, vehicle routing problem (VRP) and lot sizing problem (LSP). The aim of solving the PRP is to optimize the production, inventory, distribution and routing decisions simultaneously. In this study, a hybrid local search algorithm which integrates an adaptive threshold accepting function with a short-term tabu list is proposed. The algorithm is applied to a set of randomly generated problem instances. The performance of the developed algorithm is evaluated according to the computational results.

*Speaker

A Mathematical Programming Framework that Integrates Customer Decisions within the Distribution Planning of Petroleum Products

Yan Hsu [1], José Walteros * [1], Rajan Batta [1]

[1] University at Buffalo – 342 Bell Hall, Buffalo, New York 14260-1660, United States

This paper develops a methodological framework for designing the daily distribution and replenishment operations of petroleum products by simultaneously considering the perspectives of both the transporter and its customers. Over the last few decades a wide variety of distribution problems have been studied in the form of vehicle routing problems. Nevertheless, many of those approaches assume that the customers' decisions are completely decoupled from those of the transporter. i.e., the order quantities and expected delivery time windows are given to the transporter as hard constraints. Most models assume that there are always feasible routes that satisfy such requirements. In contrast, in competitive markets like the one of petroleum products—in which the transportation decisions must also meet strict regulatory policies—finding feasible solutions that cope with all customer and governmental requisites is often impossible. We provide empirical evidence that minor alterations to the customer requirements, triggered by some strategic decisions by the transporter, can in turn flexibilize the transporters' restrictions, allowing for better routing strategies that reduce late deliveries. In this context, the transporter has no direct control over the customers' inventory planning. Therefore, if the transporter wants the customers to select more favorable requirements (e.g., wider delivery time windows), the transporter must provide incentives to the customers for selecting more lenient alternatives (e.g., discounts for wider time windows) or impose some mild restrictions (e.g., blocking a few time windows). The main objective of this project is studying the interactions that exist between these strategic and operational decisions within a unified approach.

*Speaker

Lower bound on the logistic ratio objective function for bulk distribution inventory-routing problem

Tamara Jovanovic *† [2,1], Michel Vasquez‡ [1], Rodolphe Giroudeau§ [2]

[2] Laboratoire d'Informatique de Robotique et de Microélectronique de Montpellier (LIRMM) – Université Montpellier II - Sciences et techniques, CNRS : UMR5506 – CC 477, 161 rue Ada, 34095 Montpellier Cedex 5, France

[1] Laboratoire de Génie Informatique et d'Ingénierie de Production (LGI2P) – Ecole Nationale Supérieure des Mines d'Alès – École des Mines d'Alès - Site EERIE Parc Scientifique Georges Besse - 30035 Nîmes Cedex 1, France

Bulk distribution inventory-routing problem (IRP) typically occurs in the gas industry. In this paper we tackle the one-to-many problem structure, where both customers and vehicules can have different capacities. Such problem is proposed by Air Liquide within ROADEF/EURO 2016 challenge. The objective function to be minimized is represented as so-called logistic ratio, which is the ratio between the total transportation cost and the total delivered amount of a concerned product. Time dimension of this problem is the main factor rising the complexity. All the routing and delivery decisions have to be made in terms of minutes, and the whole horizon can be given in terms of months. For this reason, it is very important to have some knowledge on the objective function behaviour. The logistic ratio, as an objective function of IRP, is not well studied in the literature. We define an LP and an iterative method that gives us a sequence of lower bounds to the optimal solution of our problem. The tightness of these lower bounds does not necessary depend on the total number of customers to be served, but on the number of small capacitated customers.

*Speaker

†Corresponding author: tamara.jovanovic@mines-ales.fr

‡Corresponding author: michel.vasquez@mines-ales.fr

§Corresponding author: Rodolphe.Giroudeau@lirmm.fr

In-port routing and scheduling with stochastic travel times in chemical shipping

Eline Skogen [1], Aurora Elgesem [1], Xin Wang *† [1], Kjetil Fagerholt [1,2]

[1] Norwegian University of Science and Technology (NTNU) – Norway
[2] The Norwegian Marine Technology Research Institute (MARINTEK) – Norway

In chemical shipping, the tankers can spend up to 40% of their voyage duration in ports. Apart from the time needed for ordinary port-call operations, such as loading/unloading cargoes, tank washing and inspection, much time spent in ports is wasted queuing for service at terminals. Proper in-port routing and scheduling therefore become of great importance, as reducing the time spent in ports can directly increase the profitability of the tankers and bring improvements to the total performance of the shipping company. This research considers a tanker arriving at a particular port with commitments of both picking up and delivering various cargoes at their corresponding terminals within the port, and aims to find an optimized plan with shortest time spent in port that comprises sequencing decision for visiting terminals and the corresponding departure plan. We also take into account stochastic travel times between the terminals within the port. The primary source of such uncertainties is waiting for the terminals to be ready to receive the tanker. Two stochastic models are proposed for the in-port routing problem, both addressing the stochasticity in travel times, but with different objectives representing different optimization focuses of the shipping company. The models are tested on real data collected from a chemical shipping company based in Norway. The computational results show that the solutions produced by the two models provide valuable decision supports in the company's port call operations.

*Speaker
†Corresponding author: xin.wang@iot.ntnu.no

A simple LNS-based heuristic for Two-Echelon Routing Problems

Ulrich Breunig *† [1], Verena Schmid [2], Richard Hartl [3], Thibaut Vidal [4]

[1] University of Vienna – Oskar-Morgenstern-Platz 1, 1090 Vienna, Austria
[2] Christian Doppler Laboratory for Effcient Intermodal Transport Operations, University of Vienna – Austria
[3] University of Vienna – Austria
[4] Pontifical Catholic University of Rio de Janeiro (PUC Rio) – Brazil

We address optimisation problems arising in the context of city logistics. The focus lies on two-level transportation systems with a single depot: both the Two-Echelon Vehicle Routing Problem (2E-VRP) and the Two-Echelon Location Routing Problem (2ELRP) seek to produce vehicle itineraries to deliver goods to customers with mandatory transit through intermediate facilities. In the 2EVRP the locations of intermediate facilities – called satellites – are given and their use is not associated with additional cost. The 2ELRP problem class explicitly takes strategical decisions into account: the use of vehicles and satellites incurs additional fixed costs. The first echelon with large trucks operating between depot and satellites can be seen as a VRP with split deliveries. The second echelon corresponds to a multi-depot VRP: smaller vehicles operate between several satellites and the customers. A local-search metaheuristic, based on the principle of destroy and repair from Large Neighbourhood Search, is developed and implemented to find high quality solutions within limited computing time. The proposed algorithm is tested with several different benchmark instances for two-tiered problem classes with a single depot.

*Speaker
†Corresponding author: ulrich.breunig@univie.ac.at

Designing and optimizing an LNG supply chain using LocalSolver

Thierry Benoist *† [1], Frédéric Gardi‡ [1], Romain Megel§ [1], Clément Pajean¶ [1], Michel Ben Belgacem‖ [2], Delphine Leblanc** [2], Frédéric Legrand†† [2], Sławomir Pietrasz‡‡ [2]

[1] Innovation 24 & LocalSolver – Bouygues – 24 avenue Hoche 75008 Paris, France
[2] ENGIE CRIGEN – ENGIE – France

This talk deals with the optimization of the sizing and configuration of a Liquefied Natural Gas (LNG) supply chain. This problem is encountered at ENGIE, a French multinational electric utility company which operates in the fields of electricity generation and distribution, natural gas and renewable energy.
Some clients need to be supplied in LNG from sources. The consumption at each client is known for each time step. Different kind of transportation resources, vessels or trucks, are available to supply LNG from sources to clients, possibly using intermediate hubs. Each is characterized by its storage capacity and its costs, and the list of sites that it can visit. A tour is a distribution travel starting from a source with full capacity and visiting a certain number of site, unloading a fraction of the capacity at each site, and finally getting back the starting source. A planning is a set of tours over the horizon. The cost of the planning is composed of fixed costs and operating costs. The objective is to minimize this cost over a long-term horizon, typically 20 years.
Having described the problem and its stakes, we show how to model and solve it efficiently using LocalSolver set-based modeling features. The resulting software is now used by ENGIE.

*Speaker
†Corresponding author: tbenoist@localsolver.com
‡Corresponding author: fgardi@localsolver.com
§Corresponding author: rmegel@localsolver.com
¶Corresponding author: cpajean@localsolver.com
‖Corresponding author: michel.benbelgacem@engie.com
**Corresponding author: delphine.leblanc@engie.com
††Corresponding author: frederic.legrand@engie.com
‡‡Corresponding author: slawomir.pietrasz@engie.com

The Timetable Planning Problem for the High Speed Trains of the Chinese Railways

Valentina Cacchiani [1], Feng Jiang [2], Paolo Toth *† [3]

[1] DEI, University of Bologna – Bologna, Italy
[2] School of Transportation and Logistics, Southwest Jiaotong University – Chengdu, China
[3] DEI, University of Bologna – Italy

We study the Train Timetabling Problem (TTP) of the high-speed trains at the Chinese railways. In particular, we focus on the Beijing-Shanghai line, that is a double-track line with 29 stations along which more than 300 trains run every day between 06:00 and midnight. TTP calls for determining, in the planning phase, an optimal schedule for a given set of trains, while satisfying track capacity occupation constraints.
In this work, we are given on input a set of feasible timetables for the trains already planned along the line, and the main goal consists of scheduling as many additional trains as possible: for each additional train, we are given its departure time, its traveling time between each pair of stations and its set of compulsory stops with the corresponding minimum stopping times. In order to schedule the additional trains, we are allowed to change their departure times and to increase their stopping times. Moreover, we investigate the possibility of modifying the timetables of the already planned trains, even by changing their stopping patterns, i.e. we allow to add or remove some stops.

Beside the main goal, a second objective is to obtain a regular schedule, i.e. a schedule showing regularity in the train frequency and in the train stopping patterns.
To solve this problem we propose a heuristic algorithm and test it on real-world instances of the Chinese Railways.

*Speaker
†Corresponding author: paolo.toth@unibo.it

A Dynamic Programming Approach for Optimizing Train Speed Profiles

Jørgen Haahr *† [1], David Pisinger [1], Mohammad Sabbaghian [2]

[1] Danmarks Tekniske Universitet (DTU) – Denmark
[2] Cubri ApS – Netherlands

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

*Speaker
†Corresponding author: jorgenhaahr@gmail.com

A rich vehicle routing problem in express freight transportation

Luigi De Giovanni *† [1], Nicola Gastaldon [2], Filippo Sottovia [2]

[1] Dipartimento di Matematica - Università di Padova (DM-UniPD) – via Trieste 63 35121 Padova, Italy
[2] Trans-cel – Via L. da Zara, 33 35020 Albignasego - PD, Italy

We consider the rich VRP arising at Trans-Cel, an Italian freight transportation company owning a fleet of 15 trucks with different capacities, loading facilities and operational costs. The company receives short- and medium-haul transportation demands consisting of a pick-up and a delivery with soft or hard time windows falling in the same day or in two consecutive days. Routes are planned on a daily basis taking into account constraints on maximum duration, number of consecutive driving hours and compulsory drivers' rest periods. Routes may not terminate at the depot, the termination point determining the next-day starting point. Several additional issues are considered among which: soft and hard constraints on route termination points, transshipment at the depot, fast route re-optimization triggered by additional real-time demands or vehicle faults, preferences on demands to be satisfied by a same vehicle. The objective is to maximize the profit defined as the difference between the revenue associated to satisfied demands and the operational costs, mainly depending on vehicles' type and on route length. In order to provide the core of a decision support tool to be used at the planning and operational stages, we propose a heuristic algorithm. Initial routes are determined by an enhanced least-cost insertion heuristic. The solution is then improved by a granular tabu search with intensification and diversification phases, and neighborhood based on selected insertion, swap and 2-opt moves. Results validated on the field attest for an estimated 9% profit improvement with respect to the current policy based on human expertise.

*Speaker
†Corresponding author: luigi@math.unipd.it

The Waste Collection Vehicle Routing Problem with Time Windows and uncertain demands : Model and solution approaches

Quentin Tonneau *† [1], Nathalie Bostel [2], Pierre Dejax [1], Thomas Yeung [1]

[1] Institut de Recherche en Communications et en Cybernétique de Nantes (IRCCyN) – École Nationale Supérieure des Mines - Nantes – 1, rue de la Noë BP92101 44321 Nantes Cedex 03, France
[2] Université de Nantes- IRCCyN – Université de Nantes – 58 rue Michel Ange, BP 420 44606 Saint-Nazaire cedex, France

With more than ten billion kilograms of waste produced every day in the world, waste logistics management has become a major cost reduction and optimization challenge. We address a vehicle routing problem to collect waste (e.g., glass, paper, plastic, etc.) from recycling bins in public spaces or from industrial companies. This problem considers a single depot for the vehicles and a set of intermediate facilities (i.e., disposal sites) where trucks can dump their content in order to continue their collection tour. Each bin must be fully emptied when visited and trucks must also to visit a disposal site before returning to the depot in order to arrive empty. Each node (i.e., depot, facility and bin) is characterized by its own service time and accessibility hours.
This problem is known as the Waste Collection Vehicle Routing Problem with Time Windows (WCVRP-TW). We propose a mathematical model and solution methods in order to solve the deterministic version of this problem. A stochastic approach where quantities of waste brought to containers are uncertain is also proposed to improve the solution robustness in real applications. We compare our approach with existing deterministic benchmarks and test realistic scenarios of alternative demand to measure the solutions' flexibility and robustness. In particular, we apply this approach on real data provided by a French waste transport and logistics company.

*Speaker
†Corresponding author: qtonneau@gmail.com

Fleet size and mix split-delivery vehicle routing: a study of MIP formulations

Arthur Maheo * [1,2], Tommaso Urli† [1,2], Philip Kilby [1,2]

[1] National ICT Australia (NICTA) – Australian Technology Park ; Level 5, 13 Garden Street ; Eveleigh NSW 2015 // Tower A ; 7 London Circuit ; Canberra City ACT 2601 // Lvl 2 / Bldg 193 (Dept. of Electrical and Electronic Engineering) ; The University of Melbourne VIC 3010 // Level 4, 223 Anzac Parade ; Kensington NSW 2052 // Level 5, Axon Building (47) ; Staff House Road ; St Lucia Qld 4072 // Innovation House ; First Avenue ; Mawson Lakes SA 5095, Australia
[2] Australian National University (ANU) – The Australian National University Canberra ACT 0200 Australia, Australia

In this paper we benchmark various Mixed Integer Programming (MIP) models for a real-world daily delivery problem arising in Queensland, Australia. Our client is faced with the task of satisfying the demand of ambient and refrigerated goods to be delivered at often remote grocery stores. This study has been carried out in the context of a tender for the delivery of goods called by a large grocery stores chain. Since winning the tender would require restructuring the available fleet, our client is also interested in streamlining the design of an efficient fleet, able to carry out the deliveries over the long term.
From a classification standpoint, this represents a "rich" Vehicle Routing Problem (RVRP). In this particular variant, the vehicles have different operation costs and capacities, but only some of them are refrigerated. Moreover, some of the demands are larger than a truckload, therefore requiring split deliveries. Finally, because we are also interested in designing an efficient fleet to support the demand, we allow the solver to choose the most suitable set of vehicles.

This problem has been addressed in [Kilby and Urli, 2015] using a Constraint Programming (CP) approach. The results are compared to an admittedly simple MIP model, but suggest that a MIP-based decomposition scheme could obtain better scalability results.
This work is a preparatory step aimed at identifying the best among various different MIP models for the daily problem. The best performing model will then be used within a decomposition scheme to address the complete multi-day variant.

*Speaker
†Corresponding author: tommaso.urli@nicta.com.au

A general and scalable fleet design approach for rich vehicle routing problems

Francesco Bertoli * [1,2], Philip Kilby [1,2], Tommaso Urli† [1,2]

[1] National ICT Australia (NICTA) – Australian Technology Park ; Level 5, 13 Garden Street ; Eveleigh NSW 2015 // Tower A ; 7 London Circuit ; Canberra City ACT 2601 // Lvl 2 / Bldg 193 (Dept. of Electrical and Electronic Engineering) ; The University of Melbourne VIC 3010 // Level 4, 223 Anzac Parade ; Kensington NSW 2052 // Level 5, Axon Building (47) ; Staff House Road ; St Lucia Qld 4072 // Innovation House ; First Avenue ; Mawson Lakes SA 5095, Australia

[2] Australian National University (ANU) – The Australian National University Canberra ACT 0200 Australia, Australia

In this paper we consider the problem of designing a feasible and efficient fleet to carry out the daily activities of a freight company over an extensive planning horizon, e.g., one year. Such activities require to operate the fleet so as to satisfy the demand of a set of customers subject to a variety of real-world constraints, e.g., capacities, time windows, driving regulations, etc., and are commonly modelled as "rich" Vehicle Routing Problems (RVRP).
One approach to solve the long-term fleet design problem consists in aggregating the single-day problems into a multi-day problem, and solving it using a fleet size and mix (FSMVRP) formulation. In a FSMVRP, the solver is allowed to choose which (and how many) vehicles to use, as long as the overall fleet is consistent throughout the horizon. The problem with this approach is that, when the length of the horizon grows, scalability issues arise, and obtaining good-quality solutions becomes hard.

Here, we propose an iterative two-stage method based on a novel MIP formulation. In our approach, every single-day problem is solved individually, and the solutions are used to generate a new fleet that is guaranteed to be feasible in the multi-day context. Our approach is independent of the underlying RVRP problem, provided that a suitable solver is available, and has shown encouraging scalability properties.
As a case study, we consider a split-delivery multi-compartment vehicle routing problem arising in a real-world fuel delivery context, and we produce an efficient fleet based on 300 days of demand data.

*Speaker

†Corresponding author: tommaso.urli@nicta.com.au

The multi-product multi-depot vehicle routing problem with inventory restrictions

Florian Arnold * [1], Kenneth Sörensen [1]

[1] University of Antwerp – Belgium

In reality, the optimal distribution of different goods from potentially multiple depots to customers depends on the inventory levels in the depots. Customers can only be served if sufficient inventory of the demanded product is available. When a depot runs out of stock, delivery might have to be organized by another depot, and, thus, routing decisions have to be adapted. Likewise, not every product might be stored in every depot, due to inventory policies or facility constraints.
There seems to exist no model that captures this interaction between inventory and routing aspects at the supplier accurately, even though vertical supply chain integration is a major trend in logistics. We aim at filling this gap by introducing the multi-product multi-depot vehicle routing problem with inventory constraints (MPMDVRP).

The problem is defined as follows: given several depots with defined stock levels for several products, find the lowest-cost routes such that the known demands of a set of customers is satisfied and the capacity and inventory constraints of vehicles and depots are not violated. This problem has not been described in the literature before, but it is closely related to the multi-depot vehicle routing problem and the inventory routing problem.
We study the complexity of the MPMDVRP and develop a heuristic based on variable neighborhood search with specifically designed operators. With this algorithm, we investigate the effect of different inventory policies on the optimal routing, and derive guidelines to utilize the potential of integrated inventory and routing decisions in modern logistic systems.

*Speaker

Time uncertainties in a city distribution scheme with synchronization

Alexandra Anderluh * [1], Rune Larsen [2]

[1] Vienna University of Economics and Business (WU Vienna) – Welthandelsplatz 2 1020 Vienna, Austria
[2] Technical University of Denmark (Department of Transport) (DTU Transport) – Anker Engelunds Vej 1 Building 116 2800 Kgs. Lyngby, Denmark

Freight distribution within a city has to face a wide variety of requirements and difficulties with time uncertainty amongst them. Especially, when looking at a complex distribution scheme with numerous synchronizations between different types of vehicles, the delay of one vehicle may cause delays of other vehicles as well. Therefore, we investigate the influence of time uncertainties on such a distribution scheme by a Monte Carlo Simulation approach. We first solve the Vehicle Routing Problem with synchronization constraints under deterministic assumptions. Then we iteratively evaluate the robustness of the solution using Monte Carlo Simulation, and we use a relocation operator to increase the robustness of the solution. Our algorithm generates a Pareto frontier of solutions based on cost and robustness, and can therefore be used to obtain solutions that are executable in practice. Therefore, the result of our algorithm can give planners an additional decision support.

*Speaker

The Stochastic Multi-period Time Windows Assignment Problem

Jean-François Côté * [1], Alice Raffaele [2], Renata Mansini [2]

[1] Université Laval – Canada
[2] Università degli Studi di Brescia – Italy

This work addresses the challenge of establishing delivery schedules to consumers who buy goods online or buy furniture and appliances. The difficulties faced by home delivery companies are due to the high level of uncertainty of the future demand. Several works done in the past that tackled this problem assumed to some point that future demand is known or only considered daily schedules. As information systems have more and more historical data, it is possible to build scenarios of the future demand, and we propose a stochastic programming approach to offer more robust delivery schedules that span over several days. In this talk, we present a heuristic to solve the stochastic multi-period time windows assignment problem. We consider a home delivery company that wishes to plan the delivery schedules for a time horizon across its delivery areas. The solution approach is based on the concept of a priori optimization. That is, time windows are assigned to the delivery areas in the first stage without taking into account the future demand. Then, in the second stage, future customers are known and routes satisfying the first stage time windows are planned. The objective is to minimize the expected cost of the second stage. The resolution approach of the first stage consists of a Variable Neighborhood Search that tries to move the time windows to different periods in order to improve the current solution. The second stage is solved with the Adaptive Large Neighborhood Search. Computational experiments demonstrate the value of this approach.

*Speaker

Interval Travel Times for Reliable City Logistics Vehicle Routing

Patrick-Oliver Groß *† [1], Marlin Ulmer [1], Dirk Mattfeld [1]

[1] Technische Universität Braunschweig - Decision Support Group – Mühlenpfordtstraße 23 38106 Braunschweig, Germany

In city logistics, customers expect fast and reliable services, e.g., delivery at a promised delivery time. Due to varying traffic volumes and limited traffic infrastructure in urban areas, travel times are generally uncertain and differ during the day. In this environment, city logistics service providers have to fulfill deliveries cost-efficient and reliable. To ensure cost-efficient routing while satisfying promised delivery times, information on the variation of travel times between customers needs to be derived from real world data and integrated in the planning of delivery tours.
Recently, interval travel times (ITT) gained in importance in city logistics vehicle routing as they are able to represent the variation of travel times. In addition, ITT can be derived with relatively low effort due to low data requirements and straightforward calculation methods. Hence, ITT are a suitable travel time information model to enable cost-efficient and reliable routing in urban areas.

However, VRP solution methods for integrating ITT are still missing and real world size problem instances are computational challenging. Thus, we develop a metaheuristic solution approach that identifies tours with respect to efficiency and reliability by exploiting ITT.
The developed solution approach is applied in a case study that considers floating car data (FCD) from the city of Braunschweig as a proxy for a typical medium sized European city. ITT are derived from the FCD and incorporated in the solution approach. Computational experiments show, that the incorporation of ITT increases reliability significantly while maintaining efficiency of routes.

*Speaker
†Corresponding author: p.gross@tu-braunschweig.de

Anticipation of Stochastic Travel Times Matrices Changes for Dynamic Vehicle Routing Induced by Emission-Driven Traffic Management

Felix Köster * [1], Marlin Ulmer [1], Dirk Mattfeld [1], Geir Hasle [2]

[1] TU Braunschweig – Germany
[2] Sintef ICT – Norway

Many European cities have experienced an increase in congestion and pollution through the growth of urban traffic. To reduce pollution and to meet a new pollution limiting EU regulation, cities can install dynamic emission-driven traffic management systems (TMs). If the air pollution at a supervised pollution hotspots exceeds a threshold, the TMs changes settings for traffic infrastructure, e.g. traffic lights to reduce traffic around the particular hotspot. The coordination of settings for a hotspot exceedance is called a "strategy". Each strategy changes the traffic flows in the city and has an individual traffic situation.
Courier, express and parcel services (CEP) route vehicles to deliver parcels to urban customers and are therefore influenced by traffic management decisions. For CEP's delivery routing, a TMs strategy induces a set of travel times between the customers. This research looks into the possibility of improving CEP routing efficiency, if information about the strategy can be acquired from a cooperative traffic management. A dynamic adaption of the routing to the new set of travel times and anticipation of future strategy changes is necessary for cost-efficient deliveries.
The test instance for this VRP is modeled after the emission-driven traffic management system of Brunswick with real life emission data. To solve this problem, we introduce a rollout algorithm, which is combined with a commercial solver. The anticipation of future traffic strategy is done by sampling future emission developments. Results show that anticipation and a cooperative traffic management is beneficial for CEP and leads to more efficient routes.

*Speaker

A compact linear programming model to supply a local bioraffinery

Birome Holo Ba * [1], Christian Prins [1], Caroline Prodhon [1]

[1] Université de Technologie de Troyes (LOSI) – Université de Technologie de Troyes – France

This contribution addresses the problem of modeling and optimizing biomass supply chains for biorefineries. Indeed, efficient supply chains are essential to provide conversion facilities with sufficient quantities of quality biomass at reasonable prices. The problem is described and modeled.
A network model and a data model are developed to allow describing the structure of the supply chain and its data, without affecting the underlying mathematical model. For given refinery needs, its exact resolution by CPLEX specifies the logistic activities in the network (amounts harvested, baled, transported, stored etc.) and the necessary equipment, in order to minimize a total cost including harvesting costs, transport costs and storage costs. We develop a compact mathematical model capable of dealing with instances corresponding to the system envisaged for a biorefinery located near Compiegne, France with more than 400 farms, and 46 storage locations in 52 weeks planning horizon. To find a good compromise between quality and finesse of the solution, a linear program (LP), based on the state-task network, aggregates certain activities of a farm through a "macro-task" management. The macro-tasks are used as "black boxes" in order to approximate the costs of the harvest in a farm. The mathematical model is able cope with large-scale instances. Case studies are described to illustrate this multi-biomass and multi-period tactical planning model. Tests and analyzes of the results are presented. In less than one minute, a LP with nearly 600 000 variables and almost as many constraints is solved for real case study.

*Speaker

Closed-loop Supply Chain Network Design under Demand and Return Uncertainty

Halit Uster *† [1], Sung Hwang [2]

[1] Southern Methodist University – United States
[2] NetJets – United States

In this study, we consider an integrated closed-loop supply chain (CLSC) network design problem under uncertainty in regards to product demand and return quantities. To incorporate uncertainty in decision-making, we formulate a two-stage stochastic mixed integer linear programming model to determine the optimal locations of (re)manufacturing and processing facilities along with their capacity levels and forward and reverse product flows in the CLSC network to minimize total of design and expected operation costs.
For the solution of the model and its analysis, we develop a Benders decomposition approach that is enhanced for computational efficiency via induced constraints, strengthened Benders cuts, and the use of multiple Benders cuts as well as mean-value scenario based lower-bounding inequalities obtained via dual subproblem disaggregation. Computational results illustrate that the enhancements provide substantial improvements in terms of solution times and quality.
Using our model and the solution approach within a sample average approximation (SAA) framework, we provide further analysis of network designs based on inspection location and recovery rates. Although product inspection at the retailer or the collection center locations generally reduce costs by avoiding use of resources unnecessarily, our analysis also indicates that parameters such as product type and reason-for-return, expected recovery rates, inspection costs, and transportation costs can be instrumental in deciding where the return product inspection should take place and, in turn, dictating the overall cost as well as the structure of the CLSC network.

*Speaker
†Corresponding author: uster@lyle.smu.edu

The probabilistic orienteering problem

Enrico Angelelli [1], Claudia Archetti [1], Carlo Filippi * [1], Michele Vindigni [1]

[1] University of Brescia – Italy

The probabilistic orienteering problem (POP) is defined on a directed graph where a cost is associated with each arc and a prize is associated with each node; each node will be available for visit only with a certain probability. A server starts from a fixed origin, visits a subset of nodes, and ends at a fixed destination. In a first stage, a node subset is selected and a corresponding a priori path is determined such that the server can visit all nodes in the subset and reach the destination without exceeding a time limit. In a second stage, after the list of available nodes is revealed, the server follows the a priori path by skipping the absent nodes. The POP consists in determining a first-stage solution that maximizes the expected profit of the second-stage path, i.e., the difference between the expected total prize and the expected total cost. We discuss the relevance of the problem and formulate it as a linear integer stochastic problem. We develop a branch-and-cut approach for the POP and several matheuristic methods, corresponding to different strategies to reduce the search space of the exact method. Extensive computational tests on instances with up to 100 nodes show the effectiveness of the exact method and the efficiency of the matheuristics in finding high quality solutions in a few minutes. Moreover, we provide an extended analysis on a subset of instances to show the value of explicitly modelling the stochastic information in the problem formulation.

*Speaker

A Branch-and-Bound for Speed Optimization in Pickup and Delivery Problem under Track Contention

Tommaso Adamo * [1], Tolga Bektaş [2], Gianpaolo Ghiani [1], Emanuela Guerriero [1], Emanuele Manni [1]

[1] University of Salento (Lecce, Italie) – Italy
[2] University of Southampton (Southampton, UK) – United Kingdom

This article deals with the Speed Optimization Problem (SOP) for the Pickup and Delivery Routing Problem under Track Contention, a particular vehicle routing problem in which loads have to be transported between origin-destination pairs by means of vehicles traveling along a capacitated network. The aim is to find for each vehicle a conflict-free routing and to determine the corresponding travel speeds, in order to minimize the total energy consumption.
These problems arise in at least three different contexts that we are aware of. The first is the movement of Automated Guided Vehicles in Material Handling Systems, particularly those using batteries. A second application context is the routing of Unmanned Aerial Vehicle in controlled airspace. Finally, the problem might arise in scheduling and routing of trains where a given track might only be occupied by a single train due to safety considerations.
In this article, we propose a Branch-And-Bound algorithm for the problem, based on the relaxation obtained by removing track-contention constraints. In particular, the resulting relaxed problem is nonlinear and separable, and its optimal solution can be determined by solving in quadratic time a SOP for each vehicle. We devise a feasibility-check procedure aiming to determine if the optimal solution of the relaxation problem corresponds to a conflict-free routing. Finally, the branching procedure applies space-based and time-based branching constraints, so that to cut off conflicts detected by the feasibility-check procedure. We demonstrate the efficiency and applicability of the proposed approach by solving instances of increasing complexity.

*Speaker

A Metaheuristic Approach to Fisheries Survey Route Planning

Ana Paias * [1,2], Marta Mesquita [2,3], Laura Wise [4]

[1] DEIO, Faculdade de Ciências, Universidade de Lisboa – Universidade de Lisboa, Campo Grande, Edificio C6, 1749-016 Lisboa, Portugal
[2] Centro de Matemática, Aplicações Fundamentais e Investigação Operacional (CMAFCIO) – Portugal
[3] Instituto Superior de Agronomia, Universidade de Lisboa – Tapada da Ajuda, 1349-017 Lisboa, Portugal
[4] Instituto Português do Mar e da Atmosfera (IPMA) – Av. Brasília, 1449-006 Lisboa, Portugal

Every autumn, a research vessel carries out a sampling survey tour to estimate the abundance of several demersal species of the Portuguese continental waters. The sampling operations are made at predefined geographical locations, the fishing stations, within predefined multiple time windows.The vessel route starts and ends at the port of Lisbon and must visit all fishing stations. According to a predefined periodicity, the vessel must enter a port to supply food, refuel and/or change crew. Given the geographical locations of the fishing stations/ports and the current weather conditions, the objective is to minimize the total traveled distance and the completion time. We present a MILP model that highlights three combinatorial subproblems, namely a clustering subproblem dividing the set of fishing stations into two subsets, a routing subproblem defining the spatial movement of the vessel, and a scheduling subproblem establishing the times at which each location is visited. The size of the real instances addressed in this paper make the exact resolution of the model impractical. Despite the existence of a high dependency among the referred three subproblems, one may devise a hierarchic ordering of the decisions that are involved in the resolution of the model, which suggests the use of sequential approaches. Therefore, we propose two sequential heuristic approaches that combine genetic algorithms and ALNS to obtain feasible solutions. Computational experience with real data shows that the heuristics are suitable tools to solve the problem, obtaining good feasible solutions in short CPU time.

*Speaker

Waste collection inventory routing with non-stationary stochastic demands

Iliya Markov *† [1,2], Yousef Maknoon [1], Jean-François Cordeau [3], Sacha Varone [2], Michel Bierlaire [1]

[1] Ecole Polytechnique Federale de Lausanne (EPFL) – Switzerland
[2] Haute Ecole de Gestion de Genève (HEG Genève) – Switzerland
[3] HEC Montréal – Canada

We solve a complex logistical problem inspired from practice, in which a heterogeneous fixed fleet of vehicles is used for collecting recyclable waste over a planning horizon. Each tour starts and ends at the depot, and is a sequence of collections followed by disposals at the available dumps, which can be used when and as needed along the tour. We impose a mandatory dump visit just before the end of the tour, as well as time windows and a maximum tour duration. Each container is equipped with a sensor, which communicates the waste level at the start of the day. Given a history of observations, a forecasting model is used to estimate for each container the point demand forecasts for each day of the planning horizon. The problem falls under the framework of inventory routing. Our main contribution lies in the direct incorporation of probabilistic information, which affects the cost through the probabilities of container overflows and route failures. We develop a mixed integer non-linear program and an adaptive large neighborhood search algorithm, which is integrated with a demand forecasting model specifically designed for our purpose, and tested and validated on real data. We will present numerical experiments on benchmark instances of the vehicle routing and inventory routing problems, and on state-of-practice data. Furthermore, we will analyze the value of stochastic information and the importance of the emergency collection cost, and will present ideas for future research based on model reformulations for different container overflow risk profiles.

*Speaker
†Corresponding author: iliya.markov@epfl.ch

The Directed Profitable Rural Postman Problem with Incompatibility Constraints

Renata Mansini * [1], Marco Colombi [1], Angel Corberán [2], Isaac Plana [3], José Maria Sanchis [4]

[1] University of Brescia, Dept. of Information Engineering – Italy
[2] University of Valencia, Dept. of Statistics and Operational Research – Spain
[3] University of Valencia, Dept. of Mathematics for Economics and Business – Spain
[4] Polytechnic University of Valencia, Dept. of Applied Mathematics – Spain

We study a variant of the Directed Rural Postman Problem (DRPP) where profits are associated with arcs to be served, and incompatibility constraints may exist between nodes and profitable arcs leaving them. If convenient, some of the incompatibilities can be removed provided that penalties are paid. The problem looks for a tour starting and ending at the depot that maximizes the difference between collected profits and total cost as sum of traveling costs and paid penalties, while satisfying remaining incompatibilities. The problem, called Directed Profitable Rural Postman Problem with Incompatibility Constraints (DPRPP-IC), originates in the domain of the transportation service procurement where a company (typically a shipper or a carrier) needs to decide which customer transportation requests to serve in a tour while satisfying constraints that may exclude the joint selection of some requests. We propose two problem formulations involving a different number of variables and constraints, and introduce a matheuristic procedure exploiting the presence of the Generalized Independent Set Problem (GISP) and of the Directed Rural Postman Problem (DRPP) as subproblems. Computational results on a large set of instances show how the matheuristic is extremely effective outperforming the result obtained in one hour computing time by a straightforward branch-and-cut approach implemented with IBM CPLEX 12.6.2 on instances with up to 500 nodes, 1535 arcs, 1132 profitable arcs, and 10743 incompatibilities.

*Speaker

Some ideas and tests of neighborhoods for the split delivery vehicle routing problem

Martin Josef Geiger * [1], Marc Sevaux [2]

[1] Helmut-Schmidt-University, University of the Federal Armed Forces Hamburg – Germany
[2] Université de Bretagne Sud - Lab-STICC – Université de Bretagne Sud [UBS], CNRS : UMR6285 – BP 92116 - 56321 Lorient cedex, France

The split delivery vehicle routing problem (SDVRP) describes an interesting generalization of the classical VRP. It allows to split-up delivery volumes of single customers between different vehicles, and thus routes/ tours. It is well known that this comes with the potential to further reduce the routing costs, and therefore may provide a competitive advantage to logistics companies.

In our work, we study the SDVRP, and develop some new ideas for neighborhood search in this application. Our concepts are based on the insight that delivery volume choices influence routing decisions, and vice versa. Therefore, we particularly test ideas for the combined modification of both the routing and the volume decisions. By doing so, we extend the set of known local search techniques (neighborhood operators) for problems in which an intersection of delivery volume optimization and routing optimization is present.

Experimental investigations on instances from the literature are carried out, and the effect of the combined operators is studied. Our findings are encouraging, but at the same time, it becomes clear that the efficient implementation of the local search plays a considerable role when comparing and analyzing results.

*Speaker

Methods for solving multiple depots split deliveries vehicle routing problems

Andréa Cynthia Santos * [1]

[1] Université de Technologie de Troyes (ICD-LOSI, UMR CNRS 6281, UTT) – Université de Technologie de Troyes – 12, rue Marie Curie, CS 42060, 10004, Troyes CEDEX, France

In post disaster relief, two main levels in the distribution process are distinguished to provide aid to the population. The macro-distribution that consists of transferring supplies (e.g. food, drugs and water) from big hubs (e.g. airports and ports) to intermediate depots; and the last-mile distribution that aims at achieving supplies to the population. If the two levels are coupled, it results in a location-routing problem. However, in the context of humanitarian logistics, several organizations provide aid according to their own protocols, without any global policies. Thus, it is reasonable and realistic to handle those problems independently. This study focuses on characteristics not still well addressed for the macro-distribution in the context of crisis management. It concerns the huge demands which imply visiting a delivery point several times, as well as servicing each delivery point by different vehicles in a shared way. This problem is modeled in this study as a Multiple Depots Split Delivery VRP (MDSD-VRP) coupling the Multiple Depots VRP (MD-VRP) and the Split Delivery VRP (SD-VRP). A mathematical formulation, bi-criteria constructive heuristics and multi-start based metaheuristics have been developed to the MDSD-VRP. Experiments are addressed for instances from the literature and scenarios of Port-au-Prince (Haiti) earthquake in 2010.

*Speaker

Web services for routing problems

Marc Sevaux * [1], Pierre Bomel [1]

[1] Université de Bretagne Sud - Lab-STICC (UBS/Lab-STICC) – Université de Bretagne Sud [UBS], CNRS : UMR6285 – BP 92116 - 56321 Lorient cedex, France

Recently, the "Cloud" has replaced the "Internet" and, despite this big change in the daily approach of communications, academic researchers are still solving the logistic problems in the same way. They gather instances from the companies, usually transform them in text files and solve the corresponding routing problems before sending back their results in another text file that has to be interpreted by decision makers. Moreover, most of the academic researchers are still working on "theoretical problems" for which the instances are sometimes far from reality (e.g. see the classical CVRP instances).

In order to make available some realistic instances and organize collaborative development in our field, we propose to implement our main algorithms related to Vehicle Routing Problems and to host them in a web-service based platform that will provide real data from currently available Internet map systems (the platform uses Open Street Maps, geolocalized points, and Mapquest for distances).

The purpose of the web-service platform is also to allow an easy adaptation of a perfectly tailored method to solve a larger specific class of problems or different variants of the same problems. The goal of this project is to create two communities: i) one community of developers that would be ready to use our platform to get or generate real life instances and ii) one community of users such as small or medium size companies that will never invest a lot in a routing software but who have needs in that domain.

*Speaker

Modelling Vehicle Routing Problems in Real Road Networks

Hamza Ben Ticha * [1,2], Nabil Absi† [1], Dominique Feillet‡ [1], Alain Quilliot§ [2]

[1] École Nationale Supérieure des Mines de Saint-Étienne (EMSE) – CMP-GC – 880 route de Mimet, 13120 Gardanne, France

[2] Laboratoire d'Informatique, de Modélisation et d'optimisation des Systèmes (LIMOS) – Université Blaise Pascal - Clermont-Ferrand II, CNRS : UMR6158 – Bât ISIMA Campus des Cézeaux BP 10025 63173 AUBIERE cedex, France

The Vehicle Routing Problem (VRP) can be described as the problem of designing a set of routes starting and ending at a depot to serve a set of customers using a fleet of vehicles. Most of proposed approaches are based on a key assumption is that the best connection between each pair of customers' locations in the road network is well defined and so the problem can be modeled with a simple weighted graph. But this assumption is not guaranteed to hold in real-world applications, as several attributes needed to be considered to model correctly the road network. Consequently, alternative paths proposing different trade-offs can be defined in the road network and not considering these alternative paths when solving the problem may be disadvantageous and potential solution could be discarded from solution space. A typical example of this situation is provided by the time-constrained vehicle routing problem VRPTW (the Vehicle Routing Problem with Time Windows). In this study, we propose to represent the road network with a multigraph representation such that we consider all possible paths between each pair of customers' locations. To illustrate the impact of our modelling approach, we developed an Adaptive Large Neighborhood Search algorithm and a Branch-and-Price exact Method. Computational experiments on modified benchmarks from the literature and on real instances show the positive impact of the multigraph impact and cost savings obtained.

*Speaker

†Corresponding author: absi@emse.fr

‡Corresponding author: feillet@emse.fr

§Corresponding author: alain.quilliot@isima.fr

A Branch & Cut algorithm for the Multi-trip Vehicle Routing Problem with Time Windows

Diego Cattaruzza * [1], Paolo Gianessi† [2]

[1] Centre de Recherche en Informatique, Signal et Automatique de Lille (CRIStAL) – Ecole Centrale de Lille – Cité Scientifique - CS 20048 59651 Villeneuve d'Ascq cedex - France, France
[2] Laboratoire d'Informatique, de Modélisation et d'Optimisation des Systèmes (LIMOS) – CNRS : UMR6158, École Nationale Supérieure des Mines - Saint-Étienne, Institut Henri Fayol – 158 cours Fauriel - CS 62362 42023 Saint-Étienne CEDEX 2 - FRANCE, France

The Multi-trip Vehicle Routing Problem with Time Windows (MTVRPTW) generalizes the well-known Capacitated Vehicle Routing Problem (CVRP) in that vehicles can perform more than one trip within a maximum shift length but must comply customer time windows.
The MTVRPTW has recently got the attention of scholars due to its applications to city logistics. A Branch & Price approach is proposed in [1], while [2] tackles a variant with limited trip duration.
We propose a three-index MILP formulation for the MTVRPTW that makes use of base and replenishment arcs. The former model the direct connection between two nodes, while the latter imply a reload operation in between two clients. Base and replenishment arc variables are vehicle-indexed. Replenishment arcs allow to represent a journey as an elementary path and thus to ensure connectivity by separating SECs on a transformation of the graph. Further sets of two-indexed variables allow to impose time windows, shift length, and service-dependent loading time constraints.
The use of classical capacity constraints to enforce the load limit on vehicles leads to a Branch & Cut algorithm. Capacity constraints are then strengthened after branching decisions to exploit some properties of the vehicle index.
Preliminary tests have been conducted, with promising results.

[1] F. Hernandez, D. Feillet, R. Giroudeau, O. Naud, "Branch-and-price algorithms for the solution of the multi-trip vehicle routing problem with time windows." EJOR, 249(2):551-559, 2016

[2] F. Hernandez, D. Feillet, R. Giroudeau, O. Naud, "A new exact algorithm to solve the multi-trip vehicle routing problem with time windows and limited duration." 4OR, 12:235-259, 2014.

*Speaker
†Corresponding author: gianessi@lipn.fr

Goods Distribution with Electric Vehicles: Integrating Battery Behaviour into Routing

Samuel Pelletier * [1,2], Gilbert Laporte [1,2], Ola Jabali [1,2]

[1] HEC Montréal – Canada
[2] Centre Interuniversitaire de Recherche sur les Réseaux d'Entreprise, la Logistique et le Transport (CIRRELT) – Canada

We introduce a new electric vehicle routing problem in which a fleet of battery electric vehicles (BEVs) must deliver goods to a set of customers over the course of a week. Freight BEVs are typically charged at a central depot and rarely use public charging stations during delivery routes. Thus, the charging schedule of the vehicles at the depot over the planning horizon must be determined such as to allow them to complete their routes, and charging can be done during the working day or at night. There are different types of charging stations at the depot, and a limited amount of stations for each of these types. The battery is modeled as an equivalent electrical circuit in order to avoid overcharging degradation. As a result, charging functions are not linear throughout the charging process. Time dependant grid capacity constraints and charging costs are considered, and an energy consumption model based on vehicle mass, speed, and road grade is used. The objective is to minimize the sum of all energy and routing costs over the planning horizon. The problem is solved with an Adaptive Large Neighborhood Search (ALNS) algorithm. The charging schedule in the final solution is updated in order to reduce battery degradation resulting from storing batteries at a high state of charge. The schedule should therefore be updated such as to charge the vehicles as closely as possible to their departure time without increasing total costs.

*Speaker

Using tricycles for express deliveries of urgent grocery needs

Stefan Schwarzbach [1], Pamela Nolz* [1], Ulrike Ritzinger [1], Bin Hu † [1]

[1] AIT Austrian Institute of Technology – Austria

Stemming from a real-world problem, we consider the distribution of food kits in an urban environment. Customers order food kits online in one of the following two variants. Either, regular orders are placed on the eve and time windows for the delivery are specified for the next day, or so called "express"-orders are placed during the day, which are delivered within 60 minutes. Note that for express-orders, some of the goods might be out of stock, since they are directly taken from an operated customer store. Aiming for an environmentally friendly delivery system, the food kits are delivered with electric tricycles. Therefore, goods are picked up in pre-defined stores and delivered to the customers respecting temporal constraints and optimizing a combination of criteria: minimal travel time, minimal time from order to delivery, maximal fulfillment of ordered goods, minimal total tour length. We model the distribution system as a dynamic pickup and delivery problem with time windows (PDPTW). The regular orders result in initial tours for the tricycles and can be optimized using state-of-the-art PDPTW algorithms. For the dynamic part, express-orders during the day are inserted into these initial tours and choosing the store where the ordered items are packed is also part of the optimization. This process is modeled as generalized PDPTW where pickup locations are represented by clusters consisting of eligible stores. Aspects such as packing time, fulfillment and distances are considered to choose the best store for the pickup.

*Corresponding author: Pamela.Nolz@ait.ac.at
†Speaker

The heterogeneous dial-a-ride problem with reconfigurable vehicle capacity

Oscar Tellez * [1], Samuel Vercraene† [1], Fabien Lehuédé‡ [2], Thibaud Monteiro§ [1], Olivier Péton¶ [2]

[1] Decision and Information Sciences for Production systems, INSA-Lyon (DISP) – INSA Lyon – Bâtiment Léonard de Vinci, 21 avenue Jean Capelle, 69621 Villeurbanne, France

[2] Institut de Recherche en Communications et en Cybernétique de Nantes (IRCCyN) – École Nationale Supérieure des Mines - Nantes – 1, rue de la Noë BP92101 44321 Nantes Cedex 03, France

Various forms of the Dial-a-Ride Problem (DARP) have been studied during the last decade. Most recently, various user types (heterogeneous users) and adapted vehicle fleets have been considered. This paper introduces a new version of the heterogeneous DARP in which a vehicle capacity can be modified during its route by reconfiguring its interior to
satisfy different user demands.

The work is motivated by the daily transport of children with disabilities at Lyon. A fleet of configurable vans is available each day to transport children to and from medical-social establishments for rehabilitative treatment. Nevertheless, today, route planners do not consider reconfiguration opportunities when designing routes.

The problem is modeled as a mixed-integer program derived from the heterogeneous DARP model, but with an extra index representing the current vehicle configuration. The considered number of passengers and vehicle fleet size make this problem virtually intractable for exact solving approaches. Thus, a meta-heuristic based on large neighborhood search is proposed and evaluated on randomly generated and real life instances.

*Speaker

†Corresponding author: samuel.vercraene@insa-lyon.fr

‡Corresponding author: fabien.lehuede@mines-nantes.fr

§Corresponding author: thibaud.monteiro@insa-lyon.fr

¶Corresponding author: olivier.peton@mines-nantes.fr

Designing two-echelon distribution networks under demand uncertainty

Imen Ben Mohamed * [1,2,3], François Vanderbeck [1,2], Walid Klibi [3,4]

[1] RealOpt (INRIA Bordeaux - Sud-Ouest) – Université Sciences et Technologies - Bordeaux I, INRIA – 200 avenue de la Vieille Tour 33405 Talence, France
[2] Institut de Mathématiques de Bordeaux (IMB) – CNRS : UMR5251, Université Sciences et Technologies - Bordeaux I, Université Victor Segalen - Bordeaux II, Université Sciences et Technologies Bordeaux I, Université Victor Segalen – Bordeaux II – 351 cours de la Libération 33405 TALENCE CEDEX, France
[3] KEDGE Business School – Ministère de l'Enseignement Supérieur et de la Recherche Scientifique – 680, Cours de la Libération, 33405 Talence Cedex, France
[4] Centre Interuniversitaire de Recherche sur les Réseaux d'Entreprise, la Logistique et le Transport (CIRRELT) – Pavillon André-Aisenstadt, bureau 3520 2920, Chemin de la Tour Montréal (Québec) H3T 1J4 CANADA, Canada

Goods delivery from manufacturing platforms to demand zones is often managed through one or more intermediate locations where storage, transshipment and consolidation activities are performed. When distribution activities cover a large geographical area, depend on hierarchical inventory rules, or concern urban deployment, multi-echelon network configurations are more appropriate. In this work, a two echelon distribution network is considered, and the strategic problem of designing the network structure under demand uncertainty is tackled. It is modeled as a stochastic multi-period two-echelon location-routing problem integrating decisions on the location and the size of second echelon facilities, decisions on the flows assignment between the echelons, and on delivery routes to serve demand zones. Furthermore, a multi-year planning horizon is considered to design the distribution network, and the uncertain customers demand is characterized by a set of scenarios. To solve the problem for large scale instances, a solution method, using a decomposition approach, is developed. Computational experiments on several instances are performed to validate the approach and to derive insights from the results obtained.

*Speaker

Combined vehicle routing and truck driver scheduling in the EU and the working time directive

Asvin Goel * [1]

[1] Kühne Logistics University (KLU) – Germany

This presentaion studies vehicle routing and truck driver scheduling problems in which truck drivers must comply with hours of service regulations in the European Union. Some of the relevant rules are imposed by EU regulations and others by national law implementing Directive 2002/15/EC. Although some previous papers have claimed to consider all rules of the working time directive, some important rules of the directive have been ignored until now. Thus all exisiting approaches for vehicle routing and truck driver scheduling in the European Union are likely to generate routes and schedules which cannot be executed without violating rules. This presentation shows how these rules can be tackled and presents an approach for scheduling driver activities complying with all of the provisions of Regulation (EC) No 561/2006 and Directive 2002/15/EC. The approach is evaluated within an exact approach for the vehicle routing and truck driver scheduling problem. An interesting finding is that the solution process is significantly accelerated by considering the additional rules of the directive. A risk analysis of the results is conducted, indicating that road safety is significantly increased by the night work provision of the working time directive.

*Speaker

A branch-price-and-cut algorithm for the mixed capacitated general routing problem with time windows

Claudio Ciancio [1], Demetrio Laganà [1], Francesca Vocaturo * [2]

[1] Department of Mechanical, Energy and Management Engineering, University of Calabria – 87036 Arcavacata di Rende (CS), Italy
[2] Department of Economics, Statistics and Finance, University of Calabria – 87036 Arcavacata di Rende (CS), Italy

We introduce the Mixed Capacitated General Routing Problem with Time Windows (MCGRPTW). This problem is defined over a mixed graph, for which some nodes, arcs and edges have strictly positive demand and must be serviced through a fleet of homogeneous capacitated vehicles. The aim is to find a set of least-cost vehicle routes that satisfy this requirement, while respecting pre-specified time windows, and without exceeding the vehicle capacity. The MCGRPTW generalizes the Capacitated Arc Routing Problem with Time Windows (CARPTW) and many other routing problems. Its main application can be found within urban waste collection, where garbage quantities are collected along the streets, but specific locations (e.g., industrial and commercial sites) need to be considered as single points due to the large amount of garbage. In this context, time windows represent common constraints in real-world cases. The transformation of routing problems in equivalent ones defines a solution approach quite often used in the scientific literature. We transform the MCGRPTW into an equivalent node routing problem over a directed graph and solve it through a branch-price-and-cut algorithm. Branch-price-and-cut is a variant of branch-and-bound, with bounds obtained by solving linear programs and performing column and cut generation; branching decisions are taken to derive integer solutions. We demonstrate the effectiveness of the solution approach through an extensive computational study, where both CARPTW and MCGRPTW instances are solved.

*Speaker

Branch-Price-and-Cut for the Generalized Truck-and-Trailer Routing Problem

Ann-Kathrin Rothenbächer * [1], Michael Drexl [1], Stefan Irnich [1]

[1] Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University – Jakob-Welder-Weg 9, D-55128 Mainz, Germany

We consider the truck-and-trailer routing problem with time windows (TTRPTW). The fleet consists of several lorries which may attach a trailer. As some customers are not accessible for a lorry with the trailer attached, the trailers can be parked at customer sites or additional transshipment locations. When a lorry returns to its trailer after a subtour, load can be transferred from the lorry to the trailer.
We extend the TTRPTW planning horizon to two days and allow customers to be visited either on both days or on only one day (in which case twice the daily supply must be collected), and we consider that the time needed for a load transfer depends on the amount of load transferred.

We tackle the problem with an exact branch-and-price-and-cut algorithm and generate the columns with a label-setting algorithm. The pricing procedure uses many known acceleration techniques, e.g., a bidirectional labelling, the ng-neighbourhood, reduced networks and relaxed dominance. Moreover, we separate subset-row inequalities to strengthen the lower bounds.
Computational studies show that our algorithm compares favourably with existing approaches on TTRP and TTRPTW benchmark instances known from literature.

*Speaker

The Interceptor Vehicle Routing Problem: formulation and Branch and Price algorithm

Claudio Gambella * [1], Bissan Ghaddar [2], Joe Naoum-Sawaya [3]

[1] Department of Electronics, Computer Science and Systems (DEI) – Italy
[2] IBM Research - Ireland – Damastown Industrial Estate, Mulhuddart, Dublin 15, Ireland
[3] Ivey Business School, Western University – Canada

We address a generalization of the Vehicle Routing Problem (VRP) which consists of intercepting moving targets with a fleet of vehicles in order to bring them to a common destination in shortest time. The targets are allowed to move from their initial known locations according to a predictable motion. We classify this problem as the Interceptor VRP. The Interceptor VRP may have applications in ride-sharing systems in which moving passengers are picked up by cars and in target tracking problems. We propose a novel Mixed Integer Second Order Conic Programming (MISOCP) formulation for the problem, along with valid inequalities for strengthening the relaxation. To solve the MISOCP problem to optimality, we design and implement a Branch and Price algorithm. Computational results are presented by comparing CPLEX to the proposed new algorithm. The Branch and Price is significantly more computationally efficient than CPLEX on the tested instances.

*Speaker

Generic and scalable annotation layers for shortest path road networks

Yann Bartesch * [1], Stefan Hug [2], Werner Heid [2], Sébastien Beolet * [1]

[1] PTV Loxane – PTV Group – Immeuble Grand Axe 10-12 boulevard de l'Oise 95031 Cergy Pontoise Cedex, France
[2] PTV AG (PTV Group) – Haid-und-Neu-Straße 15 76131 Karlsruhe, Germany

Travel time is one of the most important information in transportation. Planning algorithms use it to optimize tours, and navigation systems use it to predict the estimated time of arrival (ETA). ETA can be calculated on a real-time basis, which can help logistics companies to schedule the truck arrivals at the dock.
When we speak about dynamic travel times, we first think of traffic: statistical traffic, real-time traffic, and forecast traffic. But other events as well could modify the travel times, like toll booth and border waiting times, seasonal closures, or temporary driving bans. Apart from these time-dependent restrictions, additional restrictions depending on the vehicle type have to be considered for shortest path calculation.

All this information, coming from multiple providers, must be combined and evaluated during the shortest-path algorithm in order to calculate the travel time more accurately. Considering the big amount of data, obtaining an adequate performance is one of the main challenges of this technique.

We present a model of generic and scalable annotation layers, based on the road network, which extends the standard network information. Then we focus on how the shortest-path algorithm accesses it to finally compute the most accurate travel time.
Finally, we show how this generic approach allows to easily handle more use-cases like multi-modal routing or timetables, by dynamically integrating new data sources to the road networks.

*Speaker

A branch and cut for the Hierarchical Mixed Rural Postman Problem

Angel Corberán * [1], Marco Colombi [2], Renata Mansini [2], Isaac Plana [1], José Sanchis [3]

[1] University of Valencia, Dept. of Statistics and Operational Research – Spain
[2] Department of Quantitative Methods [Brescia] – University of Brescia, Department of Quantitative Methods, Italy
[3] Universidad Politecnica de Valencia – Spain

The Hierarchical Mixed Rural Postman Problem is defined on a mixed graph where arcs and edges that require a service are divided into subsets that have to be serviced in a hierarchical order. The problem generalizes the Rural Postman Problem and thus is NP-hard. In this talk we present a polyhedral analysis of the problem and propose a branch-and-cut algorithm for its solution based on the introduced classes of valid inequalities. Extensive computational experiments are reported on benchmark instances. The exact approach allows to find the optimal solutions in less than one hour for instances with up to 999 nodes, 694
arcs, 1984 edges and 4 hierarchies.

*Speaker

Green Hub Location Routing Problem

Nathalie Bostel [1], Xiao Yang *† [1], Pierre Dejax [2], Marc Paquet [3]

[1] Université de Nantes- IRCCyN – Université de Nantes – 58 rue Michel Ange, BP 420 44606 Saint-Nazaire cedex, France
[2] Ecole des Mines de Nantes (EMN) – Ecole des Mines de Nantes – 4 rue Alfred Kastler 44300 Nantes, France
[3] Ecole de Technologie Supérieure (ETS) – 1100, rue Notre-Dame Ouest Montréal (Qc) H3C 1K3 Canada, Canada

The Hub Location Routing Problem (HLRP) consists in determining simultaneously the location of hub facilities concentrating flows in order to achieve economy of scale, the allocation of suppliers and clients to hubs as well as designing the optimal routes to visit non hub nodes. We address the frequent case of less than truckload (LTL) transportation companies, where collection and delivery routes are distinct, due to logistics constraints. As the environment is an increasingly important concern in supply chain management, we consider both economic and environmental goals (CO2 emissions) and propose a bi-objective Green Hub Location Routing Model. Our bi-objective optimization model for the Green HLRP thus aims at minimizing both costs and CO2 emissions. The cost function includes fixed hub costs, transportation costs between hubs, local collection and delivery routing costs, handling hub costs, and fixed costs of vehicles. For the environmental objective function, we consider fixed CO2 emissions for operating the hubs as well as the handling emissions, and the emissions relative to transportation. For collection and delivery routes, the emissions are based on the load of vehicles and distances, while for inter-hub transportation, they are only distance-dependent since trucks are assumed to be fully loaded. Experimental results will be presented by solving the model with a standard MILP solver on the basis of data sets of different sizes and characteristics, in order to evaluate the relationship between cost and CO2 emissions using the epsilon constraint method.

*Speaker
†Corresponding author: xiao.yang@univ-nantes.fr

A mathematical model for two echelon location routing problem with simultaneous pickup and delivery

Ece Arzu Demircan-Yildiz *† [1], Ismail Karaoglan [2], Fulya Altiparmak [1]

[1] Gazi University – Ankara, Turkey
[2] Selçuk University – Konya, Turkey

Globalization and increasing competition make logistics an important part of life. Companies required to keep costs as low as possible in order to maintain their existence in this competitive environment. Companies want to decrease their logistic costs related with the location of the facilities and routing of the vehicles. This study focuses on Two Echelon Location-Routing Problem with Simultaneous Pickup and Delivery (2E-LRPSPD) which is a variant of the well-known Location-Routing Problem (LRP). The 2E-LRPSPD seeks to minimize total cost by locating the secondary depots and routing the vehicles between main depot to secondary depots and secondary depots to customers which satisfy pickup and delivery demands of customers and/or secondary depots at the same time. To solve the problem we propose a node-based formulation and use a family of valid inequalities to strengthen the formulation. An experimental study on the instances derived from the literature is conducted to investigate the effects of valid inequalities in terms of reaching tight lower bounds.

*Speaker
†Corresponding author: arzudemircan@gazi.edu.tr

Detecting location routing problems in geomarketing, sales force optimisation and task planning - Specific challenges of real-life instances

Werner Heid *† [1]

[1] PTV GROUP - Logistics Software – Germany

When companies attempt to optimise their sales force and task planning many decisions have to be taken and related operations must be carried out. Wrong decisions generally result in high costs and competitive disadvantages. High quality solutions allow the sales representatives to spend less time on the roads and more time with the customers.
Professional applications for supporting decision-making in practice need to meet a wide range of different requirements:

- Sales and delivery areas must be optimised. Desired results are characterised by geographically compact areas that are equally balanced regarding e.g. turnover potential or workload.

- Solutions have to provide daily and weekly visit schedules for the planning period and exact visit sequences taking into account all relevant restrictions and customer specifications.

- Alternative scenarios must be assessable in cases of business expansion and consolidation.

- All results are based on reliable travel time and distance calculations

My presentation examines the specific location routing aspects in this target system. The range of related problems comprises different types and characteristics of location routing problems, e.g. periodic problems or multiple objectives. Successful algorithmic approaches have to cope with these conditions. The talk provides an evaluation of our applied methods based on their typical behavior, observed strengths and weaknesses in day-to-day business.

*Speaker
†Corresponding author: Werner.Heid@ptvgroup.com

The impact of depot location, fleet composition and routing on emissions in city logistics

Cağrı Koç *† [1], Tolga Bektaş [2], Ola Jabali [1], Gilbert Laporte [1]

[1] HEC Montréal – Canada
[2] University of Southampton – United Kingdom

This paper investigates the combined impact of depot location, fleet composition and routing decisions in city logistics with a particular focus on vehicle emissions. We consider a city in which goods need to be delivered from several depots to customers located in nested zones characterized by different speed limits. The objective is to decide on the locations of the depots, types of vehicles to be used in deliveries and routing of the vehicles to minimize the total depot, vehicle and routing cost, where the latter can be defined with respect to the cost of fuel consumption and CO2 emissions. This talk will describe a new adaptive large neighborhood search algorithm successfully applied to a large pool of new benchmark instances. We present extensive analyses to empirically assess the effect of various problem parameters, such as depot cost and location, customer distribution and heterogeneous vehicles on key performance indicators, including fuel consumption, emissions and operational costs, and discuss findings to provide managerial insights.

*Speaker
†Corresponding author: cagri.koc@cirrelt.ca

A Mass-flow Based MILP Formulation for the Inventory Routing with Explicit Energy Consumption

Yun He * [1], Nicolas Jozefowiez [1], Cyril Briand [1]

[1] Laboratoire d'analyse et d'architecture des systèmes (LAAS) – CNRS : UPR8001 – 7 Av du colonel Roche 31077 TOULOUSE CEDEX 4, France

Our purpose is to incorporate explicit energy consumption into traditional Inventory Routing Problem (IRP) and present a Mixed Integer Linear Programming (MILP) model for this problem. Under the Vendor Managed Inventory (VMI), the IRP has several flexibilities that make it a promising basis for an energy-efficient routing. First of all, the customer demands can be distributed in different combinations. Secondly, vehicles can be routed to minimize the energy consumption. Last but not least, the time of visits can also be chosen so that rush hours are avoided without lost of customer demands. Our model takes into consideration these three decisions at the same time and use energy minimization as the main objective. The delivered quantity or mass serves as a link between inventory control and energy estimation. Traffic and road conditions are integrated to develop the routing strategy. Based on physical laws of motion, energy consumption is estimated using parameters like vehicle speed, average acceleration rate and number of stops. Experiments are conducted using benchmark instances for inventory routing with parameters for energy estimation. Both exact and heuristic methods are implemented to solve this problem. Finally, the results are compared with the traditional IRP results to analyse the influence of energy consumption to the inventory routing systems and to show the efficiency of the solution methods.

*Speaker

Green Location Routing Problem

Okan Dukkanci *† [1], Bahar Y Kara [1], Tolga Bektaş [2]

[1] Bilkent University – Bilkent University 06800 Bilkent, Ankara TURKEY, Turkey
[2] University of Southampton (UNITED KINGDOM) – United Kingdom

This talk will introduce the Green Location-Routing Problem (GLRP), an extension of the classical Location-Routing Problem that explicitly accounts for fuel consumption and CO2 emissions, the amount of which is measured by a widely used comprehensive modal emission model. The GLRP consists of (1) locating depots on a subset of a discrete set of points, from where vehicles of limited capacity will be dispatched to serve a number of customers with service requirements, and (2) routing the vehicles by determining the order of customers served by each vehicle and the speeds on each leg of the journey, such that customers are served within their respective time windows and vehicle capacities are respected. We will define a single and a bi-objective variant of the problem. The former objective is to minimize a total cost function comprising depot, fuel and emission costs. In the latter, one objective is the minimization of the fixed depot costs and the other is to minimize the total amount of emissions. We will present mixed integer programming formulations for both variants of the problem. For the single-objective GLRP, we will describe a group of valid inequalities to strengthen the formulation and a branch-and-cut algorithm building on these inequalities. As for the bi-objective GLRP, we will present an application of the ϵ-constraint method. Computational results on realistic data sets will be presented.

*Speaker
†Corresponding author: okan.dukkanci@bilkent.edu.tr

A Nurse Routing Problem with operational side-constraints

Daniele Manerba * [1], Renata Mansini [2]

[1] University of Brescia, Dept. of Information Engineering – Via Branze, 38 - 25123 Brescia, Italy
[2] University of Brescia, Dept. of Information Engineering – Italy

We study an optimization problem that aims at scheduling the daily services performed by a set of nurses to a set of patients and, simultaneously, at routing the nurses in their visiting tours. The objective of this Nurse Routing Problem (NRP) is to maximize the overall daily benefit for the patients to receive the required services, while satisfying the scarce resources available to provide the assistance (number of nurses, time, and so on).
Among the health care applications, nursing home services play a central role because of the growing request for long-term home care observed in the recent years. Nursing care providers can guarantee a wide variety of medical and supporting services for non-independent people (elderly people and disabled individuals) highly improving the quality of their life.

We further complicate the problem by considering some realistic constraints imposed by the provider or by the patients, such as workload restrictions, service priorities, and potential incompatibilities among pairs of services for a single patient in the same day.

We cast this setting as a variant of the multi-vehicle traveling purchaser problem (MVTPP) and model it through mathematical programming techniques. After evaluating several different solution strategies, finally we focus on a branch-and-price exact solution approach based on a set-covering reformulation of the problem.
Computational experiments on a considerable set of benchmark instances (adapted from other application contexts to our nursing home service problem) are in progress. Preliminary results seem promising in proving our branch-and-price efficiency.

*Speaker

A Matheuristic for the MinMax Capacitated Open Vehicle Routing Problem

Jens Lysgaard *† [1], Ana Dolores López-Sánchez [2], Alfredo García Hernández-Díaz [2]

[1] Aarhus University – Denmark
[2] Pablo de Olavide University – Spain

The MinMax-COVRP (MinMax Capacitated Open Vehicle Routing Problem) is a variation of the COVRP where the objective is to minimize the cost of the route that has the maximum cost, i.e., to minimize the makespan. Using this objective function of optimizing the longest route we are taking into account the balance of the routes which is relevant in many real-world problems.

In the MinMax-COVRP, as in the COVRP, there are a set of customer nodes with a specified demand and a depot where a fleet of identical capacitated vehicles is located. The traveling cost between the depot and each customer node and between each pair of customer nodes is known. The problem then consists in finding a set of routes performed by the vehicles and such that each route starts at the depot and ends at one of the customers, each customer is served once by exactly one vehicle, and the vehicle capacity cannot be exceeded.

To solve the MinMax-COVRP, a matheuristic that combines a multi-start heuristic with mixed-integer linear programming (MILP) is proposed. The multi-start heuristic is able to build good quality solutions very fast and the MILP serves the purpose of improve those solutions, where we have embedded the solutions of MILPs into a customized version of a local branching framework involving also pyramidal constraints and special permissions for reversals of route segments. Computational results on standard test problems show promising results.

*Speaker
†Corresponding author: lys@econ.au.dk

Impact of a Mixed Fleet on Urban Emissions Routing

Jan Fabian Ehmke * [1], Ann Campbell [2], Barrett Thomas [2]

[1] Freie University Berlin – Advanced Analytics Group (FUB) – Garystr. 21, 14195 Berlin, Germany
[2] The University of Iowa – Management Sciences – The University of Iowa, Iowa City, IA 52242, United States

Minimization of emissions has become an important issue for municipalities and logistics companies operating in urban areas. In urban areas, trucks must travel at the speed of traffic, which is time-dependent. Thus, we cannot determine an emissions-optimized speed. Instead, we derive the expected emissions from detailed speed observations. We are interested in how emissions-minimized routes change over the course of the day and when considering fleets of vehicles of different sizes. To solve this problem, we use the Comprehensive Emissions Model (CEM) to evaluate emissions. The CEM derives emissions from speed, load, and engine type. We use the CEM to evaluate our objective, and embed it within an existing local search procedure, which is a tabu-search heuristic that was originally developed for the time-dependent vehicle routing problem. The procedure is adapted to include the computation of time-dependent, expected emissions-minimized paths between each pair of customers on the route. For computational experiments, we use instances derived from a real road network dataset and 230 million speed observations. We compare the emissions-minimized routes with routes found with more traditional objective functions, e.g. minimizing distances, to understand how they differ. We then analyze how routes change with different fleet compositions, where emissions objectives can lead to quite different results than traditional costs objectives. Experiments show that up to 10% of emissions can be saved with a mixed fleet. We also intend to present results on how a more realistic combined cost objective consisting of fuel and driver costs would change the planned routes.

*Speaker

Inventory Routing Problem over the long term: a math-heuristic approach

Nabil Absi [1], Diego Cattaruzza [2], Dominique Feillet [1], Maxime Ogier * [2], Frédéric Semet [2]

[1] Ecole des Mines de Saint-Etienne - CMP (CMP -EMSE) – EMSE – 880 avenue de Mimet, F-13541 Gardanne, France

[2] Centre de Recherche en Informatique, Signal et Automatique de Lille (CRIStAL) – Ecole Centrale de Lille – Cité Scientifique - CS 20048 59651 Villeneuve d'Ascq cedex, France

The problem we present is the object of the ROADEF Challenge 2016. It consists in an Inventory Routing Problem over a long time horizon with additional features: the objective function to minimize is fractional (cost per unit delivered); there is no prior assignment of drivers to trailers; the time is accurately modelled: non-constant hourly consumption of each customer is provided while minute-precise delivery planning needs to be determined; vehicles can perform multiple trips during the working day.

The problem calls for the determination of a delivery planning that respects operational constraints and avoids customer stockouts.

We propose a two-phase method. The first constructs journeys that are stored in a set S. The journeys are time-stamped and take into account the consumption of customers over the horizon, but delivered quantities are not fixed in a journey.

The second phase solves a restricted version of the problem by Integer Programming. The mathematical formulation introduced for the second phase is a path-based formulation where binary variables indicate whether a journey is selected in the solution. Additional variables determine delivered quantities.

Initially, only journeys in S can be selected to be part of the solution.

Then, the two phases are iteratively called adding and/or removing journeys from the model with the aim of improving the solution quality.

We deal with the non-linear objective function by applying, heuristically, the reformulation proposed by Charmes and Cooper (1962) for linear programs with fractional objectives.

Experimental results on the instances of the challenge will be presented.

*Speaker

Tackling a large production-routing problem in the meat stores of a hypermarket chain

Fábio Neves-Moreira *† [1,2], Luís Guimarães [2,1], Bernardo Almada-Lobo [1,2], Raf Jans [3,4], Jean-François. Cordeau [4,3]

[1] University of Porto – Reitoria da U.Porto Praça Gomes Teixeira 4099-002 Porto, Portugal
[2] INESC TEC – R. Dr. Roberto Frias, 4200 Porto, Portugal
[3] Centre Interuniversitaire de Recherche sur les Réseaux d'Entreprise, la Logistique et le Transport (CIRRELT) – Pavillon André-Aisenstadt, bureau 3520 2920, Chemin de la Tour Montréal (Québec) H3T 1J4 CANADA, Canada
[4] HEC Montréal – 3000 Chemin de la Côte-Sainte-Catherine, Montréal, QC H3T 2B1, Canada

Even though the joint optimization of sequential activities in supply chains is known to yield significant cost savings, the literature concerning optimization approaches that handle the real-life features of industrial problems is scant. The problem addressed in this work is inspired by the case of a Portuguese hypermarket chain which applies a Vendor-Managed Inventory (VMI) policy to its meat stores. The supply chain comprises a single meat processing centre with 13 production lines and a fleet of 35 vehicles that is used to deliver different products to 188 stores spread across the country. We propose a novel methodology which analyses the company's historical data to reduce the problem size, focusing on three main dimensions. First, similar SKUs with small sales quantities are aggregated. Second, stores with similar geographic positions and served at similar times are also clustered. Third, a reduced set of potential vehicle routes is generated, taking into account the characteristics of routes performed in the past. The aggregated data are fed into an Inventory-Routing Problem (IRP) model to solve the distribution part of the problem which outputs a delivery schedule and the quantities to be supplied by the processing centre. Afterwards, a Lot-Sizing Problem (LSP) formulation defines the product setups as well as the quantities to be produced by each production line. The company's operation is still based on handmade (decoupled) production and transportation plans, despite the promising gains offered by integration. Our objective is to solve the integrated problem and quantify the potential gains of this integration.

*Speaker
†Corresponding author: fabio.s.moreira@inescporto.pt

Tactical Supply Chain Distribution Planning In The Telecommunications Service Industry

Pierre Desport * [1], Frédéric Lardeux† [1], David Lesaint‡ [1], Carla Di Cairano-Gilfedder [2]

[1] Laboratoire d'Etudes et de Recherche en Informatique d'Angers (LERIA) – Université d'Angers : EA2645 – 2, Bd Lavoisier - 49 045 Angers cedex 01, France
[2] British Telecommunications (BT) – Adastral Park, Martlesham Heath IP5 3RE, UK, United Kingdom

Supply chains are ubiquitous across industries and a considerable effort has been invested in supply chain management techniques over the last two decades. In equipment-intensive service industries, it often involves repair operations. In this context, tactical inventory planning is concerned with optimally planning supplies and repairs based on demand forecasts and in face of conflicting business objectives. It is based on a case study in the telecommunications sector where large quantities and varieties of spare parts are required for service maintenance and repair tasks at customer premises or company exchanges. Specifically, we consider a multi-echelon spare parts supply chain and tackle the problem of determining an optimal stock distribution plan given a demand forecast. We propose a mixed integer programming and a metaheuristic approach to this problem. The model is open to a variety of network topologies, site functions and transfer policies. It also accommodates multiple objectives by the means of a weighted cost function. We report experiments on pseudo-random instances designed to evaluate plan quality and impact of cost weightings. In particular, we show how appropriate weightings allow to emulate common planning strategies (e.g., just-in-time replenishment, minimal repair). We also assess plan quality and system performance against different classes of pseudo-random instances featuring different volume and distribution of stock and demand.

*Speaker
†Corresponding author: frederic.lardeux@univ-angers.fr
‡Corresponding author: david.lesaint@univ-angers.fr

Smooth Operations in Rugged Supply Chains - Balancing Operations for the Inventory Routing Problem

Erdal Aydemir *† [1,2], Martin Josef Geiger [1], Sandra Huber [1]

[1] Helmut Schmidt University, Dept. of Logistics Management, Hamburg, – Germany
[2] Suleyman Demirel University, Engineering Faculty, Dept. of Industrial Engineering, Isparta, – Turkey

Many supply chains include fluctuating demand situations. For the resulting logistics operations, which are often modelled as an inventory routing (or vehicle routing) problem, this implies that a changing number of vehicles must be used throughout the planning horizon. This circumstance puts a stress on logistics and the resulting planning problems. Our work presents a solution approach to the inventory routing problem in the environment sketched above. With the aim of levelling the number of vehicles in use, we propose a novel solution encoding based on binary matrices, which encode detailed delivery decisions for each customer and timeframe. In order to produce feasible solutions in the optimization phase, an advanced decoder is introduced and studied, that corrects out-of-stock-situations, as well as customer and vehicle capacity violations. We closely investigate the effectiveness of this solution representation approach and monitor the effect of different solution construction techniques. Experiments on benchmark instances are conducted and a comparison to a lower bound, which we have found, is given.

Key words: Inventory routing problem, smooth operations, replenishment plan

*Speaker
†Corresponding author: erdalaydemir@sdu.edu.tr

The Joint Replenishment Problem with Approximated Routing Costs

Annelieke Baller *† [1], Said Dabia [1], Wout Dullaert [1]

[1] VU University Amsterdam – VU University Amsterdam De Boelelaan 1105 1081 HV Amsterdam The Netherlands, Netherlands

In the Inventory Routing Problem (IRP) the amount and timing of deliveries to individual customers is determined to minimize inventory holding and transportation costs. Given the complexity of the IRP, existing solution approaches are limited to solving small to medium-sized instances. We propose an alternative approach reminiscent of the Joint Replenishment Problem to minimize inventory holding and transportation costs in large scale distribution problems. Rather than servicing customers in an explicit route, subsets of customers are created and their routing cost is approximated.
To determine replenishment quantities at the level of individual customers and delivery moments at the level of subsets of customers, a branch-and-price framework is used. The master problem selects for each day at most one customer subset to be delivered by one or several vehicles to minimize costs. The customers subsets are determined by a pricing problem for which we are examining alternative approaches using routing cost approximations developed by a.o. Daganzo (1984).
The inventory routing problem under consideration is inspired by a real life case in replenishing ATMs. The banch-and-price framework is therefore tested on both artificial problem instances and real-life data.

*Speaker
†Corresponding author: a.c.baller@vu.nl

Liner shipping speed optimization with synchronization and port call restrictions

Line Reinhardt * [1], Christian Plum [2], David Pisinger [1]

[1] Danmarks Tekniske Universitet (DTU) – Denmark
[2] Maersk Line – Esplanaden 50, 1098 Copenhagen K, Denmark

Speed optimization for Liner shipping operations under emission control policies and canal and port workshifts is presented. Clearly speed optimization produces a win-win situation where companies save money on fuel and the environment benefits from the resulting reduced emissions. Liner shipping routes are periodic and transshipment between routes frequently occurs. Clearly speed optimization is not applicable to real life situations if canal and port workshifts are not satisfied in the solution delivered. Therefore it is very important to ensure the existing canal and port workshifts are introduced into model. Moreover the cost found when speed optimizing must also reflect the different fuel types and their costs to ensure over all savings for the company and to ensure compliance with the different environmental regulations. In this paper we expand the Liner shipping speed optimization problem with transit times to the real-life situation with canal and port workshifts and emission control areas and the fuel types required. Moreover we introduce services with alternative frequency. The transit times, limits the length of a journey on the network. The routes are not considered in the model, but the model could be used in a two phase heuristic for routing problems with transshipment and transit time requirements. Test results are shown on real-life instances from a major liner shipping company.

*Speaker

Global planning in a multi-terminal and multi-modal maritime container port

Stefan Balev [1], Sophie Michel *† [2], Eric Sanlaville‡ [3], Xavier Schepler§ [4]

[1] Laboratoire d'Informatique, de Traitement de l'Information et des Systèmes (LITIS) – Université du Havre, Normandie University – France
[2] Laboratoire de Mathématiques Appliquées du Havre (LMAH) – Normandie University – France
[3] Laboratoire d'Informatique, de Traitement de l'Information et des Systèmes (LITIS) – Normandie University, Université du Have – France
[4] Ecole des Mines de Saint- Etienne, LIMOS UMR CNRS 6158 – Ecole des Mines de Saint- Etienne – France

In the world-wide transport network, container ports act as intermodal interfaces, where containers are transferred between mother vessels, feeder vessels, river barges, trains and trucks. Nearby container ports are competing for traffic. Different factors have been identified as contributing positively to the attractiveness of a port, among which the operational efficiency of its terminals, and its connections to hinterland. New critical questions arise from the increase of vessel sizes, the contention of service roads, the urge for massified, cleaner transport modes. Container terminal operations have received considerable attention in the literature in recent years. Most of the studies focus on one isolated problem that occurs in one terminal, e.g. berth planning, quay crane scheduling, storage space allocation, etc. Only a few studies consider globally the flow of containers through several terminals in a port. However, a better partitioning of the workload between terminals, and the use of specialized terminals or platforms to help massifying the flows, may significantly improve the enlarged port competitiveness. This presentation proposes a multi-periodic tactical model to handle vessels, barges, trains, trucks and their containers over several cooperating terminals. The primary objective is to minimize weighted turnaround time. The problem is formulated as a mixed-integer linear program. Apart from direct solving by a MIP solver, we propose a new heuristic to solve MILPs made of several subproblems weakly linked together by constraints, called restrict-and-fix. Numerical experiments are conducted on realistic generated instances with up to three terminals. Results show the effectiveness of the approach.

*Speaker
†Corresponding author: michels@univ-lehavre.fr
‡Corresponding author: eric.sanlaville@univ-lehavre.fr
§Corresponding author: xavier.schepler@gmail.com

Robust Supply Vessel Planning with Heuristics

Yauheni Kisialiou *† [1], Irina Gribkovskaia‡ [1]

[1] Molde University College – Britvegen 2, 6410 Molde, Norway

Supply vessel planning problem arises in the upstream offshore oil and gas logistics, where supply vessels are the most expensive logistics resource. A fleet of supply vessels provides delivery of necessary materials and equipment to a set of offshore installations on a periodic basis from an onshore supply base. The problem itself involves scheduling, routing and packing decisions. The objective is to define an optimal fleet composition and a least-cost weekly sailing plan of scheduled vessels' voyages used repetitively over a season. Oil and gas operators require reliable and continuous service since the downtime of an installation is too costly. The challenge is that the service of installations in the winter season is affected by uncertain weather conditions, which influence vessels sailing and service times leading to delays and impossibilities to provide service as planned. Therefore, planners create vessel schedules with sufficient robustness against weather uncertainty to avoid frequent use of extra vessels. Robustness in practice is achieved by increasing the duration of voyages. In our study, we present and compare several known methodologies for construction of robust supply vessel schedules, and consider new approaches for incorporating robustness into a weekly sailing plan during its generation with heuristics. While previous research dedicated to robust supply vessel planning deals with problems of small and medium size, we develop a heuristic algorithm able to provide robust schedules for realistic large size problems.

*Speaker

†Corresponding author: yauheni.kisialiou@himolde.no

‡Corresponding author: Irina.Gribkovskaia@hiMolde.no

Unpredictability and inconsistency - routing in the domain of security services

Philipp Salzmann *† [1], Michael Schilde [1], Karl Doerner [1]

[1] University of Vienna – Vienna, Austria

Based on the most recent literature covering consistency, security aspects and surveillance tasks with respect to vehicle routing problems, we provide multiple problem formulations for two general routing problems in the domain of security related operations that cover a wide range of different applications as well as an easily accessible definition of the term inconsistency. While consistency tries to generate similarities in at least one of many criteria between different solutions, we assume inconsistency to aim for solutions with differences in at least one criterion. We present mathematical formulations to obtain those differences in two different criteria: node (time) inconsistency or arc (route) inconsistency as well as a combination of those. Our main focus in terms of the formulation was to deliver an assessment of the trade-off between additional routing costs and diversity in the set of found routes. An analysis of the two problem variants is given concerning their advantages in direct comparison against each other and their deterministic and stochastic formulation. We also considered other problems that were accessible with our formulation (e.g., robust production planning, routing in disaster relief). Since this work focuses on a new problem class, we tried to open the field of security related routing to the research by offering new test instances based on input and data from one of the biggest Austrian security service providers, a broad range of formulations, and first benchmarks with different solution approaches (with focus on matheuristic approaches).

*Speaker
†Corresponding author: philipp.salzmann@univie.ac.at

The Location Routing Problem with Intraroute Facilities

Maximilian Schiffer * [1], Grit Walther [1]

[1] Chair of Operations Management , RWTH Aachen University (RWTH-OM) – Kackertstraße7 52072 Aachen, Germany

The transportation sector faces major challenges in developing green, flexible and efficient logistic concepts. While electric vehicles play a key role in various future logistic concepts to cope with environmental impacts, freight replenishing or unloading goods on routes is addressed for same day deliveries or waste disposal. Within these concepts intermediate stops at intraroute facilities (e.g. charging stations or freight replenishment facilities) are needed to keep vehicles operational on their routes. While intermediate stops have already been addressed from a vehicle routing perspective for different application cases (e.g. electric fleets, waste disposal, grocery distribution, city logistics), location routing approaches addressing integrated routing and siting decisions for intraroute facilities are still sparse. Besides a first location routing approach focusing on simultaneous routing and siting decisions for electric logistic fleets, no research has been done in this field yet. Thus, a generic modeling approach addressing the whole range of application cases is still missing. Against this background, we present the Location Routing Problem with Intraroute Facilities, a generic model for simultaneous vehicle routing and intraroute facility siting decisions. In addition, we present an Adaptive Large Neighbourhood Search to solve large instances for the proposed application cases. Within this context we derive new penalty functions allowing for time efficient concatenation operators considering time dependent replenishing on routes. Results are shown focusing on simultaneous siting and routing decisions for electric logistic fleets. To highlight the benefit of the LRPIF, results are compared to the results of vehicle routing approaches.

*Speaker

Location-allocation and load assignment problem for a package delivery company

Maria I. Restrepo *† [1], Frédéric Semet [2], Thomas Pocreau [3]

[1] INOCS – Inria-Lille, Nord-Europe – France
[2] CRIStAL – Ecole Centrale de Lille – Cité Scientifique – BP 48, 59651 Villeneuve d'Ascq, France
[3] Colisweb – Colisweb – France

We study a location-allocation and load assignment problem for a package delivery company where order requests from customers are not known beforehand, as they are revealed dynamically throughout the day. The objective of the study is to generate, for each courier, a daily master plan and a detailed schedule to efficiently satisfy a random demand over time and to rapidly adjust to meet the sporadic, tightly constrained, delivery requests.
We propose to solve the problem through a two-phase method. The first phase is modeled as a two-stage stochastic programming problem where first-stage decisions correspond to the allocation of daily shifts to couriers and to the assignment of available couriers to geographic zones at each time period. Second-stage decisions (recourse actions) correspond to the allocation of a volume of packages to deliver at each time period, at each area by each courier and to the utilization of an external resource to cover unsatisfied demand. The second phase is modeled as an assignment problem where delivery patterns are generated and assigned to couriers in a dynamic way according to the master plan and the partial demand realization.
Preliminary computational experiments on real and randomly generated instances show that the use of our method prevents from incurring additional costs when compared with a deterministic approach.

*Speaker
†Corresponding author: maria-isabel.restrepo-ruiz@inria.fr

VRPTW with European Union regulations

Naima Belakbir *† [1], Ahcène Bounceur [1], Stéphane Croguennec [2], Reinhardt Euler [1], Marc Le Pouliquen [1], Marc Sevaux [3], Jean François Trevien [2]

[1] Université de Bretagne Occidentale - Lab-STICC (UBO/Lab-STICC) – Université de Bretagne Occidentale (UBO), CNRS : UMR6285 – 3 rue des Archives - CS 93837 - F29238 Brest cedex 3, France
[2] SYSTRANS – SYSTRANS – Rue Didier Daurat, 29600 Saint-Martin-des-Champs, France
[3] Université de Bretagne Sud - Lab-STICC (UBS/Lab-STICC) – Université de Bretagne Sud [UBS], CNRS : UMR6285 – BP 92116 - 56321 Lorient cedex, France

In the European Union, truck drivers must comply with a Regulation (EC) No 561/2006 , which provides a set of basic rules on daily or weekly driving time and break or rest periods after specific driving times. The resulting problem is a Vehicle routing problem with time windows (VRPTW) combined with a truck driver scheduling problem. It aims to find a set of routes for a fleet of vehicles, such that each customer is visited within its given time window, the accumulated load to be delivered (or collected) does not exceed the capacity of the vehicle, each truck driver can comply with applicable hours of service regulations, and the total transportation costs are minimized. This project is conducted in collaboration with SYSTRANS, a society specialized in solving large scale real-world VRPTWs. So far, our problem has attracted little attention in the vehicle routing literature. Heuristic approaches have been introduced by Goel (2009), Kok et al.(2010), Prescott-Gagnon et al. (2010) and Goel and Vidal (2014). For our case, the metaheuristic introduced by Goel and Vidal (2014) appears to be quite appropriate, due to its important contribution in terms of solution quality and computational efficiency. We intend to implement this algorithm, to test it on instances arising from SYSTRANS real-world applications, and to finally integrate European regulations.

*Speaker
†Corresponding author: n.belakbir@systrans.fr

Exact and heuristic splitting procedure for fixed sequence services for Home Health Care Routing Problem

Mohamed Cissé * [1], Yannick Kergosien [1], Christophe Lenté [1]

[1] Laboratoire d'Informatique de l'Université de Tours (LI) – Polytech'Tours, Université François Rabelais - Tours : EA6300 – 64, Avenue Jean Portalis, 37200 Tours, France

We focus on Home Health Care Routing Problem (HHCRP). HHCRP consists in designing routes followed by a team of home care workers to care a group of patients living in a given geographical area. For this scheduling stage, the decision maker has to take into account many constraints : time windows, qualification requirements, synchronization, temporal dependencies, continuity of care. HHCRP is then an extension of Vehicle Routing Problem (VRP) augmented by many unusual size-constraints coming from Home Care context. In this study, we propose an extension of the so-called Split Tour for HHCRP. Split Tour is the kernel of many successful heuristics for VRP. Given a fixed sequence of services to schedule, which represents a giant tour of services without trip delimiters, we propose a label setting algorithm in order to extract the optimal solution based on this fixed sequence. This algorithm takes into account the constraints of HHCRP. Valid inequalities has been added in order to reduce the labels generated thus decreasing the computational time. Due to the fact that the algorithm is exponential in theory, many suboptimal approaches has been implemented leading to faster algorithms : limiting the number of labels for each node, limit the number of total labels generated, relaxing synchronization constraints. Computational experiments has been conducted on randomly generated sequences and optimal sequences from instances of literature. We compare the results of the algorithm to those of CPLEX. Finally, some research perspectives are outlined.

*Speaker

Adaptive State Space Partitioning for Dynamic Vehicle Routing Problems

Ninja Soeffker * [1], Marlin Ulmer [1], Dirk Mattfeld [1]

[1] Technische Universität Braunschweig – Germany

Real-world routing applications are scientifically approached in the field of stochastic dynamic vehicle routing problems (DVRPs). For many of these problems, anticipation of uncertainty is mandatory. For a dynamic decision making that anticipates uncertainty, i.e., integrates stochastic information, methods of approximate dynamic programming (ADP) have been established in many research fields, e.g., managerial finance. These methods approximate the expected future outcomes of states in an approximation process and provide these estimates to allow anticipatory decision making. The application of ADP to DVRPs is limited because the structure of DVRPs is rather complex and the vast state space impedes the approximation process. States spaces are therefore often aggregated or partitioned in an a priori manner. Since DVRPs are complex, the required knowledge about the problem structure is often not available. Important information is then neglected permanently. Both approximation process and resulting solution quality are obstructed. In this work, we propose to partition the state space in an adaptive manner induced by the approximation process. Areas of the state space with many observations as well as areas with varying estimates of the future have to be considered in more detail. In order to focus on those areas of the state space that are "interesting", we successively adapt the partitioning of the state space during the approximation process. We analyze the results of the proposed method for a DVRP with one vehicle and stochastic pickup requests. Results show that a problem-specific partitioning and an efficient approximation can be achieved enabling anticipatory decision making.

*Speaker

A heuristic time-bucket approach for solving large-scale TSPTW arising in postal services

Alexis Bretin * [1]

[1] Ecole Polytechnique de Montreal – Campus de l'Université de Montréal 2500, chemin de Polytechnique Montréal (Québec) H3T 1J4, Canada

Parcel delivery is becoming an important activity of the postal services. The customers are divided into disjoint territories and one route must be established for each territory. Typically, around 10% of the customers (mostly commercial ones) must be serviced within relatively tight time windows. The others can be serviced at any time. In this context, the problem of building a route for a territory corresponds to a traveling salesman problem with time windows (TSPTW). This problem has recently been formulated using time buckets. However, for instances with 100 to 200 customers and no time windows for most of them, the time-bucket model becomes intractable. In this talk, we propose a heuristic approach that starts by clustering the customers to obtain a reduced-sized problem, then solves the corresponding time-bucket model, before desaggregating the clusters to obtain a final solution. We consider different clustering and desaggregation procedures and present various computational results to compare their effectiveness.

*Speaker

A real-world routing and scheduling problem of employees with different skills in multiple working locations

Alina-Gabriela Dragomir * [1], Pamela Nolz† [2], Ulrike Ritzinger‡ [2], Karl Doerner§ [1]

[1] University of Vienna – Vienna, Austria
[2] AIT Austrian Institute of Technology – Austria

We address a real-world routing and scheduling problem motivated by the difficulties in the Austrian tourism sector. Due to insufficient private and public mobility there occurs an imbalance between the demand for workforce and for employment. Although the demand is high on both sides, it appears low because of little possibility for people to reach potential workplaces. In our solution employees are flexibly scheduled to work in shifts of different skills and locations while all necessary transportation is provided. All schedules comply with detailed time constraint requirements of both employees and employers. The routing is modeled as pickup and delivery problem with time windows comprising inconvenience constraints and route duration constraints. Transportation is provided by multiple homogeneous vehicles that share a common depot. The overall objective of the problem is to create good schedules for the employees that comply with an efficient transportation, while fulfilling the requirements of the employers. The problem is presented and two different working time models are compared. The restrictive model corresponds to the traditional approach with rigid person and hour requirements per shift. The flexible model corresponds to an innovative approach using gliding time, and person and hour range requirements. A metaheuristics based on large neighborhood search is developed and solutions for both working time models are presented.

*Speaker
†Corresponding author: Pamela.Nolz@ait.ac.at
‡Corresponding author: Ulrike.Ritzinger@ait.ac.at
§Corresponding author: karl.doerner@univie.ac.at

Analysing metaheuristic algorithms for the vehicle routing problem with time windows

Jeroen Corstjens *† [1], An Caris [1], Benoît Depaire [1], Kenneth Sörensen [2]

[1] Hasselt University – Belgium
[2] University of Antwerp – Belgium

A large number of heuristic procedures have been developed to solve vehicle routing problems. These methods operate according to the setting of various parameters. This is often done by trial-and-error, by testing on a limited sample of benchmark instances, or simply quoting values from literature without any rigorous examination of their suitability in the used context. A configuration is rarely obtained through the use of some rigorous statistical procedure, but is usually based on personal experience and rules of thumb, often involving monotonous and time consuming experiments. Furthermore, such an approach limits any conclusions made to the specific problems considered in the used benchmark set. No statements can be made for unseen problem instances. A more rigorous parameter tuning can be obtained through the use of established experiment designs and the proper statistical tools.

We propose a new methodological framework that applies a multilevel regression perspective with the aim of gaining complete insights over the full range of algorithmic parameter values and problem characteristics. The regression analysis will allow us to identify the impact each parameter value and heuristic component has on performance, which parameter and component combinations achieve better results and what influence the problem characteristics have. Are any perceived gains in (meta)heuristic performance statistically significant or are they simply due to chance.

A first multilevel regression analysis is performed on a set of artificially generated VRPTW instances that are solved using a simplified version of the Adaptive Large Neighbourhood Search metaheuristic.

*Speaker
†Corresponding author: jeroen.corstjens@uhasselt.be

Horizontal Cooperation in Dial-a-Ride Services

Yves Molenbruch * [1,2], Kris Braekers [1,2], An Caris [2]

[1] Research Foundation Flanders (FWO) – Egmontstraat 5, BE-1000 Brussels, Belgium
[2] Hasselt University – Agoralaan Gebouw D, BE-3590 Diepenbeek, Belgium

A dial-a-ride system is an application of demand-dependent, collective people transportation. Users request a trip between an origin and a destination of choice, to which service level requirements are linked. The service provider attempts to develop efficient vehicle routes and time schedules, respecting these requirements and the technical constraints of a pickup and delivery problem. Given the ageing population, dial-a-ride systems gain importance to complement regular transportation modes. They also prevent isolation of vulnerable groups in society.
The current practice consists in that users choose a service provider to submit their request. Multiple providers operating in the same area solve separate routing problems based on the requests they received. However, research in freight transportation shows that horizontal cooperation may allow carriers to obtain joint operational benefits. The aim of the present research is to determine whether this also applies to people transportation, characterized by tighter quality requirements. Providers may exchange requests that are difficult to serve in their own routes and/or relocate vehicles among their depots.
Computational tests are carried out using a new large neighborhood search algorithm. Different data sets are used, ranging from artificial benchmark instances to data with real-life characteristics, such as clustered requests. Horizontal cooperation considerably reduces joint distance traveled and required fleet size. A pattern can be observed in which requests are exchanged among providers. These results provide support for the creation of an overarching body which collects all user requests in a certain area, after which a globally optimal route planning can be constructed.

*Speaker

Two cluster-based approaches for the Pick-up and Delivery Problem with Time Windows

Zaher Al Chami * [1], Hervé Manier [1], Marie-Ange Manier [1], Mohamad Khalil [1]

[1] Université de Technologie Belfort-Montbéliard (UTBM) – Research team OPERA (OPtimisation Et RéseAux) – 90010 Belfort Cedex, France

The Pickup and Delivery Problem with Time Windows (PDPTW) is an NP-hard problem since it is a generalization of well-known Vehicle Routing Problem with Time Window (VRPTW). The PDPTW models the situation in which a fleet of vehicles based at a depot must be routed to visit exactly once a set of nodes with known demands. Hence, vehicles have to transport loads from pickup locations to delivery locations while respecting capacity and time constraints. In our studies, we aim to solve the PDPTW with paired demands. To this purpose, a simple MILP mathematical model for the problem is first introduced. Likewise other optimization approaches, the new formulation can efficiently solve case studies involving at most 50 nodes to optimality in a short CPU time. To overcome this limitation, a preprocessing stage clustering nodes together is initially performed to yield a more compact cluster-based MILP problem formulation. In this stage, two different algorithms were developed: the first one is based on Euclidean distance between different nodes and the other one is a modified version of well-known K-means algorithm. Once we have applied one of those algorithms, a common function must be applied in order to verify that each customer-supplier pair belongs to the same cluster. We tested and compared our proposed approaches on numerous benchmark problems featuring different sizes, clustered/random node locations and time window distributions have been solved in acceptable CPU times.

*Speaker

Biosolver: a VRPTW solver for the nurses tour scheduling problem with hard time constraints

Stéphane Chrétien [1,2], Julien Coupey *† [3], Jean-Marc Nicod [4], Christophe Varnier [4]

[1] Laboratoire de Mathématiques (LM-Besançon) – CNRS : UMR6623, Université de Franche-Comté – UFR Sciences et techniques 16 route de Gray 25 030 Besançon cedex, France
[2] National Physical Laboratory (NPL) – Hampton Road Teddington Middlesex TW11 0LW, United Kingdom
[3] FEMTO-ST Institute – CNRS : UMR6174, Université de Technologie de Belfort-Montbeliard, Ecole Nationale Supérieure de Mécanique et des Microtechniques, Université de Franche-Comté – 32 avenue de l'Observatoire - 25044 BESANCON, France
[4] Département Automatique et Systèmes Micro-Macatroniques (FEMTO-ST/AS2M) – Université Technologique Belfort-Montbéliard, Ecole Nationale Supérieure de Mécanique et des Microtechniques, Université de Franche-Comté, CNRS : UMR6174 – 24, rue Alain Savary 25000 - BESANCON, France

In the nurses tour scheduling problem, many blood samples are collected at the patients' respective locations. This problem is difficult because of the hard timing constraints which have to be imposed in order to route the samples to the laboratory before they get too corrupted for any reliable medical diagnosis. To comply with the ISO 15189 norm, those constraints imply a drastic need to monitor the return and travel times of the collected samples. Moreover, many laboratories have recently undertaken a significant grouping of their collection activities. As a result, the nurses tour scheduling problem is now often a large scale combinatorial optimization problem.

The Biosolver project aims at proposing a tool to provide reliable solutions to the VRPTW (Vehicle Routing Problem with Time Windows) variant resulting from our model of the nurses tour scheduling problem. The additional constraints applying on return and travel times have a strong impact on the characteristic features of the solutions – often requiring multi-trips – and are especially challenging for validity concerns.

Our strategy uses a refined tuning of Solomons heuristics and a stochastic search based on Metropolis-Hastings' algorithm. The solver handles actual road topography and is used in production on a daily basis, providing solutions roughly improving by 30% over human-planned travel times. Our approach enjoys fast convergence with low variance in the solution quality, a crucial aspect for industrial use. Finally, performance is shown to compare well on usual VRPTW benchmarks although the approach is not specifically taylored for these problems.

*Speaker
†Corresponding author: julien.coupey@femto-st.fr

VRP++ - A software library for data structures supporting the fast and simple implementation of routing algorithms

Jörn Schönberger * [1]

[1] Technical University of Dresden (Tu Dresden) – Germany

In theory, VRP researchers are perfectly prepared to implement algorithms. They can produce self-explaining code that can be easily re-used. Their implementation job is well limited and focusses on the implementation of innovative algorithm issues only. Finally, they are able to realize a new implementation quickly so that new algorithmic ideas can be assessed immediately. Obviously, the observation of the reality reveals different issues: most generated code is readable only by its originator(s) and can hardly be reused. A lot of "overhead" implementation effort is needed until an algorithm runs: data structures needed to be defined and the preparation of features for data reading and results printing is needed. Finally, the effort to implement new algorithm ideas is often quite comprehensive since inflexible data structures have to be adjusted but the corresponding code is quite dispersed. The selection of an inappropriate coding language like MATLAB, Visual Basic or other scripting languages results in inefficient algorithm performance. Overall, implementation is quite time consuming and requires excellent programming skills that are often not available. VRP++ is a collection of C++ data structures and software classes. It enables students with small programming skills/experience to quickly code VRP-algorithms in C++. It prevents a lot of the unnecessary overhead implementation and offers functions to setup, manipulate or delete vehicle route sets. By means of some simple examples, we demonstrate the ease of using the VRP++ code to set up structured and understandable C++- code for algorithms to solve different types of vehicle routing problem scenarios.

*Speaker

An Adaptive Large Neighborhood Search for the Dial-a-Ride Problem

Timo Gschwind *† [1], Michael Drexl [1]

[1] Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University Mainz (JGU Mainz) – Germany

In the Dial-a-Ride Problem (DARP), user-specified transportation requests from origin to destination points have to be serviced by a fleet of homogeneous vehicles. The problem variant we consider aims at finding a set of minimum-cost routes satisfying pairing and precedence, capacity, time-window, maximum route-duration, and maximum user ride-time constraints. We propose an adaptive large neighborhood search (ALNS) for its solution. The key novelty of the approach is an exact constant-time algorithm for evaluating the feasibility of request insertions in the repair steps of the ALNS. Computational results indicate that the basic version of our ALNS is competitive to state-of-the-art methods for the DARP regarding both solution quality and computation times. To increase the solution quality, we propose two optional improvement techniques: A local-search based, intra-route improvement of all routes of promising solutions using the Balas-Simonetti neighborhood and the solution of a set-partitioning model including all routes generated during the search. Using these techniques, the proposed algorithm outperforms the state-of-the-art methods in terms of solution quality. New best known solutions are found for several benchmark instances.

*Speaker

†Corresponding author: gschwind@uni-mainz.de

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

Kris Braekers *† [1], Attila Kovacs [2]

[1] Hasselt University – Belgium
[2] University of Southampton – United Kingdom

Dial-a-ride services provide disabled and elderly people with a personalized mode of transportation to preserve their mobility. Typically, several users with different pickup and drop off locations are transported on a vehicle simultaneously. The focus in Dial-A-Ride Problems is mainly on minimizing routing cost. Service quality has been taken into account by imposing time windows and limiting the maximum ride time of each user. We extend the classical DARP by an additional feature of service quality referred to as driver consistency. Users of dial-a-ride services are often sensitive to changes in their daily routine. This aspect includes the person who is providing the transportation service, i.e., the driver of the vehicle. Our problem, called the Driver Consistent Dial-A-Ride Problem, considers driver consistency by bounding the maximum number of different drivers that transport a user over a multi-period planning horizon. We propose different formulations of the problem and examine their efficiency when applied in a branch-and-cut fashion. Additionally, we develop a large neighborhood search algorithm that generates near-optimal solutions in a short amount of time. Extensive computational experiments are conducted in order to assess the quality of the solution approaches. Results reveal that the cost of offering driver consistency varies greatly in magnitude. Depending on the instance, the cost of assigning one driver to each user can be up to 22.33% higher compared to a low-cost solution. However, routing cost increases by not more than 3.75% if users are transported by at least two drivers.

*Speaker
†Corresponding author: kris.braekers@uhasselt.be

The Third VeRoLog Solver Challenge

Gerhard Post *† [1], Bas Den Heijer [1]

[1] ORTEC – Netherlands

The Third VeRoLog Solver Challenge will be organized by ORTEC and VeRoLog. The case is based on the business of one of ORTEC's customers: it is a routing problem for the delivery and pickup of instruments to test milk quality for a planning horizon of several days. Milk farmers can request certain instruments. Such a request will have a time window for delivery of the instruments and a number of days that the instruments have to stay at the farm. After these days have passed the instruments have to be picked up again, and either can be brought back to the depot, or transported immediately to another farm. In the presentation we will describe the problem in detail, and present the tools for the challenge

*Speaker

†Corresponding author: Gerhard.Post@ortec.com

A matheuristic for the anticipatory service network design of bike sharing systems

Bruno Albert Neumann Saavedra * [1], Michael Römer [2], Teodor Gabriel Crainic [3], Bernard Gendron [3], Dirk Christian Mattfeld [1]

[1] Technische Universität Braunschweig – Germany
[2] Martin-Luther-Universität Halle-Wittenberg – Germany
[3] Université de Montréal – Canada

Bike sharing systems (BSS) have enhanced the public transportation system in several cities by offering bike rentals through automated rental stations. User can realize short-term free-of-charge trips between any pair of the BSS's stations. This provides a suitable solution for the "last mile" problem between other modes of transport and final destination of the user.
In order to fulfill a high percentage of the expected demand, a sufficient provision of bikes and free bike racks need to be ensured at each station during the day. However, due to spatial and temporal characteristics of the demand, e.g., commuting, some stations tend to run empty or full at particular times of a day. Empty and full stations prohibit rental and return of bikes, respectively. To rebalance the system, redistribution vehicles are available in order to relocate bikes among stations, yielding suitable time-of-day target fill levels.

We present the anticipatory time-dependent service network design, the core of the BSS's tactical planning level. The optimization model anticipates the scheduling of redistribution vehicles, bike relocation decisions, by considering the operational costs. The multi-objective function minimizes the penalizations applied for expected unmet demand and violation of self-predefined fill level specifications.
We propose a matheuristic to solve real-world-size problem instances. The solution approach combines neighborhood search with exact solution techniques provided by a commercial mixed-integer linear programming solver. The matheuristic is tested by computational experiments on a set of challenging problem instances.

*Speaker

Modeling Mobility Demands for Bike Sharing Systems

Jan Brinkmann* [1], Marlin Ulmer [1], Dirk Mattfeld † [1]

[1] Technische Universität Braunschweig – Germany

Due to increasing urban mobility demands, (station-based) bike sharing systems (BSS) have become an essential part of urban passenger transportation. In the last years, significant amount of work on controlling, especially on balancing BSS has been carried out. Until now, instances for computational studies are derived from historical data of trips, i.e., observations of spatio-temporal rental and return realizations for a particular real-world BSS. Thus, results of different approaches for similar problems are generally not comparable and not generalizable respectively. Further, customer detours and "lost sales", i.e., unsuccessful rentals and returns are usually not considered sufficiently. To allow a comparison and to consider lost sales, artificial BSS instances are required representing typical spatio-temporal mobility demand of BSS. In this contribution, we present models of parameterizable artificial BSS instances. To this end, we do not draw on data analysis of real-world BSS but analyze BSS business models, city structures, mobility demand patterns, and behavior of cyclists to model spatio-temporal demands for bike rentals and returns and the resulting trips respectively. To prove the rigor of the models, we compare the artificial BSS instances to trip observations of the according real-world BSS. Comparisons show that artificial and real-world BSS comprise the same spatio-temporal mobility demands.

*Corresponding author: j.brinkmann@tu-braunschweig.de

†Speaker

Workforce Scheduling and Vehicle Sharing to Reduce Carbon Emissions and Improve Service Quality

Pol Arias * [1], Jiyin Liu [1], Rupal Rana [1]

[1] Loughborough University – United Kingdom

Most previous research on the Vehicle Routing Problem (VRP) assumes that each driver is assigned to one and only one vehicle. However, in recent years, VRP variants with different settings and features found in practice have drawn attention from researchers. Along this line, vehicle sharing has attracted interest of big companies as it becomes increasingly important to reduce vehicle emissions. In this study, we consider a problem where workers with appropriate skills are to be assigned to perform tasks at various locations. The times needed for these tasks can be much longer than travel times between the locations. Therefore different workers sharing a vehicle could be beneficial. We introduce a mathematical programming model combining the vehicle routing and the task scheduling decisions with time constraints and allowing workers to share vehicles when travelling among the task locations. In addition, we present some computational results on small instances to validate our model.

*Speaker

The Vehicle Routing Problem with Occasional Drivers

Claudia Archetti* [1], Martin Savelsbergh† [2], M. Grazia Speranza ‡§ [1]

[1] University of Brescia – Italy
[2] Georgia Institute of Technology – United States

The concept of collaborative consumption in transportation has been explored in several different directions recently. We consider a setting in which a company not only has a fleet of capacitated vehicles and drivers available to make deliveries, but may also use the services of occasional drivers who are willing to make a single delivery using their own vehicle in return for a small compensation if the delivery location is not too far from their own destination. The company seeks to make all the deliveries at minimum total cost, i.e., the cost associated with its own vehicles and drivers plus the compensation paid to the occasional drivers. The option to use occasional drivers to make deliveries gives rise to a new and interesting variant of the classical capacitated vehicle routing problem. We design and implement a multi-start heuristic which produces solutions with small errors when compared with optimal solutions obtained by solving an integer programming formulation with a commercial solver. A comprehensive computational study provides valuable insights into the potential of using occasional drivers to reduce delivery costs, focusing primarily on the number and flexibility of occasional drivers and the compensation scheme employed.

*Corresponding author: claudia.archetti@unibs.it
†Corresponding author: martin.savelsbergh@isye.gatech.edu
‡Speaker
§Corresponding author: grazia.speranza@unibs.it

Horizontal co-operation in a clustered distribution context

Christof Defryn *† [1], Kenneth Sörensen [2]

[1] University of Antwerp (UAntwerpen) – Belgium
[2] University of Antwerp – Belgium

By dividing the distribution area in zones, the complexity of the large-scale distribution problem faced by courier companies can be reduced. As a result, the underlying optimisation problem can be modelled and solved as a clustered vehicle routing problem. In this research, the concepts of horizontal co-operation are applied to a group of courier companies. By allowing the exchange of zones between different collaborating partners, the global efficiency of executing the transportation requests might increase, resulting in a lower total logistics cost for the coalition (coalition efficiency). However, it should be ensured that all individual partners feel comfortable with the proposed solution and that the workload, cost,... is allocated back to the partners in a fair way.
We propose a two-level view on the collaborative clustered vehicle routing problem. A master problem, taking care of the coalition efficiency, is in charge of suggesting profitable interactions between the partners (cluster exchange). For each partner involved in this interaction, a slave problem is solved with the aim of evaluating the suggested move by defining an acceptance condition (cost price). Only if both partners agree, the move is executed.
As a result, an integrated solution approach that ensures both coalition efficiency and individual partner efficiency is obtained. Furthermore, a cost allocation method is included implicitly in the optimisation procedure.

*Speaker
†Corresponding author: christof.defryn@uantwerpen.be

Optimization of Inbound and Outbound Delivery Scheduling under Stochastic Dynamic Demand

Sila Cetinkaya *† [1], Liqing Zhang [2], Eylem Tekin [3]

[1] Southern Methodist University – United States
[2] United Airlines – United States
[3] University of Houston – United States

In this paper, we consider a joint inbound and outbound delivery scheduling problem applicable for a vendor operating under a vendor-managed inventory contract. Under the terms of the contract, the vendor has flexibility over the timing and quantity of resupply decisions at a group of retailers located in a given geographical region. Each retailer generates a stochastic order stream transmitted to the vendor using electronic data interchange capability. In this setting, employing a temporal shipment consolidation policy allows the vendor to hold smaller orders from the retailers and to release them in a combined load realizing transportation scale economies and improving truck utilization. Both the inbound and outbound deliveries incur fixed and linear costs leading to a challenging stochastic dynamic programming formulation of the problem at hand. We examine the optimal joint policy specifying the inbound and outbound delivery schedules so that transportation economies of scale are realized without excessive inventory holding and/or order delay. We characterize the structure of the exact policy and prove that clearing policies are not necessarily optimal.

*Speaker
†Corresponding author: sila@smu.edu

The stochastic delivery problem: introduction and solution by branch-and-price

Alexandre Florio * [1], Richard Hartl [1], Dominique Feillet [2]

[1] University of Vienna – Oskar-Morgenstern-Platz 1 A-1090 Vienna, Austria, Austria
[2] École Nationale Supérieure des Mines de Saint-Étienne (EMSE) – CMP-GC – 880 route de Mimet, 13120 Gardanne, France

We introduce the Stochastic Delivery Problem (SDP). The SDP is the problem faced by parcel delivery companies more concerned about maximizing customer satisfaction than minimizing routing costs alone. In this context, customer satisfaction is highest when the delivery attempt is successful - i.e., the customer is available for receiving the goods at the time the parcel company visits him.
To fully define the SDP we need to introduce the notion of customer availability profiles. These are general functions representing the likelihood of customers being available for deliveries at any instant during the regular delivery period.

The main objective in the SDP is to minimize the expected number of unsuccessful deliveries. To achieve this it might be optimal to visit the same customer more than once in a route. This is a key difference between the SDP and other related routing problems such as the Team Orienteering Problem.

We formulate the SDP as a set-partitioning problem and we apply the successful branch-and-price methodology for routing problems. In our case, however, the definition of strong dominance rules is not possible due to the generality of the availability profiles. For this reason, to solve the pricing problem we employ a labeling algorithm that, at each extension, bounds the minimum reduced costs that such extension can generate. We discuss different approaches to efficiently calculate these bounds, and present some acceleration strategies for solving the pricing problem.

Finally, we present some promising results for a few SDP instances.

*Speaker

A ruin & recreate approach to the capacitated vehicle routing problem

Jan Christiaens * [1], Greet Vanden Berghe [1]

[1] KULeuven – Belgium

Capacitated vehicle routing remains a challenging combinatorial optimization problem despite the significant academic progress of the last decades. The applicability of exact mathematical algorithms remains limited to relatively small capacitated vehicle routing problem (CVRP) instances. Heuristics are employed when solving larger size instances, which are representative of real world industrial challenges.
This abstract summarizes recent achievements in CVRP research and subsequently focuses on the development of an original powerful local search heuristic which entirely replaces the commonly applied 'set of neighbourhoods or heuristics'. This new heuristic is named ruin-adjacent-customer-strings & recreate strategy for VRP (VRP RACS&R).

A simulated annealing algorithm was constructed whose internal perturbation is solely dependent on the VRP RACS&R. Experiments were set up to assess performance, in terms of both computational speed and solution quality, on the recently published set of 100 CVRP instances. Current benchmarks were obtained by both an iterated local search based matheuristic (ILS-SP) and unified hybrid genetic search (UHGS).

Producing improvements for 39 instances and equal-quality solutions for 37 instances reveal VRP RACS&R's potential to replace existing heuristics for the CVRP. Computation times are considerably less (by 40% or more) than previous state of the art algorithms.
Work supported by IWT, Conundra (Baekeland grant 130855), the Belgian Science Policy Office (BELSPO) in the Interuniversity Attraction Pole COMEX (http://comex.ulb.ac.be) and Leuven Mobility Research Center. Editorial consultation provided by Luke Connolly, KU Leuven.

*Speaker

Total Risk Routing Minimization for the Fleet Size and Mix Problem for Hazardous Materials Distribution

Gustavo Bula *† [1,2], Caroline Prodhon‡ [1], Fabio Gonzalez§ [2], Hasan Afsar [1], Nubia Velasco [3]

[1] Laboratoire d'Optimisation des Systèmes Industriels (LOSI) – Université de Technologie de Troyes – Université de Technologie de Troyes 12, rue Marie Curie CS 42060, 10004 Troyes Cedex, France
[2] Machine learning, perception and discovery Lab (MindLab) – Cra 45 Calle 30 Bogotá, Colombia
[3] Universidad de los Andes, Administración de Empresas (UA) – Colombia

This work deals with a variant of Heterogeneous Vehicle Routing Problem (HVRP) in the context of hazardous materials (HazMat) transportation. The objective is to determine the set of routes that minimizes the total routing risk. This function is considered as dependent of the vehicle load and the population exposure to an incident when the vehicle is traversing a path connecting two customers. As the total routing risk is a nonlinear function, a piece-wise linear approximation is used. An algorithm composed by a local search procedure, a perturbation movement, and a probabilistic acceptance criterion was implemented. The local search procedure utilizes six different inter-route neighborhood structures. Two are the building blocks for evaluating and implementing all the neighborhoods: concatenation of two routes and splitting of a route. The six neighborhoods are explored exhaustively and the evaluation of resulting routes is performed in constant time. The number of feasible solutions that can be reached from an initial solution, and the total relative improvement are defined as neighborhood characteristics. Three different neighborhood ordering were applied to solve some instances of the HVRP for HazMat transportation with unlimited fleet and fixed costs: random neighborhood ordering, increasing value of the total relative improvement, and decreasing value of the total relative improvement. The results obtained are competitive in terms of computational efficiency and solution quality in comparison to those found using a mixed integer linear programming solver.

*Speaker
†Corresponding author: gabula@unal.edu.co
‡Corresponding author: caroline.prodhon@utt.fr
§Corresponding author: fagonzalezo@unal.edu.co

A Parallel Multi-Start NSGA II Algorithm for the Solution of Multiobjective Route-based Fuel Consumption Open Vehicle Routing Problems

Iraklis-Dimitrios Psychas* [1], Magdalene Marinaki† [1], Yannis Marinakis ‡§ [1], Nikolaos Matsatsinis¶ [1]

[1] Technical University of Crete (TUC) – University Campus 73100 Chania - Crete, Greece

In this paper, the Parallel Multi-Start NSGA II (PMS-NSGA II) algorithm is proposed and presented for the solution of four different Multiobjective Route-based Fuel Consumption Open Vehicle Routing Problems (MRFCOVRPs). In all problems the first objective function corresponds to the optimization of the total travel time of the vehicles and the second objective function corresponds to the minimization of the fuel consumption of the vehicles taking into account the travel distance, the load of the vehicles and other route parameters when the decision maker plans delivery or pick-up routes. In both cases (delivery or pick-up routes) the algorithm is tested for symmetric and asymmetric cases. The main differences of PMS-NSGA II compared to the NSGA II is the use in the PMS-NSGA II of three different local search methods for the creation of the initial population, the use of more than one populations (Parallel Multi-Start method) that are evolved in parallel, the use of a number of Pareto Fronts (equal to the number of populations) and the way that the Variable Neighborhood Search algorithm is used for the improvement of each solution separately. The results of the PMS-NSGA II and of the NSGA II algorithms are compared using four different evaluation measures in order to prove the effectiveness of the PMS-NSGA II algorithm and of each new characteristic of the proposed algorithm separately. A number of instances are used based on suitable modifications and combinations of classic benchmark instances used for the solution of TSP and CVRP.

*Corresponding author: ipsychas102@gmail.com
†Corresponding author: magda@dssl.tuc.gr
‡Speaker
§Corresponding author: marinakis@ergasya.tuc.gr
¶Corresponding author: nikos@dpem.tuc.gr

The Green Load Dependant Vehicle Routing Problem with Backhauls: A Revisited Case Study

Javier Belloso [1], Angel Juan [2], Javier Faulin * [3], Adrian Serrano [3]

[1] Departamento de Ingeniería Matemática e Informática, Universidad Pública de Navarra – Universidad Pública de Navarra Campus de Arrosadía 31006 Pamplona, Spain
[2] Universitat Oberta de Catalunya [Barcelona] (UOC) – Spain
[3] Universidad Pública de Navarra – Campus de Arrosadia 31006 Pamplona, Spain

Environmental management principles are gaining interest in today's highly competitive environment. Green logistics improvements presented in this paper are twofold. As a general framework, we consider the Vehicle Routing Problem with Backhauls (VRPB), where delivery and pick-up customers are to be served from a central depot. At the same time, the minimization of the CO2 emissions is included into the objective function as well as minimization of distance. Load factor is considered into the minimization objectives through the new introduced model: Load Dependant Vehicle Routing Problem with Backhauls (LDVRPB). Our methodology will be constructed taking this variant as a basis. The resolution procedure uses a multi-start approach designed to avoid the local minima. The algorithm employs a biased-randomized version of the classical savings heuristic, together with some local search processes. The savings list of edges is randomized using a skewed probability distribution. In order to validate our methodological approach we have revisited a real case of a company working in the food distribution sector in Spain. The obtained results show improvements above 7% in both distances and CO2 emission reductions.

*Speaker

Modelling choices in Green Vehicle Routing

Richard Eglese * [1]

[1] Lancaster University – United Kingdom

The subject of this presentation concerns models used to plan routes for road freight vehicles where environmental effects are taken into account. Greenhouse Gas (GHG) emissions for conventionally powered vehicles will be considered.
The types of models that are used to estimate GHG emissions are presented and compared in terms of the inputs needed and their complexity. Their use within vehicle routing models will be explored particularly considering the role of the speeds of the vehicles within the models.

For illustration, a model is presented for routing a fleet of delivery vehicles that minimizes the fuel emissions in a road network where speeds depend on time. In this model, the path for each vehicle between customers must be determined, and also the speeds of the vehicles along each road in their paths are treated as decision variables. The vehicle routes are limited by the capacities of the vehicles and there ar time constraints on the total length of each route. The objective is to minimize the total emissions in terms of the amount of GHG emissions produced, measured by the equivalent weight of CO2 (CO2e).

A column generation based tabu search algorithm is adapted to solve the problem. The method is tested with real traffic data from a London road network. The results are analyzed to show the potential saving from the speed adjustment process.

*Speaker

Dynamic path generation for the Proactive Route Guidance approach

Valentina Morandi * [1], Martin Savelsbergh [2], Enrico Angelelli [1], M. Grazia Speranza [1]

[1] University of Brescia – Italy
[2] Georgia Institute of Technology – United States

The presented proactive route guidance approach aims at integrating a system perspective: eliminating congestion on the road network, and a user perspective: minimizing distance travelled. The approach assigns paths to users so as to minimize congestion while not increasing their distance travelled too much. By limiting the set of paths considered for an origin-destination pair to those that have a relative difference in length with respect to the shortest path, the path's so-called Travel Inconvenience, which is below a given threshold, a maximum level of inconvenience is ensured and a certain level of fairness is maintained. An important feature of the approach is that it only solves linear programming models. The models require a complete enumeration of all those paths that are allowed by the maximum travel inconvenience level for each origin-destination pair. The generation may be very time consuming when big instances and/or high values of maximum travel inconvenience are considered. The aim is to present a dynamic method able to generate only a limited number of paths for each origin-destination pair. The impact of the dynamic approach on the number of generated paths and computational time will be shown in an extensive computational study carried out with different Maximum Travel Inconvenience values, network topologies and demand patterns.

*Speaker

A Benders based heuristic for a m-TSP with multiple time windows and selective cities

Marta Mesquita * [1,2], Ana Paias† [2,3]

[1] Instituto Superior de Agronomia, Universidade de Lisboa – Tapada da Ajuda, 1349-017 Lisboa, Portugal
[2] Centro de Matemática, Aplicações Fundamentais e Investigação Operacional (CMAFCIO) – Portugal
[3] DEIO, Faculdade de Ciências, Universidade de Lisboa – Universidade de Lisboa, Campo Grande, Edificio C6, 1749-016 Lisboa, Portugal

We address a variant of the TSP with multiple time windows (TSPSTW) in which the set of cities is partitioned into two subsets: mandatory and selective cities. All mandatory cities should be visited once within one of predefined time windows, ensuring that a visit occurs during working hours. A subset of the selective cities, whose cardinality depends on the tour completion time, should be visited within one of the associated time windows. The objective is to plan m circuits, each circuit not exceeding a predefined number of days, minimizing the total traveled distance and the completion time. We present a MILP model for the problem and propose a heuristic approach based on Benders decomposition. The heuristic alternates between the solution of a m-TSP master problem, defining the order by which mandatory cities are visited in each circuit, and the solution of a scheduling subproblem, establishing the starting time of each visit as well as the visits to selective cities. A genetic algorithm is developed to obtain feasible solutions for the master problem whereas a heuristic algorithm is proposed to solve the primal subproblem. In each iteration, a benders' cut, built from the dual solution obtained using feasibility and slackness conditions, is added to the master problem and the surrogate relaxation of all the cuts inserted so far is considered. Computational experience with real based instances shows that, at low computational expenses, Benders' cuts guided the building of the m circuits so as to obtain better feasible solutions for TSPSTW.

*Speaker
†Corresponding author: ampaias@fc.ul.pt

An Exact Method for the Periodic Inventory Routing Problem in a Lean Production System

Demetrio Laganà *† [1], Luca Bertazzi‡ [2], Jeffrey Ohlmann§ [3], Domenico Ventura¶ [1]

[1] Department of Mechanical, Energy and Management Engineering, University of Calabria – University of Calabria Via P. Bucci Cubo 46 C 87036 - Arcavacata di Rende (CS), Italy
[2] Department of Economics and Management (DEM) – Via S. Faustino 74/b-25122 Brescia, Italy
[3] The Henry B. Tippie College of Business at The University of Iowa (Tippie College of Business) – United States

We present a mixed-integer linear programming model to determine a periodic routing plan that supports the lean principles of level production planning and standardized work. We consider a lean production system consisting of a single manufacturing plant and a set of geographically-dispersed suppliers that supply a distinct product (component) to the plant. To facilitate level production planning, we require that the pickup amounts at each supplier are multiples of the daily demand and in exact proportion to the number of days since the last pickup. This results in an Inventory Clearing policy in which the inventory level of each supplier in every period is equal to zero after the pick-up. We seek to determine an inbound routing plan that collects component inventory from suppliers and delivers it to the plant at the minimum transportation and inventory holding cost. We present reformulations of the periodic IRP, under the Inventory Clearing policy, derived from the periodic single item Lot Sizing problem with Proportional Shipments. We define a generic family of valid inequalities, and then introduce delivery route inequalities for which the separation problem of generating violated inequalities can be solved effectively. A Branch-and-Cut algorithm is implemented to demonstrate the strength of the proposed reformulations.

*Speaker
†Corresponding author: demetrio.lagana@unical.it
‡Corresponding author: luca.bertazzi@unibs.it
§Corresponding author: jeffrey-ohlmann@uiowa.edu
¶Corresponding author: domenico.vnt@gmail.com

Fleet sizing and cyclic delivery scheduling for in-plant inventory routing

Necati Oğuz Duman *† [1], Gultekin Kuyzu [1]

[1] TOBB University of Economics and Technology (TOBB ETU) – Turkey

In assembly lines, materials are supplied to workstations from an in-plant warehouse known as the supermarket. The delivery process is done with vehicles known as tow trains, and wagons attached to them. Determining the number of tow trains, number of wagons attached to each train, amount of materials to be delivered to each station by which train, and scheduling and routing the trains are decisions continuously made in production plants. Avoiding congestion is a major concern in these decisions.
The in-plant inventory routing problem considers finding delivery routes and schedules of tow trains with minimum cost. Our objective is to determine the minimum cost fleet size, cyclic delivery routes and schedules, while preventing material stockouts at workstations and avoiding congestion under deterministic demand.

In this study, we develop an integer linear programming model to determine the fleet size, and to design the routes and schedules of the trains. Due to the complexity of the problem, we introduce heuristics to find good quality solutions. We test the effectiveness of our algorithms on randomly generated test instances.

*Speaker
†Corresponding author: necatioguzduman@gmail.com

An efficient algorithm for the Cyclic Inventory Routing Problem subproblem

Wouter Lefever *† [1,2,3], Khaled Hadj-Hamou [3], El-Houssaine Aghezzaf [1,2]

[1] Ghent University – Belgium
[2] Department of Industrial Systems Engineering and Product Design – Belgium
[3] Univ. Grenoble Alpes, CNRS, Laboratoire G-SCOP (G-SCOP) – Institut Polytechnique de Grenoble - Grenoble Institute of Technology – 46 Avenue Félix Viallet, 38000 Grenoble, France

The Single-Vehicle Cyclic Inventory Routing Problem (SVCIRP) is an optimization problem that provides a cyclic logistical plan, which maximizes the collected rewards while minimizing transportation and inventory costs, for the distribution of a product to a selected subset of retailers using one vehicle. It appears as a fundamental building block when column generation based methods are used to solve the cyclic inventory routing problem (CIRP). The current formulations for this problem all use a non-convex objective function. The presence of this non-convex objective function is a main complication in solving the SVCIRP efficiently, which in turn hinders the development of efficient solution methods for the CIRP. We examined the structure and mathematical properties of the SVCIRP and reformulated the problem so that its continuous relaxation is a convex problem. We proposed an adjusted branch-and-bound algorithm that solves the SVCIRP efficiently. Compared to the benchmark instances for this problem we were able to find new 23 out of 50 new best solutions and proved optimality of 22 other instances.

*Speaker
†Corresponding author: wouter.lefever@ugent.be

Adaptive Memory Programming for the Multi-Product Vehicle Routing Problem with Cross-Docking

Amalia Nikolopoulou *† [1], Panagiotis Repoussis [2,3], Christos Tarantilis [1], Emmanouil Zachariadis [1]

[1] Athens University of Economics and Business, Department of Management Science and Technology (AUEB) – Patision 76, 10434, Athens, Greece
[2] Athens University of Economics and Business, Department of Marketing and Communication (AUEB) – Patision 76, 10434, Athens, Greece
[3] Stevens Institute of Technology, School of Business – 1 Castle Point Terrace, Hoboken, NJ 07030, United States

This work studies the vehicle routing problem with cross-docking. A new realistic generalization of the problem is introduced, where customers require multiple products from several suppliers. Overall, the aim is to design the minimum cost set of routes for transporting various products via a cross-dock, given a set of suppliers and customers with known demands. The generated routes are subject both to capacity and maximum route duration constraints. An Adaptive Memory Programming framework is proposed for solving the problem. The framework incorporates a Tabu Search algorithm for intensification local search as well as novel adaptive memory mechanisms for generating provisional solutions and for guiding the search process. Computational experiments on well-studied benchmark instances of the literature with time window constraints, indicate that the proposed method is capable of generating high quality solutions within short computational times. Furthermore, the effect of using two different types of vehicles for the pickup and delivery routes is investigated. Lastly, various experiments on randomly generated instances are also performed to evaluate how the number of products and the geographical distributions affect the transportation cost.

*Speaker
†Corresponding author: amalianikolop@gmail.com

Solving the Multi-Vehicle Covering Tour Problem with a Dynamic Programming-Based Operator

Leticia Vargas *† [1], Nicolas Jozefowiez [1], Sandra Ngueveu [2]

[1] Laboratoire D'Analyse et D'Architecture des Systèmes (LAAS) – Université de Toulouse INSA – 7, avenue du Colonel Roche F-31400 Toulouse, France

[2] Laboratoire D'Analyse et D'Architecture des Systèmes (LAAS) – Université de Toulouse INP – 7, avenue du Colonel Roche F-31400 Toulouse, France

The multi-vehicle Covering Tour Problem (m-CTP) belongs to the class of routing problems known as tour location problems (TLPs). Compared to classic routing problems, in TLPs there is an additional level of decision making regarding the choice of the customers to visit and the customers not to visit. Then the customers to visit are clustered in routes and the best visitation order is found for each route.

In the m-CTP, the goal is to find m minimal-length routes over a subset of vertices such that the vertices outside the routes lie within a given distance from a vertex in any route. This study focusses on the case with restriction on the number of vertices allowed in a route, but no restriction on the route length.

The problem is NP-hard, and few solution methods have been proposed. We present a resolution procedure centred on a Selector operator which is dynamic programming based, and uses some techniques to avoid unnecessary creation of states. This operator is embedded in an adaptive large neighbourhood search, local search framework composed of several competing destroy and repair sub-heuristics chosen during the search with a frequency corresponding to their historic performance. The method is competitive as shown by the results obtained through computational experiments conducted on standard instances, and evaluated using the output of a state-of-the-art heuristic and exact algorithm.

*Speaker

†Corresponding author: lgvargas@laas.fr

A genetic algorithm based approach to vehicle routing problem with indirect deliveries in humanitarian logistics

Christian Clavijo Lopez *† [1], Nacima Labadie‡ [1], Caroline Prodhon§ [1]

[1] Laboratoire d'Optimisation des Systèmes Industriels (LOSI) – Université de Technologie de Troyes, Institut Charles Delaunay, 12 rue Marie Curie CS 42060 10004 TROYES Cedex, France

Humanitarian logistics specializes in the coordination of activities for the delivery of supplies and services after the occurrence of natural catastrophes (earthquakes, tsunamis or floods), and man-made crises (wars, spills or nuclear emergencies).
One of the most critical aspects is the distribution of humanitarian aid (water, food, personal items, health care assistance) to affected people, who are located separately in the disaster zone. Decisions on vehicle routing play an important role, since it determines the efficiency and effectiveness of disaster relief activities.

Humanitarian agencies should consider different criteria for delivering limited supplies by means of constrained resources. Apart from early response, equality and fair distribution among aid-recipients need to be considered.

The purpose of the study is to provide a modelling approach to deal with aid-distribution in the initial phase of response, taking into account the particularities in humanitarian relief operations. It considers disconnections in the routing system between nodes caused by inaccessible ways, for which an auxiliary transportation mode is necessary.
The mathematical model aims to minimize the total suffering of the system based on a cumulative time function. The problem is known to be a VRP with cumulative-time objective and indirect deliveries. The solution approach is based on MIP models that solve to optimality small instances. Additionally, an approximated approach based on genetic algorithms proves to return close-to-optimal solution for medium-size instances randomly generated.

*Speaker
†Corresponding author: cjclavijo@ulg.ac.be
‡Corresponding author: nacima.labadie@utt.fr
§Corresponding author: caroline.prodhon@utt.fr

Equity Objectives in Vehicle Routing: A Survey and Analysis

Piotr Matl *† [1], Thibaut Vidal [2], Richard Hartl [1]

[1] University of Vienna – Austria
[2] Pontifical Catholic University of Rio de Janeiro (PUC Rio) – Brazil

Logistics is multi-objective. The complexity of real-life planning and decision-making often cannot be reduced to cost only. Non-monetary aspects such as service quality, consistency, as well as social and environmental responsibility can be equally important differentiators in developed and competitive markets. A more holistic view of logistics can therefore improve the practical value and effectiveness of decision support systems.

In this contribution we focus specifically on VRP models dealing with equity and balancing objectives. Such models aim to capture the trade-off between cost optimization on the one hand, and equitable workload distribution and balanced resource utilization on the other. Although many contributions are found in the literature, there has been little discussion about how equity or balance should be defined in the context of vehicle routing, and measures for assessing this objective have been proposed and implemented without critical evaluation of their relative merits.

The purpose of our study is to take a step back and provide a more thorough foundation on which equity can be included in multi-objective VRP models. We survey and categorize the literature on equitable vehicle routing and collect the commonly applied inequality measures. Following an analysis of their theoretical properties, we conduct a computational study to examine how different equity objectives impact the properties of Pareto-efficient solutions and fronts. Significant differences are identified, methodological and theoretical implications are highlighted. We conclude by calling attention to some paradoxes of optimizing equity and point to open avenues for incorporating equity and balance criteria into logistics models.

*Speaker
†Corresponding author: piotr.matl@univie.ac.at

A Memetic Algorithm for the Mixed Capacitated General Routing Problem with Route Balancing

Geir Hasle *† [1], Lukas Bach‡ [1], Elin Halvorsen-Weare [2], Ingvild Lyckander [3], Christian Schulz [1]

[1] SINTEF – P.O. Box 124 Blindern, 0314 Oslo, Norway
[2] MARINTEK – Norway
[3] Norwegian University of Science and Technology (NTNU) – Norway

Lately there has been increasing research on the Mixed Capacitated General Routing Problem (MCGRP), a generalization of the Capacitated Vehicle Routing Problem and the Capacitated Arc Routing Problem. Although it is an important aspect of real-life VRPs, route balancing has drawn surprisingly little attention in the literature. A VRP solution, however close to optimal regarding travel cost, will often be considered useless in practice if the variation in duration, cost, or workload between routes is large.
We investigate a bi-criteria MCGRP with Route Balancing (MCGRP-RB) where total cost is one criterion and route balance the second. As route balance objective we minimize the difference in cost between the longest and the shortest route. Our approach is true bi-criteria optimization, and our goal is to find good approximations to the Pareto front in reasonable time. To this end we propose a memetic algorithm with two crossover operators and three mutation operators. All non-dominated solutions are kept in an archive. Separate archives are maintained for solutions that have high quality for one of the objective functions to enforce longitudinal diversity. Further, for each individual a rank is computed, which effectively creates several fronts of different quality.

A computational study shows that the method is able to produce the exact Pareto front for small instances. For larger instances, it yields new dominating solutions for several standard MCGRP test instances. At the conference, detailed results will be presented and compared, both to approximations produced by a competing metaheuristic, and to exact Pareto fronts.

*Speaker
†Corresponding author: geir.hasle@sintef.no
‡Corresponding author: Lukas.Bach@sintef.no

A Two-Phase Heuristic Approach for the Biobjective k-Dissimilar Vehicle Routing Problem

Sandra Zajac *† [1]

[1] Helmut Schmidt University / University of the Federal Armed Forces Hamburg – Holstenhofweg 85 22043 Hamburg, Germany

In cash-in-transit operations, significant amounts of money need to be delivered or picked up from a set of customers leading to some risk of robbery. A potential approach to decrease this risk is to generate k spatially dissimilar vehicle routes. By periodically changing the implemented route to a spatially dissimilar route, the unpredictability of the actually driven route can be increased which in turn can reduce the risk of robbery. A solution to the k-dissimilar vehicle routing problem is therefore a solution set. It will only be accepted by the decision maker if the difference between the distances of the longest route in the set to the distance of the shortest solution in the considered instance is within reasonable limits. Since the k shortest vehicle routes are often similar to each other, the k-dissimilar vehicle routing problem is inherently bi-objective. In this paper, the tradeoff between the minimization of the longest route and the maximization of the minimum dissimilarity between two vehicle routes is examined for k > 1. For this, a new dissimilarity index is defined which measures the spatial distance of two solutions on the base of a grid in an intuitive way. A two-phase heuristic approach is presented which takes into account these two objectives and approximates the efficient set of all solution sets. The method as well as the impact of different parameter settings are tested and studied on selected instances of the capacitated vehicle routing problem.

*Speaker

†Corresponding author: sandra.zajac@hsu-hh.de

Combining load plan design and vehicle routing

Juliette Medina *† [1], Michael Hewitt [2], Fabien Lehuédé [1], Olivier Péton [1]

[1] LUNAM / Ecole des Mines de Nantes / IRCCyN (EMN) – Ecole des Mines de Nantes – 1, rue de la Noë - BP 92101 - 44321 NANTES CEDEX 3 - France, France

[2] Loyola University of Chicago – United States

Freight transportation has received a growing attention in the last decades from the operations research community. In particular, more and more efficient models and algorithms are developed to optimize the design of freight transportation networks and the flow of goods in these networks. The distribution of goods in large structured networks is generally organized in two layers: (i) a long haul network, made of logistics hubs and terminals, and (ii) a local distribution network between a terminal and its associated customers. The routing of goods in long haul networks is studied in the field of service network design and, more precisely, load plan design. Local distribution deals with solving vehicle routing problems. Due to practical aspects and scales considerations, these two types of optimization problems are generally solved separately.

The company 4S Network acts as a 5PL provider for suppliers of the retail industry in France. It offers a service that facilitates the pooling of shipments at logistic hubs, called Collaborative Routing Centers (CRC). Pooled distribution routes are then subcontracted to local carriers. The synchronization of routes at CRCs is a key element to reduce costs and satisfy delivery deadlines. The resulting optimization problems integrate aspects from load plan design and vehicle routing.

Our goal is to propose an algorithm to solve integrated load plan design and vehicle routing problems. It is based on recent advances involving continuous time management in service network design problems.

*Speaker

†Corresponding author: juliette.medina@mines-nantes.fr

GPU parallelization of ALNS for the DCVRP

Lukas Bach * [1], Geir Hasle [1], Christian Schulz [1]

[1] SINTEF – P.O. Box 124 Blindern, 0314 Oslo, Norway

In recent years the computational capacity of the Graphics Processing Unit (GPU) in ordinary desktop computers has increased significantly compared to the Central Processing Unit (CPU). It is interesting to explore how this alternative source of computing power can be utilized. Most investigations of GPU-based solution methods in discrete optimization are based on swarm intelligence or evolutionary algorithms.

One of the best single-solution metaheuristics for discrete optimization is Adaptive Large Neighborhood Search (ALNS). GPU parallelization of ALNS has not been reported in the literature. We investigate ALNS on the GPU by developing a data parallel ALNS algorithm for the Distance-constrained Capacitated Vehicle Routing Problem (DCVRP). To achieve good utilization of the GPU, it was necessary to adapt the set of destroy and repair operators of a state-of-the-art CPU implementation.

The data parallel ALNS is implemented in NVIDIA CUDA. The Performance of a state-of-the-art CPU implementation and our GPU version is compared experimentally on an Intel Core i7-4770K with 3.5 GHz and an NVIDIA GeForce GTX TITAN. We use three standard DCVRP benchmarks: the Christofides, Mingozzi, and Toth instances, the Kelly instances, and the Li, Golden, and Wasil instances – in total a set of 46 instances with the number of customers ranging from 50 to 1200. On average, our GPU implementation of ALNS yields competitive solution quality with less runtime than the CPU implementation. However, on larger instances it is easier to utilize the parallelism of the GPU and achieve both improved solution quality and considerably improved runtime.

*Speaker

Optimization of a multimodal container transport network: application to the hinterland of the port of Shangha´i

Yulong Zhao * [1], Nathalie Bostel [1], Lu Chen [2], Pierre Dejax [1]

[1] Institut de Recherche en Communications et en Cybernétique de Nantes (IRCCyN) – École Nationale Supérieure des Mines - Nantes, Ecole Centrale de Nantes, PRES Université Nantes Angers Le Mans [UNAM], CNRS : UMR6597, Ecole Polytechnique de l'Université de Nantes – 1, rue de la Noë BP92101 44321 Nantes Cedex 03, France

[2] Jiao Tong University – Shanghai Jiao Tong University, School of Mechanical Engineering, 200240, China

As a fundamental component of the international transportation, the container transport between seaports and their hinterland has been the subject of many research concerns. A typical port-hinterland system is always based on a multimodal infrastructure network that includes road, railway and waterway modes. As an example, the port of Shangha´i is the 1st container seaport in the world, and its hinterland extends along the Yangtze River which is the most important economic region of China. In this paper, we present a multimodal container transport network model and its application to the improvement of the flows within the hinterland of the Shangha´i port, especially to reach a better share of the flows by the different modes. To that purpose, a tactical multimodal multiproduct single period network flow assignment model is proposed to evaluate scenarios including the current situation and possible new policies. This MILP model considers a set covering framework including a path-based formulation of the flows through the network, with the objective of minimizing the total transport cost to satisfy the demands subject to time constraints. A solution method is developed based on the column generation procedure. By analyzing the current hinterland network of the Port of Shangha´i, scenarios for improvements may be considered such as increasing the capacity of railway container transport and building new intermodal transfer terminals connecting the railway system to the sea port. The application of our model suggests that with these policies the total transport costs and duration could be reduced.

*Speaker

Lower Bounds for the Container Ship Stowage Planning Problem

Roberto Roberti *† [1], Dario Pacino [1]

[1] Technical University of Denmark – Anker Engelunds Vej 1 Building 101A 2800 Kgs. Lyngby, Denmark

In this talk, we deal with the problem of finding an optimal stowage plan for containers in a container ship. Containers on board are placed in stacks, located in many bays. The container ship follows a predefined route visiting a set of ports, and, at each port, containers destined to that port are unloaded, while containers destined to the next ports are loaded. As containers can be accessed only from the top of the stack, a number of shifting operations (i.e., operations of unloading/reloading a container destined to one of the next ports to access a container destined to the current port) need to be performed. Many operational constraints have to be satisfied to provide a realizable stowage plan, but we focus on the most basic version of the problem, called the Container Ship Stowage Planning Problem (CSSPP), as introduced by Avriel and Penn, Computers and Industrial Engineering (1993). Different heuristic approaches for the CSSPP have been proposed in the literature, but very little has been done in terms of lower bounds and exact methods for the problem. To the best of our knowledge, only two compact formulations have been proposed so far. We introduce alternative formulations and analyze the lower bounds that can be achieved from the corresponding linear relaxations. Promising computational results on real-life instances with different features will also be presented.

*Speaker

†Corresponding author: rorob@transport.dtu.dk

Managing the Flow of Containers in a Multimodal Network

Mohamed Hemmidy * [1], Adnan Yassine [1], Cédric Joncour [1], Sophie Michel [1]

[1] Laboratoire des Mathématiques Appliquées du Havre (LMAH) – Université du Havre – France

Due to the project of the Seine axis and its national importance, the ports of Paris and grand maritime ports of Rouen and Le Havre met since 2009 in the Economic Interest Group HAROPA. To avoid saturation of roads, the development of new river and rail services within the Havre port becomes imperative. We are interested in organizing an extensive harbor at the operational level. Deciding the mode of transport which is going to be used and the quantities stored and transiting multimodal hubs become a first class operational problem. We propose a mathematical model taking into account the different aspects of the issue. The objective of the problem is to minimize the overall cost of transportation in compliance different specificities related to the transport and storage containers. Several constraints should be considered. First, we need to meet the demand between the sites. For each demand, we have to respect a time window for care and a time window for delivery. Traffic may be restricted or even stopped on some routes in specific time slots. In addition, for inland waterway and rail transport, the transport capacity is limited. Also, in the level of multimodal platforms, we have a storage capacity and limited productivity. We also consider additional constraints due to the incompatibility between goods (hazardous-food, chemicals-explosives, etc.). We do not encounter this problem in this form in the literature. A method based on this formulation permits to solve realistic instances.

*Speaker

New advances for the block relocation problem

Fabien Tricoire * [1], Andreas Beham [2], Judith Fechter [2]

[1] University of Vienna – Vienna, Austria
[2] University of Applied Sciences Upper Austria – Austria

The block relocation problem (BRP) considers a set of blocks randomly distributed into stacks. All blocks have to be retrieved in a predefined sequence and at a given time, only those blocks which are on top of a stack may be retrieved. Otherwise, relocations are required. The aim of the BRP is then to retrieve all blocks in the predefined sequence while minimising the total number of relocations. Applications include the management of containers at container terminals, as well as the handling of steel slabs in steel production factories. A common assumption is that a block can only be relocated if it is above the next block to be retrieved according to the sequence, resulting in the restricted BRP. We introduce new heuristics and exact algorithms for the unrestricted BRP, which yields more opportunities for optimisation. Our contributions include fast heuristics able to tackle very large instances within seconds, a new fast metaheuristics that provide very competitive performance on benchmark data sets as well as a branch-and-bound algorithm that outperforms the best existing exact method and provides new optimal solutions. The heuristics use known lower bounds to determine which moves should be performed. The branch-and-bound algorithm relies on a look-ahead mechanism using the same lower bounds. It is also adapted to tackle the restricted BRP, again outperforming existing methods for that problem.

*Speaker

A MIP formulation for a Rich Vehicle Routing Problem in the food retailing industry

Felix Tamke * [1]

[1] Technische Universität Dresden (TUD) – TU Dresden 01062 Dresden, Germany

We consider a Rich Vehicle Routing Problem (RVRP) occurring at a large German food retailer. The company has to distribute the goods from a central warehouse to a number of supermarkets with respect to various constraints on a daily basis. To accomplish this task, it engages several carriers which supply the necessary amount of trucks and drivers. The payment of the carriers is regulated by distinct transport tariffs for the supply of each supermarket and each commodity class. Latter results from four different transport temperatures (deep-frozen to non-chilled) and leads to the usage of partitioned vehicles with up to three compartments alike. Since rearranging of the cargo on the load bed is prohibited plus unloading is only possible from the rear end and a compartment is solely accessible if the previous ones are empty a Last-In-First-Out loading policy is needed. Furthermore, the splitting of deliveries is allowed and backhauls are required to return used loading aids. To the best of our knowledge, there is no scientific and exact approach combining those properties. The described problem is modeled as a mixed integer program (MIP) using the three-index vehicle flow formulation. The MIP is solved by a branch-and-cut algorithm using the solver Gurobi. Known valid inequalities as well as derived problem specific valid inequalities are used to strengthen the linear relaxation and to break the formulation-inherent symmetry. Computational tests show that small instances of this challenging and practice-oriented RVRP can be solved to optimality within reasonable time.

*Speaker

Some Exciting New Problems in Vehicle Routing

Daniele Vigo [1], Bruce Golden [*†] [2]

[1] Alma Mater Università di Bologna - Department of Electric, Electronic and Information Engineering (DEI) – Viale Risorgimento, 2 40136 Bologna, Italy
[2] University of Maryland - Department of Decision, Operations and Information Technologies Robert H. Smith School of Business – College Park, MD 20742-1815, United States

The Vehicle Routing Problem (VRP) is one of the most studied optimization problems because it has many practical applications in logistics and transportation and it is so challenging to solve. During the last decade, many new variants of the VRP have been proposed. Some incorporate new constraints (e.g., parallelization and balance) or practical features, such as the on-board rearrangement of the load. Others integrate various phases of the supply chain planning process, as in inventory routing, or consider new technologies, such as electric/hybrid vehicles, RFID, telemetry, robots, and drones. Still others focus on the environmental consequences of vehicle routing. In addition, connections between vehicle routing and big data are starting to emerge. We outline some of this exciting, recent work in our presentation.

[*]Speaker
[†]Corresponding author: bgolden@rhsmith.umd.edu

Integrated Production and Outbound Distribution Planning in the Automotive Industry

Felix Zesch *† [1], Bernd Hellingrath [2]

[1] 4flow – Hallerstr. 1 10587 Berlin, Germany
[2] Westfälische Wilhelms-Universität Münster (WWU) – Leonardo-Campus 3 48149 Münster, Germany

Sustainable production and distribution become increasingly important for vehicle manufacturers. The distribution of finished vehicles provides many possibilities for rail transport to transshipment points, given the high transportation volume and the railroad access at both manufacturing plant and transshipment point. Yet, often trucks are used for shipping cars from the plant to the transshipment point. We propose an integrated planning of production and distribution on an aggregate level several weeks before production. It is compared to the currently applied two-step approach.
After a brief review of the state of the art in integrated production-distribution planning, general and industry-specific requirements are derived. A mathematical optimization model is subsequently created, combining a multi-resource general assignment problem (MRGAP) and a minimum cost network flow problem (MCNFP). The separately obtained solutions of MRGAP and MCNFP are provided as a starting point for a standard solver on desktop hardware to speed up the solution process. The model is applied to three different use cases with industry data from a German vehicle manufacturer. Solutions are evaluated with KPI considering cost, performance, environment, and computing time. The integrated model proves superior in all but the last category. On average, considered costs are reduced by 27%, rail transport is increased by 29%, waiting time for transport is reduced by 35%.
Finally, a corresponding business process for the application of the model is outlined, describing interfaces to other planning activities such as sequencing. The process can be used for implementing a decision support system.

*Speaker
†Corresponding author: f.zesch@4flow.de

Formulation and value of an integrated order picking-vehicle routing problem

Stef Moons *† [1], Katrien Ramaekers [1], An Caris [1]

[1] Hasselt University (UHasselt) – Martelarenlaan 42, 3500 Hasselt, Belgium

Order picking and distribution are interrelated as goods can only be delivered when the order picking process is completed. Historically, these problems are solved sequentially which often lead to suboptimal solutions. Integrating these subproblems into a single problem can add value. In an integrated problem both subproblems are solved simultaneously in order to obtain an overall optimal solution. Existing studies focus on integrated production scheduling-vehicle routing problems (PS-VRP).

In this presentation, an integrated order picking-vehicle routing problem (OP-VRP) will be formulated. Different orders need to be picked by order pickers in a warehouse. Thereafter, these orders need to be delivered using a fleet of vehicles. Due to the increase in the number of e-commerce transactions, customers order more frequently in smaller quantities. Customers expect a fast delivery within tight time windows. Therefore, the objective of the mathematical formulation is to minimize the total earliness and tardiness of order delivery.

The formulated mathematical problem is solved exactly using CPLEX for a small number of customer orders, order pickers and vehicles. Furthermore, a sequential approach is compared with the formulated OP-VRP to measure the value of integration. In the sequential approach, first an order picking problem is solved. Thereafter, the output of this problem is used as input for a VRP. In the integrated approach both problems are solved simultaneously. Preliminary results of the comparison between the two approaches will be provided.

*Speaker

†Corresponding author: stef.moons@uhasselt.be

Scheduling resource-constrained projects with transportation constraints

Philippe Lacomme *† [1], Aziz Moukrim [2], Alain Quilliot [1], Marina Vinot [1]

[1] Laboratoire d'Informatique, de Modélisation et d'optimisation des Systèmes (LIMOS) – Institut Français de Mécanique Avancée, Université Blaise Pascal - Clermont-Ferrand II, Université d'Auvergne - Clermont-Ferrand I, CNRS : UMR6158 – Bât ISIMA Campus des Cézeaux BP 10025 63173 AUBIERE cedex, France

[2] Heuristique et Diagnostic des Systèmes Complexes (HEUDIASYC) – CNRS : UMR7253, Université de Technologie de Compiègne – Université de Technologie de Compiègne - Centre de Recherches de Royallieu - rue Roger Couttolenc - CS 60319 - 60203 COMPIEGNE cedex, France

In this paper, the traditional resource-constrained project scheduling problem (RCPSP) is extended with transportation constraints on the resources between activities. The assignment of resources problem and the routing scheduling problem (which involves the strategic (*i.e.*, assignment of resources) and tactical/operational (i.e., routing scheduling) decision levels in supply chain management) are interdependent problems. Assuming that the project structure (location, duration and demand of activities) is provided it is also considered that decisions are known at the strategic level of the transportation problem. The routing of resources from a production facility to another is achieved by a heterogeneous fleet of vehicles. To solve the scheduling resource-constrained project with transportation constraints, we take advantage of a flow network model. By starting with a flow structure for the RCPSP with an insertion algorithm, we can propose a giant trip representation for the routing problem. This approach falls into the indirect split resolution scheme and a new splitting algorithm is introduced to obtain the routing solution of the specific pickup and delivery problem (PDP) which can be extended to the dial-a-ride problem (DARP). To improve this solution a local search is defined on the flow structure. A new set of instances is introduced and numerical experiments prove the efficiency of the approach. This work is the first step to solve problems with more than one resource and to minimize several objectives simultaneously.

*Speaker

†Corresponding author: placomme@isima.fr

The capacitated vehicle routing problem with sequence-based pallet loading and axle weight constraints

Hanne Pollaris * [1], Kris Braekers [1,2], An Caris [1], Gerrit K. Janssens [1], Sabine Limbourg [3]

[1] Hasselt University – Martelarenlaan 42 3500 Hasselt, Belgium
[2] Research Foundation Flanders (FWO) – Egmontstraat 5, BE-1000 Brussels, Belgium
[3] University of Liege (ULg), HEC Management School, QuantOM – Rue Louvrex 14 (N1), 4000 Liege, Belgium

The capacitated vehicle routing problem with sequence-based pallet loading and axle weight constraints is an extension of the classical Capacitated Vehicle Routing Problem (CVRP). It integrates loading constraints in a routing problem and is based on a real-world transportation problem. The demand of the customers consists of pallets. These pallets may be placed in two horizontal rows inside the vehicle. Sequence-based loading is imposed which ensures that when arriving at a customer, no pallets belonging to customers served later on the route block the removal of the pallets of the current customer. Furthermore, the capacity of a truck is not only expressed in total weight and number of pallets but also consists of a maximum weight on the axles of the truck. Axle weight limits pose a challenge for transportation companies as they incur high fines in the event of non-compliance. Weigh-In-Motion (WIM) systems on highways monitor axle weight violations of trucks while driving which increase the chances that axle weight violations are detected. Furthermore, trucks with overloaded axles represent a threat for traffic safety and may cause serious damage to the road surface. In this presentation, an Iterated Local Search (ILS) methodology is proposed to tackle the problem on realistic-size instances with networks consisting of 50, 75 and 100 customers. The effects of integrating axle weight restrictions in a CVRP on total routing costs are analyzed by comparing the results with those of the CVRP without axle weight restrictions.

*Speaker

The Split Delivery Vehicle Routing Problem with Time Windows and Synchronization Constraints

Nicola Bianchessi *† [1], Michael Drexl [1], Stefan Irnich [1], Christian Tilk [1]

[1] Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University – Jakob-Welder-Weg 9, D-55128 Mainz, Germany

In classical routing problems concerning the delivery of goods, each customer is served exactly once. On the contrary, by allowing split deliveries, customers may be served by means of multiple visits. This potentially results in substantial savings in travel costs, like in the Split Delivery Vehicle Routing Problem (SDVRP), the variant of the Vehicle Routing Problem (VRP) in which split deliveries are allowed (see Archetti and Speranza (2012) and Irnich, Schneider, and Vigo (2014)).

Even if split deliveries are beneficial to the distributor, on the customer side several visits may be undesirable: At each visit the customer has to interrupt his primary activities and handle the delivery.

In order to mitigate the inconveniences to the customers, Gulczynski, Golden, and Wasil (2010) and Xiong et al. (2013) consider a variant of the SDVRP in which split deliveries are allowed only if a minimum fraction of the customer's demand is delivered at each visit.

To the same purpose, but with a different prospective, we investigate the possibility to embed synchronization constraints into the definition of the routing problem: All split deliveries occurring to a customer must take place in a time interval of a given duration. Since time dimension is relevant, we consider the SDVRP with Time Windows (SDVRPTW) and define the corresponding variant with synchronization constraints (S-SDVRPTW). We design a branch-and-cut algorithm able to solve both the SDVRPTW and the S-SDVRPTW, and report on computational results showing the impact of synchronization constraints.

*Speaker

†Corresponding author: nbianche@uni-mainz.de

Vehicle routing and scheduling as a resource transfer problem

Illa Weiss *† [1], Christoph Schwindt [1]

[1] Clausthal University of Technology – Germany

In this talk we propose the resource transfer problem (RTP), a framework for modeling and solving rich vehicle routing and resource-constrained scheduling problems in a unified way. Basically, the RTP consists in scheduling a set of activities to be performed at different locations in a network using a set of vehicles and further resources like personnel, machines, or handling facilities. The activities may represent pickups and deliveries, visits of patients to ambulant medical care services, or tasks of multiple projects distributed over different sites. They have to be scheduled subject to generalized precedence relations defining minimum and maximum time lags between their start or completion times. Certain resources are shared among the locations, causing resource transfers in the network. The transfers are operated by a fleet of heterogeneous vehicles, which may, e.g., differ in load capacities, driving speeds, or access limitations. Within the RTP framework, we are able to model different types of VRP's, scheduling problems, and their combinations. Moreover, we can include a great variety of further side constraints arising in practical vehicle routing and scheduling applications. Examples of problem settings covered by the RTP are the dial-a-ride problem, the VRP with backhauls, the VRP with pickup and delivery, multi-mode resource-constrained project scheduling problems, or multi-site scheduling problems. As a solver for RTP we present a time-oriented branch-and-bound algorithm employing constraint propagation to prune the search space. We report on preliminary computational experience with the algorithm.

*Speaker

†Corresponding author: illa.weiss@tu-clausthal.de

The Active-Passive Vehicle-Routing Problem, Part I: Solution by Column Generation

Christian Tilk * [1], Nicola Bianchessi [1,2], Michael Drexl [1], Stefan Irnich [1], Frank Meisel [3]

[1] Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University Mainz (JGU Mainz) – Germany
[2] Department of Information Engineering, University of Brescia, Italy – Italy
[3] Christian-Albrechts-Universität zu Kiel (CAU) – Germany

This paper presents a branch-and-price algorithm for the exact solution of the active-passive vehicle-routing problem (APVRP). The APVRP covers a range of logistics applications where pickup-and-delivery requests necessitate a joint operation of active vehicles (e.g., trucks) and passive vehicles (e.g., loading devices such as containers or swap bodies). The problem supports a flexible coupling and decoupling of active and passive vehicles at customer locations in order to achieve a high utilization of both resources. Accordingly, the operations of the vehicles have to be synchronized carefully in the planning. The contribution of the paper is twofold: Firstly, we present an exact branch-and-price algorithm for this class of routing problems with synchronization constraints. To our knowledge, this algorithm is the first such approach that considers explicitly the temporal interdependencies between active and passive vehicles. The algorithm is based on a non-trivial network representation that models the logical relationships between the different transport tasks necessary to fulfill a request as well as the synchronization of the movements of active and passive vehicles. Secondly, we contribute to the development of branch-and-price methods in general, in that we solve, for the first time, an ng-path relaxation of a pricing problem with linear vertex costs by means of a bidirectional labeling algorithm. Computational experiments show that the proposed algorithm delivers improved bounds and solutions for a number of APVRP benchmark instances. It is able to solve instances with up to 76 tasks, 4 active, and 8 passive vehicles to optimality within two hours of CPU time.

*Speaker

The Active-Passive Vehicle-Routing Problem, Part II: Comparison of Column-Generation Subproblem Solvers

Christian Tilk [1], Nicola Bianchessi* [1,2], Michael Drexl† [1], Stefan Irnich ‡ [1], Frank Meisel§ [3]

[1] Chair of Logistics Management, Gutenberg School of Management and Economics, Johannes Gutenberg University Mainz (JGU Mainz) – Germany
[2] Department of Quantitative Methods, University of Brescia – University of Brescia, Department of Quantitative Methods, Italy
[3] Christian-Albrechts-Universität zu Kiel (CAU) – Christian-Albrechts-Platz 4, 24118 Kiel, Germany

Recently, Meisel and Kopfer (2014, OR Spectrum) introduced the Active-Passive Vehicle-Routing Problem (APVRP). Therein two classes of vehicles are required to fulfill pickup-and-delivery requests: Non-autonomous passive vehicles such as containers transport the cargo from its pickup to its delivery location. Autonomous active vehicles such as trucks can carry passive vehicles from one to another location. In the basic version we consider, each passive vehicle can load only one request at a time and each active vehicle can transport only one passive vehicle at a time. Each request must be executed by the same passive vehicle, while different active vehicles can be involved. For example, one active vehicle may deliver a passive to a pickup location and another active may later transport the passive from the request's pickup to its delivery point. Therefore, synchronization of active and passive vehicles is required. A column-generation algorithm is used to solve the APVRP, where the subproblem is a Shortest Path Problem with Time Windows and linear node costs (SPPRC-LNC). In this second part, we compare different solution methods for the SPPRC-LNC. The baseline approach is a labeling algorithm capable of solving the ng-tour relaxation bidirectionally. We compare is with a direct MIP-formulation, in which routing and resource variables are coupled without big-M technique. Moreover, the SPPRC-LNC can be solved with a column-generation algorithm giving rise to an overall nested column-generation algorithm.

*Corresponding author: bianchessi@uni-mainz.de
†Corresponding author: drexl@uni-mainz.de
‡Speaker
§Corresponding author: meisel@bwl.uni-kiel.de

A large neighborhood based matheuristic for the vehicle routing problem with cross-docking and dock resource constraints

Philippe Grangier * [1,2], Michel Gendreau [1,3], Fabien Lehuédé [2], Louis-Martin Rousseau [1,3]

[1] Centre Interuniversitaire de Recherche sur les Réseaux d'Entreprise, la Logistique et le Transport (CIRRELT) – Pavillon André-Aisenstadt, bureau 3520 2920, Chemin de la Tour Montréal (Québec) H3T 1J4 CANADA, Canada
[2] LUNAM / Ecole des Mines de Nantes / IRCCyN (EMN) – Ecole des Mines de Nantes – 1, rue de la Noë - BP 92101 - 44321 NANTES CEDEX 3 - France, France
[3] Ecole Polytechnique de Montreal (EPM) – Campus de l'Université de Montréal 2500, chemin de Polytechnique Montréal (Québec) H3T 1J4, Canada

The Vehicle Routing Problem with Cross-Docking (VRPCD) is a variant of the Pickup and Delivery Problem with Transfers with one compulsory transfer point: vehicles start by collecting items, then return to the cross-dock where they unload/reload some items and eventually visit delivery locations. The VRPCD has been proposed to model the routing part of the cross-docking distribution strategy, whict has been largely used since 1980s and is known to help reducing delivery costs compared to traditional distribution systems. In the VRPCD, it is assumed that a truck undergoes consolidation operations as soon as it arrives at the cross-dock. However, in real life the processing capacity of the cross-dock is a limiting factor, and as such several recent articles have outlined the need for a model that would take it into account in the routing problem. To that end, we introduce an extension of the VRPCD in which the number of vehicles that can simultaneously be processed at the cross-dock is limited. We call it the Vehicle Routing Problem with Cross-Docking and Dock Resource Constraints (VRPCD-DR). To solve it, we adapt a recently proposed method for VRPCD that relies on large neighborhood search and periodic calls to a set partitioning based problem. In particular we focus on feasibility tests in the reinsertion part of the LNS, as the capacity constraints at the cross-dock makes the scheduling subproblem NP-Hard. Our method has been tested on instances adapted from the VRPCD.

*Speaker

Heuristics for routes duration minimization in full truckload routing with resource synchronization

Axel Grimault * [1], Nathalie Bostel† [2], Fabien Lehuédé‡ [3]

[1] Institut de Recherche en Communications et en Cybernétique de Nantes (IRCCyN) – Ecole des Mines de Nantes – 1, rue de la Noë BP92101 44321 Nantes Cedex 03, France
[2] Université de Nantes- IRCCyN – Université de Nantes – 58 rue Michel Ange, BP 420 44606 Saint-Nazaire cedex, France
[3] LUNAM / Ecole des Mines de Nantes / IRCCyN (EMN) – Ecole des Mines de Nantes – 1, rue de la Noë - BP 92101 - 44321 NANTES CEDEX 3 - France, France

In public works companies, raw materials have to be transported by a fleet of heterogeneous trucks between sites for road building and levelling works. For some operations, in particular asphalt laying, some transportation requests may share a resource at their pickup or delivery locations (i.e. a loader machine or an asphalt paver). Hence, the routes that serve these requests have to be synchronized on this resource. This problem has been introduced as the full truckload pickup and delivery problem with resource synchronization (FT-PDP-RS).
The objective is to minimize a cost function composed of three terms: (i) fixed cost of using a truck, (ii) traveling cost and (iii) routes duration cost. The problem is solved with an Adaptive Large Neighborhood Search (ALNS) algorithm. An efficient feasibility procedure has been proposed to evaluate the feasibility of insertions.
We investigate the integration of a term that depends on routes duration in the cost function of the FT-PDP-RS. Integrating route duration minimization raises new difficulties, as "as early as possible" schedules are not optimal for a given set of routes. We present various approaches that have been proposed to handle this problem. The algorithms are evaluated on real life instances.

*Speaker
†Corresponding author: nathalie.bostel@univ-nantes.fr
‡Corresponding author: fabien.lehuede@mines-nantes.fr

Label Setting algorithm with Dynamic update of Pareto Front

Antoine Giret *† [1], Yannick Kergosien [1], Emmanuel Néron [1], Gael Sauvanet [2]

[1] Laboratoire d'Informatique de l'Université de Tours (LI) – Polytech'Tours, Université François Rabelais - Tours : EA6300 – 64, Avenue Jean Portalis, 37200 Tours, France
[2] La Compagnie des Mobilités – La Compagnie des Mobilités – 30 rue André Theuriet, Tours, France

To compute short paths on road networks in a cycling context, several criteria can be used like the distance, the security or the attractiveness of a route. Thus, a Multi Objective Shortest Path problem should be solved. We propose a new exact method, called Label Setting algorithm with Dynamic update of Pareto Front, in order to enumerate all solutions of Pareto front solution. The proposed algorithm is based on a two-phase method. In the first phase an approximation of the Pareto front is obtained with feasible solutions and some lower and upper bounds of each criterion is determined. The second phase performs a label setting algorithm with some improvement techniques that uses the previous lower and upper bounds to dynamically update the Pareto Front. Numerical experiments are performed on real data sets - with conflicting criteria - and on instances of the literature that allow to show the efficiency of the proposed method. In a second time, we propose and test a heuristic to obtain an approximation of the Pareto front on big networks and in a much lower computation time.

*Speaker
†Corresponding author: antoine.giret@univ-tours.fr

Integrated Aircraft Routing and Crew Pairing at Air France

Axel Parmentier * [1], Frédéric Meunier [2]

[1] Centre d'Enseignement et de Recherche en Mathématiques et Calcul Scientifique (CERMICS) – École des Ponts ParisTech (ENPC) – 6 et 8 avenue Blaise Pascal Cité Descartes - Champs sur Marne 77455 Marne la Vallée Cedex 2, France
[2] CERMICS - ENPC – École des Ponts ParisTech (ENPC) – 6 et 8 avenue Blaise Pascal Cité Descartes - Champs sur Marne 77455 Marne la Vallée Cedex 2, France

Once an airline has chosen the set of flights it operates, it must solve two problems. The Aircraft Routing Problem selects the sequences of flights or rotations operated by airplanes, and the Crew Pairing Problem selects the rotations operated by crews in order to minimize operational costs, while ensuring that each flight is covered by one aircraft and one crew, and that rotations respect aircraft maintenance and crew working rules. These two problems are usually solved sequentially, but as the feasible crew rotations depend on feasible aircraft rotations, the sequential approach leads to non-optimal solutions. This talk focuses on algorithms for Air France Integrated Aircraft Routing and Crew Pairing Problem. Column generation based matheuristics have been developed for the Integrated Problem during the last decade. The column generation subproblem builds feasible rotations, and happens to be a non-linear Resource Constrained Shortest Path Problem (RCSPP). Due to the complexity of the new European IR-OPS crew working rules, the usual RCSPP algorithms do not enable to solve exactly or approximately the subproblem in reasonable time. We introduce new bounds to discard partial solutions in the RCSPP, which enable to solve all Air France subproblem instances in at most a few seconds. We design a new cutting plane approach to transfer information between the Aircraft Routing and the Crew Pairing problems. Finally, we enforce robustness of the solution with respect to delay propagation through probabilistic constraints. Numerical experiments prove the efficiency of the approach on Air France instances.

*Speaker

Heuristics for the bi-objective Unidirectional Road Network Design Problem with Disruptions

Yipeng Huang * [1], Andréa Cynthia Santos [1], Christophe Duhamel [2]

[1] Institut Charles Delaunay, Laboratoire d'Optimisation des Systèmes Industriels (ICD-LOSI, UTT) – Université de Technologie de Troyes – 12, rue Marie Curie, CS 42060, 10004, Troyes CEDEX, France
[2] Université Blaise Pascal – Université Blaise Pascal - Clermont-Ferrand II – France

This study addresses a typical situation of disruptions happening on road networks. Predictable (e.g. planned maintenance, fair, sport, cultural event and demonstration) or unpredictable (e.g. accident, bad weather conditions and natural disaster) events can affect the network in urban areas. This requires the definition of alternate paths to avoid the blocked segments. The number of such disruptions typically depends on the city size. For instance, 8 000 interruptions are managed each year in Troyes conurbation, France. Due to the strong connectivity property, the alternate paths can require, in some cases, changing the segments' direction; these changes also have to take into account the disruptions time scale and the type of vehicles supposed to be rerouted. In this work, we investigate a version of this problem to manage disruptions on city centres or touristic areas. It is modelled as a bi-objective Unidirectional Road Network design problem with Disruptions and strong connecting requirements (bi-URND) and consists in defining alternate paths such that the number of arc reversals and distances are minimized, while ensuring that the final graph remains strongly connected. Metaheuristics based on Random Keys Genetic Algorithms (RKGA) to solve the bi-URND are proposed and tested over medium-size and large scale graphs.

*Speaker

The Prize-Collecting Vehicle Routing Problem with Setup Costs and Service Level Requirements

Christos Orlis * [1], Wout Dullaert [1], Demetrio Laganà [2], Daniele Vigo [3]

[1] VU University Amsterdam – Netherlands
[2] University of Calabria – Italy
[3] University of Bologna – Italy

We consider a novel variant of the Prize-Collecting Vehicle Routing Problem servicing customers with either deterministic or stochastic demand inspired by a real-life case. The objective is to maximize the profit obtained by servicing a selection of these customers. Each type of request is associated with a minimum acceptable service level and a profit level or prize. Service level requirements describe the minimum percentage of customer requests to be serviced. Furthermore, we take into account the setup costs of using additional resources for serving customers. We present a stochastic programming formulation of the problem in which the stochastic constraints are reformulated as probabilistic constraints. A deterministic equivalent mixed-integer programming model is derived. We propose a tailored algorithm that exploits the problem structure, and we present some preliminary computational results in order to assess the effectiveness of the proposed algorithm.

*Speaker

A Local Branching Matheuristic for the Multi-Vehicle Routing Problem with Stochastic Demands

Ola Jabali *† [1,2], Florent Hernandez‡ [1,3], Michel Gendreau§ [1,3], Walter Rei¶ [1,4]

[1] Centre Interuniversitaire de Recherche sur les Réseaux d'Entreprise, la Logistique et le Transport (CIRRELT) – Pavillon André-Aisenstadt, bureau 3520 2920, Chemin de la Tour Montréal (Québec) H3T 1J4 CANADA, Canada
[2] HEC Montréal – Canada
[3] Ecole Polytechnique de Montreal (EPM) – Campus de l'Université de Montréal 2500, chemin de Polytechnique Montréal (Québec) H3T 1J4, Canada
[4] Université du Québec à Montréal - UQAM (CANADA) – Canada

In this paper we propose a local branching matheuristic for the vehicle routing problem with stochastic demands (VRPSD). The actual demands are revealed upon arrival at customer locations. In this setting, a failure may occur if a vehicle does not have sufficient capacity to serve the observed demand of a customer. In the event of a failure, a recourse action is performed by having the vehicle return to the depot, replenish its capacity and resume its planned route at the point of failure. Thus, the objective of the VRPSD is to minimize the sum of the planned routes cost and of the expected recourse cost. Considering a local branching framework, we introduce an intensification procedure applied at each node of the local branching tree. We design a diversification strategy. Finally, we dynamically allocate the computation time within the branching tree. Extensive computational results demonstrate the effectiveness our matheuristic when compared to the optimal solutions.

*Speaker
†Corresponding author: ola.jabali@hec.ca
‡Corresponding author: florent.hernandez@cirrelt.ca
§Corresponding author: michel.gendreau@cirrelt.ca
¶Corresponding author: walter.rei@cirrelt.ca

Fast robust solutions to stochastic VRPs using SIMD instructions

Rune Larsen * [1]

[1] Technical University of Denmark (Department of Transport) (DTU Transport) – Anker Engelunds Vej 1 Building 116 2800 Kgs. Lyngby, Denmark

As information availability increases, and the ability to redirect vehicles becomes evermore common and cheap, methods for exploiting the new capabilities are evolving. Routing problems from the real world tends to be stochastic in nature, and their deterministic counterparts from academia an approximation. If the degree of stochasticity is significant, including it in the optimization often results in solutions that are of better quality and much more likely to be feasible. Given enough time, the optimal robust solution to the stochastic problem can be found. For online problems that time is rarely available.
A method is presented, that allows for more robust solutions through distribution sampling and Single Instruction Multiple Data (SIMD) instructions. SIMD instructions such as Advanced Vector Extensions (AVX) are available on most modern desktop processors, and they can be integrated into most existing heuristics for the deterministic problems with modest effort.
The focus is on the application of these methods in a dynamic reoptimization environment. The overhead of the method is demonstrated to be small, and different sampling strategies are presented, and their impact on solution cost and robustness are analysed.

*Speaker

Iterated local search for the workforce scheduling and routing problem

Fulin Xie *† [1], Chris Potts [1], Tolga Bektaş [2]

[1] School of Mathematical Sciences, CORMSIS, University of Southampton – United Kingdom
[2] Southampton Business School, CORMSIS, University of Southampton – United Kingdom

The combination of the general scheduling problem with the traditional vehicle routing problem gives rise to the Workforce Scheduling and Routing Problem (WSRP) that arises in practical applications. Given a number of service technicians with different skills and tasks at different locations with time windows and skill requirements, the WSRP consists of finding the assignment and ordering of technicians to tasks such that they only attend to tasks that they are skilled to perform, within the respective time windows, and that the total cost of the routing is minimised. This paper describes an iterated local search algorithm for solving the WSRP. The performance of the proposed algorithm is evaluated against an off-the-shelf optimizer and an existing adaptive large neighbourhood search algorithm on benchmark instances. The results indicate that the proposed algorithm can produce high-quality solutions in reasonable computational times. Keywords: workforce scheduling, vehicle routing, iterated local search

*Speaker
†Corresponding author: fulin.xie@hotmail.com

The technician routing problem with conventional and electric vehicles

Alejandro Montoya * [1,2], Christelle Guéret [2], Jorge E. Mendoza [3], Juan G. Villegas [4]

[1] Departamento de Ingeniería de Producción, Universidad EAFIT (EAFIT) – Carrera 49 N^o 7 Sur-50, Medellin, Colombia
[2] Laboratoire angevins de recherche en ingénierie des systèmes (EA 7315) (LARIS) – LUNAM Université, Université d'Angers – 4 boulevard lavoisier 49016 Angers, France
[3] Laboratoire d'Informatique de l'Université de Tours (LI) – Polytech'Tours, Université François Rabelais - Tours : EA6300 – 64, Avenue Jean Portalis, 37200 Tours, France
[4] Departamento de Ingeniería Industrial, Universidad de Antioquia – Calle 67 No. 53 - 108, Medellin, Colombia

The technician routing problem (TRP) consists in routing a set of technicians to serve a set of geographically scattered requests. This problem considers time windows, and the working schedule and skills of the technicians. Existing TRP studies assume that the technicians ride conventional internal combustion vehicles. However, nowadays, some companies are using electric vehicles on their operations of maintenance and repair. In this research, we introduce the technician routing problem with conventional and electric vehicles (TRP-CEV). This problem is an extension of the TRP, arising when the technicians use a mixed-fleet of conventional and electric vehicles (EVs). In the TRP-CEV decisions involve not only the routes but also the vehicle-to-technician assignment and the battery charging program for the EVs (where and how much to charge). The objective function of TRP-CEV seeks to minimize the total cost, defined as the sum of the energy and fuel costs, the fixed cost of battery charging, and the fixed cost of using each vehicle. We propose a mixed-integer linear programming formulation of the TRP-CEV that, running on a commercial optimizer, can solve small instances of the problem. To tackle large-scale instances we propose a metaheuristic approach. We present computational experiments on both randomly generated instances and real-world data from a public utility.

*Speaker

An Iterated Local Search Algorithm for Traveling Repairman Problem with Profits

Mualla Gonca Avci * [1], Mustafa Avci [1]

[1] Dokuz Eylül University – Turkey

Traveling repairman problem with profits (TRPP) is a generalization of the traveling repairman problem (TRP). TRPP generally arises as a routing problem on relief supply. In TRPP, a time-dependent profit is associated with each node, and there is no obligation to visit all nodes. The objective of the problem is to maximize total collected revenue. In this context, a multi-start iterated local search algorithm in which the variable neighborhood descent algorithm (VND) is integrated with an adaptive perturbation mechanism is developed for the solution of the TRPP. The performance of the developed algorithm is tested on randomly generated problem instances. The results indicate the effectiveness of the proposed approach.

*Speaker

Bi-objective optimization of vehicle routing problem for distribution of perishable food: A goal programming approach

Ufuk Yapar *† [1], Fulya Altiparmak [2]

[1] Gazi University – Turkey
[2] Gazi University – Ankara, Turkey

In increased competition environment, ensuring customer satisfaction has received a lot of attention from the companies. One of the most challenging sectors in providing customer satisfaction is the food sector dealing with perishable foods. This study considers the distribution problem of the perishable foods and formulates it as a bi-objective vehicle routing problem with objectives of maximization of freshness and minimization of total traveled distances. First, we propose a goal programming formulation of the problem. Since the vehicle routing problem is in the class of NP-hard problems, its goal programming variation is also NP-hard. Second, we develope a heuristic algorithm based on simulated annealing to solve the problem. Efficiency of the develped heuristic algorithm is tested on various size problems derived from Solomon vehicle routing problem with time windows benchmarks. Results show that the proposed algorithm is quite effective in reaching optimal or near-optimal solutions.

*Speaker
†Corresponding author: ufuk.yapar@hotmail.com

A variable neighborhood tabu search algorithm for the Vehicle Routing Problem with Multiple Time Windows

Maaike Hoogeboom * [1], Wout Dullaert [1], David Lai [1], Daniele Vigo [2]

[1] VU University Amsterdam – Main building VU University Amsterdam De Boelelaan 1105 1081 HV Amsterdam The Netherlands, Netherlands
[2] Università di Bologna (UNIBO) – Via Zamboni, 33 - 40126 Bologna, Italy

In the Vehicle Routing Problem with Multiple Time Windows (VRPMTW) every customer has to be served in one of its k time windows. Our objective is to minimize the total duration (total travel time + total waiting time) by selecting an optimal combination of time windows and determining vehicle routes. Existing efficient metaheuristic developed for the VRP with Time Windows often involve insertion and removal of customers from the vehicle routes of the current solution. In the presence of multiple time windows, local search operations used for the VRPTW become more challenging: for a vehicle route of n customers there could be kˆn possible combinations of time windows. In this research we present a polynomial time algorithm to efficiently determine the optimal time window combination whenever a neighborhood operation is applied. To check if a solution is feasible and to calculate the minimal route duration, we introduce Forward and Backward Start Intervals. These intervals represent the start times of servicing a customer such that the preceding (following) customers in the route are all served in one of their time windows. A variable neighborhood tabu search algorithm is developed and compared to best-known solutions on VRPMTW instances from the literature. At the conference we will show detailed computational results and we will examine the trade-off between minimizing the total duration and minimizing the travel time.

*Speaker

A Matheuristic Approach for Solving the Electric Vehicle Routing Problem with Time Windows and Fast Recharges

Merve Keskin * [1], Bülent Çatay [1]

[1] Sabanci University – Faculty of Engineering and Natural Sciences, Istanbul, Turkey

The Electric Vehicle Routing Problem with Time Windows (EVRPTW) is an extension of the well-known VRPTW where an electric vehicle (EV) fleet is used instead of internal combustion engine vehicles. An EV has a limited driving range due to its battery capacity and may need to visit stations for recharging while servicing the customers along its route. Recharging may take place at any battery level and the energy charged may be any quantity up to the battery capacity. Furthermore, the stations may be equipped with chargers with different power supply, power voltage, maximum current options which affect the recharge duration. In this study, we model the EVRPTW by allowing partial recharges with two recharging configurations which can be referred to normal recharge and fast recharge. In fast recharge, the battery is recharged the same energy in a shorter time but at a higher cost. Our objective is to minimize the total recharging cost while operating minimum number of vehicles. We formulated this problem as a mixed integer linear program and solved the small instances using CPLEX. To solve the larger problems we develop a matheuristic approach which couples the Adaptive Large Neighborhood Search (ALNS) approach with an exact method. Our ALNS is equipped with various destroy-repair algorithms to efficiently explore the neighborhoods and uses CPLEX to strengthen the routes obtained. We carried out an extensive computational study to investigate the benefits of fast recharges and test the performance of the proposed approach using benchmark instances from the literature.

*Speaker

New techniques for Constraint Programming based heuristics for VRP

Katharina Glock *† [1], Anne Meyer [1], Guido Tack [2]

[1] Forschungzentrum Informatik (FZI) – Haid-und-Neu-Straße 10-14 76131 Karlsruhe, Germany
[2] Monash University – Australia

In order to provide flexible services for solving vehicle routing problems (VRP), logistics professionals should be enabled to easily adapt the planning tool even without having a background in optimization. Constraint Programming (CP) combines an expressive modelling language and problem-independent search methods, thus making it a promising candidate for a planning engine for such a flexible service. Users can add or remove constraints without having to modify either the core model formulation or the solution methods. Large Neighbourhood Search (LNS) proposed by Shaw (1998) is the most frequently used heuristic for solving VRP in a CP framework. We introduce the basic solution architecture with particular consideration of CP specific features. We furthermore present current research combining LNS and Monte-Carlo tree search (MCTS), an algorithm originally proposed for decision making in non-deterministic games that aims at balancing the exploration of a search tree and the exploitation of sub-trees that are likely to contain good solutions. We apply MCTS for constructing the initial solution as well as for solving the sub-problems created by the LNS. Integrated into the CP framework, MCTS provides a robust search algorithm that adjusts itself to the properties of the problem at hand, thus ensuring the flexibility of the search framework. Results are promising with respect to quality and runtime for several problem classes such as the VRP with time windows, the VRP with pickup and delivery, and the periodic VRP with time windows.

*Speaker
†Corresponding author: katharina.glock@fzi.de

The pollution-routing problem with stochastic travel times

Moncef Ilies Nasri * [1], Tolga Bektaş† [1], Gilbert Laporte [2]

[1] CORMSIS and Southampton Business School – University of Southampton, Southampton SO17 1BJ, United Kingdom, United Kingdom

[2] Centre interuniversitaire de recherche sur les reseaux d'entreprise and HEC (CIRRELT and HEC) – HEC Montreal, 3000, chemin de la Côte-Sainte-Catherine Montréal, Canada H3T 2A7, Canada

The amount of greenhouse gases emitted by a vehicle is related to the quantity of fuel consumed, which, in turn, is affected by a number of parameters including speed and load. A variant of the classical VRP where pollution has been explicitly accounted for is the Pollution-Routing Problem (PRP). In addition to finding routes, the PRP determines optimal speeds at which vehicles should travel on each leg of the route to serve a number of customers under time window constraints, so as to minimize a comprehensive cost function including fuel consumption. The PRP imposes fixed limits on vehicle speeds on each leg, which is assumed to be known with certainty at the time of planning the routes. In reality, however, vehicle speed is often affected by factors that are not known in advance with certainty, such as congestion or weather, which will change speed limits and consequently impact the optimal speeds computed. This talk will introduce a new variant of the PRP with stochastic speed limits. We will describe two formulations for this problem. The first formulation is a single-stage stochastic programming model with complete recourse. In this case, the recourse variables correspond to any delays experienced in servicing the customers and any violation of the speed limits. The second is a two-stage stochastic programming model that takes advantage of a fast speed re-optimization procedure, used in the second stage, and applied after the realization of a scenario as a "corrective" action, in the expectation of a further cost minimization.

*Speaker

†Corresponding author: T.Bektas@soton.ac.uk

Experiments with different formulations for the Capacitated Arc Routing Problem

Enrique Benavent * [1], José M. Belenguer [1], Angel Corberán [1], Isaac Plana [1], José. M. Sanchis [2]

[1] Universidad de Valencia – Spain
[2] UNIVERSIDAD POLITECNICA DE VALENCIA – Spain

In this talk we analyze two different integer programming formulations for the Capacitated Arc Routing Problem defined on an undirected graph (CARP). One formulation uses directed variables while the other uses non-directed variables.
For each formulation, a branch-and-cut algorithm has been implemented to solve the CARP optimally. All families of known valid inequalities for this problem and for the Rural Postman Problem, which is a particular case of the CARP, have been considered and their corresponding separation algorithms have been implemented.
Preliminary computational results will be presented.

*Speaker

Author Index

VRP-REP

The vehicle routing problem repository
www.vrp-rep.org

What is VRP-REP?

VRP-REP is an open data platform for sharing vehicle routing problem benchmark instances and solutions.

What can you do with VRP-REP?

- Upload VRP instances in a pre-defined format (the VRP-REP instance specification) or your own format
- Share instances with other users or the general public
- Share instances privately with referees and editors during the reviewing process
- Share your solutions with the community
- Download instances shared by other users
- Track the best known solutions for registered datasets
- Subscribe to notifications of newly contributed datasets and solutions
- Access open-source code for solution checking and instance generation
- Propose extensions and enhancements to the VRP-REP instance specification
- Browse the VRP-REP database of VRP publications

Join the nearly 250 current users and start sharing your VRP data now!

VRP-REP
The vehicle routing repository
info@vrp-rep.org
www.vrp-rep.org

A project sponsored by:

VeRoLog
EURO Working Group on Vehicle Routing and Logistics Optimization