VeRoLog 2017 Amsterdam

10-12 Jul 2017
Amsterdam
Netherlands

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Allocating and Transporting Resources to Demand-Locations

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Imagine a scenario where we have a limited number of *resources* and a number of *demands* for these resources. For each resource, we know its present location and the point in time at which it will become available. For each demand, we know the resource it needs. We also know when, where and for how long it needs that resource. Furthermore, a resource could be compatible with other resources. This means, a demand for a particular resource could also be satisfied with one of the resources compatible to it.
Now place the scenario mentioned above in a dynamic, online setting. That is, the demands come in over time, some resources stay a bit longer at their current location, and some other resources need a break. So given this dynamic situation, the problem we tackle is to first (re-)allocate the available and soon to be available resources to as many demands as possible, and thereafter to suggest a way to transport the allocated resources to their demand-locations by solving a vehicle routing problem with pickups and deliveries (VRPPD).
We present a rolling horizon framework that solves this problem repeatedly and economically. Based on the current situation, including the status of vehicles, our framework can create new routes and update existing routes as well.

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Minimizing Total Latency in Post-disaster Debris Removal

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As a result of a natural disaster, roads can be damaged and blocked by debris and other structures. This in turn impedes accessibility between critical locations such as hospitals, disaster response centers, shelters, airports and disaster-struck areas. We study the post-disaster road clearing problem with the aim of providing a fast and effective method to determine the route of a work troop responsible for clearing the blocked roads. The objective is to minimize the total latency, that is, the sum of the waiting times until each critical location is reached by the troop over all critical nodes. The latency of a critical node is the travel time from the origin (depot) node, where the work troop is initially positioned, to that critical node. The Total Latency Problem is to find an optimal route to determine which roads should be unblocked in what order. We develop an exact mathematical model for this NP-hard problem. However, for instances with more than seven critical nodes, the exact formulation falls short of solving the problem optimally in the 3-hour time limit. Hence, we propose an efficient heuristic method to find a near-optimal solution in short running time. We test the heuristic on Istanbul data and show that optimal or near-optimal solutions are obtained within seconds.

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Multi-vehicle prize collecting arc routing for connectivity problem

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After a natural disaster roads can be damaged or blocked by debris, while bridges and viaducts may collapse. This commonly observed hazard causes some road sections to be closed and may even disconnect the road network. For effective disaster response, roads should be cleared or repaired to provide accessibility and relief services to the affected people in shortest time. We study an arc routing problem that aims to regain the connectivity of the road network components by clearing a subset of the blocked roads. In this problem, we maximize the total prize gained by reconnecting disconnected network components within a specified time limit. These prizes are determined based on the population of the components. The solution should determine the coordinated routes of each work troop starting at a depot node such that none of the closed roads can be traversed unless their unblocking/clearing procedure is finished. The coordination of the routes is required to prevent traversing blocked edges before their opening procedure is done. We develop an exact Mixed Integer Program (MIP) and a matheuristic method. The matheuristic solves single vehicle problems sequentially with updated prizes. To obtain an upper bound, we first relax the timing elements in the exact formulation and then solve its relaxed MIP, which decomposes into single vehicle problems, by Lagrangian Relaxation. We show the effectiveness of the proposed methods computationally on both random Euclidean and Istanbul road network data generated with respect to predicted earthquake scenarios.

*Speaker

The r-Depot Interdiction Vehicle Routing Problem with Demand Outsourcing

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The protection of critical facilities in supply chain networks increasingly attracts attention in the past 15 years. Critical facilities involve physical assets such as bridges, railways, terminals, power plants, hospitals, police stations, and transportation hubs among others. In this study, we introduce a bilevel optimization problem for the determination of the most critical depots in a vehicle routing network. The problem is first modelled as an attacker-defender game (Stackelberg game) from the perspective of an adversary agent (the attacker) who aims to inflict the maximum disruption on a delivery or collection type routing network. We refer to this problem as the r-depot interdiction vehicle routing problem (RDI-VRP) with demand outsourcing. The attacker is the decision maker in the upper level problem (ULP) who chooses r depots to interdict with certainty. The defender is the decision maker in the lower level problem (LLP) who re-optimizes the vehicle routes in the wake of the attack. The defender has to satisfy all customer demand either using the remaining depots or through outsourcing to a third party service provider. We solve the ULP through exhaustive enumeration which is viable when r, namely the cardinality of interdictions of the attacker, does not exceed five among 10 candidate depots. For the LLP we experiment with a savings-based heuristic and a nearest neighbourhood insertion heuristic adapted to the selective multi-depot VRP by so-called 1-node and 2-node marginal cost analyses. Our results are obtained on a set of RDI-VRP instances synthetically constructed from standard MDVRP test instances.

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Solution techniques for the Consistent Inventory Routing Problem

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Every year, the consumption of beer is around 400 million hectoliters in Europe. Although the consumption per capita and year is quite stable, demands and characteristics of the customers (bars, restaurants, stands...) are really diverse. Each establishment has different and independent opening hours, time windows and different inventory characteristics. Customers can also demand consistency in delivery times. Special events, such as sports events or music festivals, create, due to temporary high demands, the need of delivering commodity with more than one vehicle. Hence, the creation of efficient inventory routing plans is highly demanding. Thus, we face a Consistent Inventory Routing Problem with Time-Windows and Split Deliveries (CIRPTWSD). This problem integrates two core logistics decisions in supply chains that are typically investigated independently or sequentially: the optimization of inventories and transportation routing. We present a model which includes time windows, inventory and consistency management as well as split deliveries to create delivery routes. This model also includes some other characteristics as a given planning horizon and a given and constant demand in the time periods. Besides modeling the problem and solving small instances with CPLEX, we also propose a metaheuristic to obtain efficient solutions in large real world instances. It consist in a constructive phase with some local searches followed by an adaptive large neighborhood search applied to the obtained solution. Preliminary results on test instances which were derived from real world data with up to 400 customers show that our method obtains good solutions in a short amount of time.

*Speaker

Rail-rail containers transshipment: solution via mathematical programming

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This work focuses on a combinatorial optimization problem that arises in the planning of the transshipment of containers between trains. In this application, loading/unloading of trains must be performed in a loading area that is not big enough to host all the trains at the same time. For this reason, the transshipment must be made by sequentially unloading/loading groups of trains that fit in this loading area. If needed, containers may temporarily wait in a storage area. For practical reasons, the groups of trains must be designed in such a way that each train needs to enter only once into the loading area. The goal is to minimize the use of the storage area.

Following previous works, we have used a directed graph with nodes associated with trains to model this situation. As a result, this can be seen as an acyclic graph partitioning problem (AGPP). In order to solve the AGPP, we have developed a new integer programming formulation that takes advantage of some properties of its optimal solutions. This formulation has been strengthened with several families of valid inequalities, often used to break the awkward symmetries inherent to the problem. This new formulation has allowed us to obtain optimal solutions improving the efficiency of the state-of-the-art algorithm for this problem.

*Speaker

Performance of a deterministic 2e-VRP with synchronization in a real world situation

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Two-echelon Vehicle Routing Problems (2e-VRP) are hard to solve, especially when temporal and spatial synchronization constraints are taken into account. We have used a deterministic solver to handle such a problem in a city logistics setting within a reasonable amount of computational time. However, in the real world, such problems are affected by uncertainties. Especially travel time uncertainties may have a great influence on the solution, because a vehicles' delay can propagate to a number of other vehicles due to synchronization requirements. In this work, we investigate which insights we can gain from deterministic solutions that are applied in a stochastic environment. Therefore, we use scenarios based on lognormally distributed travel times to evaluate a deterministic solution under effects of stochasticity. Based on this information we reoptimize the solution in three different ways to decrease the cost under stochasticity. Furthermore, we examine the influence of time dependent travel times in the solution process for a realistic test instance of the city of Vienna. First results show that restructuring the solution can decrease stochastic cost without deteriorating the deterministic solution.

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System optimal routing of traffic flows with user constraints using linear programming

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Solving the road congestion problem is one of the major issues in modern cities since it causes time wasting, pollution, higher industrial costs and huge road maintenance costs. Among possible congestion avoidance methods, traffic assignment is a valuable choice since it does not involve huge investments to expand the road network. Traffic assignment models are traditionally devoted to two main perspectives on which the well-known Wardropian principles are inspired : the user equilibrium (user's perspective) and the system optimum (system perspective). For traffic assignment problems, it is well-known that (1) the total travel time in a user-equilibrium solution can be substantially higher than the total travel time in a system-optimum solution, and (2) the user-experienced travel time in a system-optimum solution can be substantially higher that the user-experienced travel time in a user-equilibrium solution. By seeking system optimal traffic flows subject to user constraints, a comprise solution can be obtained that balances system and user objectives. A linear programming based approach is presented to efficiently obtain a solution that effectively balances system and user objectives. Computational studies reveal that solutions with near-optimal total travel times can be found in which most users experience travel times that are better than user-equilibrium travel times and few users experience travel times that are slightly worse than user-equilibrium travel times.

*Speaker

Spatial Information in Offline Approximate Dynamic Programming for Dynamic Vehicle Routing with Stochastic Requests

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In this paper, we study the Dynamic Vehicle Routing Problem with Stochastic Customers (DVRPSC), a common problem setting for Courier, Express and Parcel service providers. We focus on the case in which a dispatcher must decide which dynamically occurring customer requests should be confirmed and how to integrate these into the existing tour of a vehicle. The vehicle must serve all confirmed requests and return to its depot within a given time limit; usually, not all requests can be confirmed. In order to confirm a maximum number of requests, anticipation of future requests for a current state's decision is necessary. To allow real-time control, the required calculations need to be conducted offline, often by means of Value Function Approximation (VFA). The calculation's outcome for every state is then stored in aggregated form and can be accessed efficiently in the online execution. Current VFAs for the DVRPSC are not able to integrate any spatial information in their aggregation but solely draw on temporal state attributes. Therefore, in problem settings expressing characteristic spatial distribution of requests, these are not able to anticipate sufficiently. In this paper, we propose Anticipatory Time Budgeting with Spatial Information (ATBS) to close this gap. We compare ATBS to a state-of-the-art VFA of the literature on a set of benchmark instances with varying spatial distribution parameters. Results show that the integration of spatial information is highly beneficial.

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Location and Selective Routing Problem with Profits in Reverse Logistics Networks

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One of the key concerns of the companies involved in product recovery management is used product (core) collection. In this paper, we consider the scenario where a company engaged in reverse logistics wants to locate facilities with limited capacity which will serve as collection centers (CCs) for the cores to be collected from service locations (SLs). The SLs as well as the amount of cores at each SL are known. Moreover, each SL has a reservation price and it will only return them if the offered acquisition price is less than this reservation price. Each SL can only be visited by a single vehicle, hence split pickups are not permitted. All vehicles are identical with respect to load capacity and speed. They must start and and their routes at the same CC without visiting any other CC in the route. The objective of the company is to maximize its profit by determining the locations of the CCs, SLs to be visited, the acquisition price offered for each unit of core collected, the number of vehicles allocated to each opened CC, and the route of each vehicle. The source of the revenue is the cost savings resulting from using the components of the cores in remanufacturing like-new products. We devise very effective and efficient Tabu search heuristic to solve this problem. The results obtained on randomly generated test instances shows that the TS heuristic is very effective and efficient when compared with the solutions of a mathematical model obtained by GUROBI.

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Inventory routing with pickups and deliveries

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This paper introduces a class of problems which integrate pickup and delivery vehicle routing problems (PDPs) and inventory management, and we call them inventory routing problems with pickups and deliveries (IRP-PD). We consider a specific problem of this class, where a commodity is made available at several origins and demanded by several destinations. Time is discretized and transportation is performed by a single vehicle. A mathematical programming model is proposed together with several classes of valid inequalities. The models are solved with a branch-and-cut method. Computational tests are performed to show the effectiveness of the valid inequalities on instances generated from benchmark instances for the inventory routing problem. Results show that the branch-and-cut algorithm is able to solve to optimality 345 over 400 instances with up to 50 customers over 3 periods of time, and 142 over 240 instances with up to 30 customers and 6 periods. A computational study shows that the average cost of a non integrated policy is more than 35% higher than the cost of an integrated policy.

*Speaker

Heuristics for the traveling salesman problem with release dates and completion time minimization

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We consider the traveling salesman problem with release dates where the objective is to minimize the completion time: TSP-rd(time). In the TSP-rd(time) an uncapacitated vehicle is loaded with goods, requested by the customers, that arrive at the depot over time. The arrival time of a product at the depot is called its release date. A single vehicle is available to perform deliveries. Each time the vehicle leaves the depot it can serve only customers whose goods have already arrived. The objective is to serve all customers while minimizing the completion time, i.e. the sum of travelling time and waiting times at the depot. We exhibit some properties, propose a mathematical formulation and describe two heuristic solution algorithms. The two algorithms have common scheme consisting of two main components, a large neighborhood search (LNS) and a local search (LS), iterated until the ending conditions are met. Given a solution, composed of one or more routes to serve all the customers, a LNS is carried out by removing a variable number of nodes from their original routes and reinserting them by either solving a MILP, in the matheuristic algorithm, or greedily, in the heuristic one. A LS is then applied on the obtained solution. Computational results and comparisons are shown on instances derived from Solomon's TSP benchmark instances.

*Speaker

An Iterated Local Search Algorithm for Multiple Traveling Repairman Problem with Profits

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Multiple traveling repairman problem with profits (MTRPP) is a generalization of the traveling repairman problem (TRP). MTRPP generally arises as a multi-vehicle routing problem on relief supply. In MTRPP, 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 mathematical model for MTRPP is developed. Additionally, a multi-start iterated local search algorithm is proposed for the solution of the MTRPP. The performance of the developed algorithm is tested on randomly generated problem instances. The results indicate the effectiveness of the proposed approach.

*Speaker

A Hybrid Method for the production routing problem with transshipment

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The production routing problem (PRP) combines two well-known optimization problems, vehicle routing problem and lot-sizing problem. The aim of solving the PRP is to jointly optimize the production, inventory, distribution and routing decisions, which typically arises in vendor managed inventory systems. In this study, we extend the classical version of the PRP by considering transshipments, either from supplier to retailers or between retailers, to further reduce the total cost. In order to solve the problem, we develop a hybrid solution technique that integrates mixed integer linear programming with constraint programming. 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.

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Planning of an Offshore Well Plugging Campaign: A Vehicle Routing Approach

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When a petroleum well no longer serves its purpose, the operator is required to perform plug and abandonment (P
A) operations on the well to avoid contamination of reservoir fluids. An increasing number of offshore wells need to be P
A'd in the near future, and the costs of these operations are substantial. Research on planning methods in order to allocate the required resources to perform these operations in a cost-efficient manner is therefore essential. We take a tactical planning level perspective and consider a set of wells that have to be P&A'd, making use of different vessels. The plugging of each well consists of the execution of a set of operations that has to be performed in a strict sequence. We use an optimisation approach and propose a mixed integer linear programming model formulation based on an extension of the uncapacitated vehicle routing problem with time windows with a heterogeneous fleet of vessels, precedence and non-concurrence constraints. The problem minimises permanent P&A costs by scheduling P&A operations and assigning routes to vessels. We refer to such a problem as a P&A campaign. We are currently able to solve instances with approximately 20 wells to optimality. Making use of a realistic case study, based on real-life data, we show that our approach may lead to significant cost savings compared to traditional planning methods.

*Speaker

On the complexity of some special cases of the Inventory Routing Problem

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In the Inventory Routing Problem (IRP) inventory management and route optimization are combined. The Traveling Salesman Problem (TSP) is a special case of the IRP, hence the IRP is NP-hard. We consider special cases of the IRP other than TSP for which it is not clear in advance whether these problems are easy to solve or NP-hard. First, we study cases in which the metric space is a half-line. The problems differ in the number of vehicles, the number of days in the planning horizon and the processing times of the customers. Our main result is a polynomial time dynamic programming algorithm for the case with uniform processing times and a planning horizon of two days. Second, for a family of problems we show that the complexity is comparable to the complexity of the Pinwheel Scheduling Problem which is long-standing open question. Third, NP-hardness is shown for problems with non-uniform processing times. Finally, we study the problem with one vehicle, an infinite planning horizon, uniform processing times and customers located in the Euclidean plane. Instead of computing the routing cost exactly, we approximate the routing cost avoiding immediate NP-hardness via the TSP. We show that with a given route cost approximation this problem is strongly NP-hard.

*Speaker

A new model and strengthening inequalities for the double TSP with multiple stacks

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In the double TSP with multiple stacks, a vehicle with several stacks performs a Hamiltonian circuit to pick up some items and stores them in its stacks. It then delivers each item to a corresponding customer by performing a second Hamiltonian circuit. The stacks are subject to a LIFO policy: only the items currently on the top of their stack can be delivered.
Petersen and Madsen (2009) model this problem as an ILP formulation involving arc and precedence variables as well as on binary variables z(r,i) indicating whether item i is in stack r.
This model easily lets one deal with instances in which the stacks have a finite capacity, and it has been used in a branch-and-cut framework by Petersen et al. (2010).
In order to reduce symmetry we also consider a new model obtained by replacing the variables z(r,i) by binary variables s(i,j) which are equal to one when items i and j are in the same stack.
In order to strengthen both formulations we introduce new exponential-size families of inequalities. We discuss the complexity of the associated separation problems and provide several efficient separation algorithms.
Both formulations are embedded in a branch-and-cut framework and compared from an experimental point of view.

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A two-commodity flow formulation for the truck and trailer routing problem

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In the Capacitated Truck and Trailer VRP (CTTRP) a limited fleet of capacitated trucks and trailers is available at a depot to serve a set of customers. Trailers are non-autonomous vehicles that can be pulled by a truck to increase its capacity. Each customer must be served by exactly one vehicle, but some of them, called truck customers, can only be reached by a truck without trailer. Trucks are thus allowed to detach and park their trailer en route at any (non-truck) customer location, make a subtour to visit some customers without trailer, and then return back to pick up the trailer before continuing the trip. We propose a two-commodity flow formulation for the CTTRP and some valid inequalities to strengthen it. We report computational results with a branch-and-cut algorithm based on the new formulation on instances derived from benchmark sets. The algorithm solves instances with up to 30 customers.

*Speaker

New path elimination constraints for multi-depot routing problems

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Multi-depot routing problems arise in distribution logistics where a set of vehicles based at several depots are used to serve a number of clients. Most variants of this problem have the basic requirement that the route of each vehicle starts and ends at the same depot. This paper describes new inequalities, namely multi-cut constraints (MCC), for multi-depot routing problems that enforce this requirement. The MCCs are exponential in size, and are equivalent to a compact three-index formulation for the problem in terms of the associated linear programming relaxations. The paper describes how a generalization of the MCCs can be obtained, in a similar manner, by using a stronger version of the three-index formulation. The connection between the compact and the exponential formulations implies a separation procedure based on max-flow/min-cut computations, which has reduced complexity in comparison with a previously known set of constraints described for the same purpose. The new inequalities are used in a branch-and-cut algorithm. Computational results with instances with 100 clients and up to 10 depots indicate that the algorithm is able to optimally solve the instances generally within a few hundred seconds of computation time.

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Solving the family traveling salesman problem

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Assume that instead of knowing exactly which cities the traveling salesman wishes to visit he only knows how many cities he has to visit in a subset of cities, which is called a family. In this case, besides determining the best order to visit the cities, like in the TSP, he also needs to choose which cities are going to be visited in each family. Let us consider that we have a depot and a partition of the set of cities into families. We intend to establish one route that begins and ends at the depot and visits a given number of cities in each family. The costs of traveling between each pair of cities and between the depot and each city are known. Hence, we want to determine the minimum cost route that satisfies the conditions stated previously. The problem described previously is the Family Traveling Salesman Problem (FTSP). Even though the FTSP is not widely studied in the literature, it seems to be a natural extension of routing problems that have a wide variety of real world applications. We propose several models for the FTSP and provide a theoretical comparison between them. With this models we were able to obtain the optimal value of benchmark instances with 127 nodes which have never been solved up to optimality. For the higher dimension instances, we propose a metaheuristic that was able to improve the optimal values of 8 out of 9 benchmark instances whose optimal value remains unknown.

*Speaker

The Split Delivery Vehicle Routing Problem with Time Windows and Customer Inconvenience Constraints

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In classical routing problems, each customer is visited exactly once. By contrast, when allowing split deliveries, customers may be served through multiple visits. This potentially results in substantial savings in travel costs. Even if split deliveries are beneficial to the transport company, several visits may be undesirable on the customer side: at each visit the customer has to interrupt his primary activities and handle the goods receipt. The contribution of the present paper consists in a thorough analysis of the possibilities and limitations of split delivery distribution strategies. To this end, we investigate two different types of measures for limiting customer inconvenience (a maximum number of visits and the temporal synchronization of deliveries) and evaluate the impact of these measures on carrier efficiency by means of different objective functions (variable routing costs, fixed fleet costs, schedule-related costs). We consider the vehicle routing problem with time windows in which split deliveries are allowed (SDVRPTW) and define the corresponding generalization that takes into account customer inconvenience constraints (SDVRPTW-IC). We design a branch-and-cut algorithm to solve the SDVRPTW-IC and report on experimental results showing the impact of customer inconvenience constraints.

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Branch-and-Cut for the Split Delivery Vehicle Routing Problem with Time Windows

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The Split Delivery Vehicle Routing Problem with Time Windows (SDVRPTW) is a notoriously hard combinatorial optimization problem. First, it is hard to find a useful compact Mixed-Integer Programming (MIP) formulation for the SDVRPTW. Standard modeling approach either suffer from inherent symmetries (MIPs with a vehicle index) or cannot exactly capture all aspects of feasibility. Second, the lack of useful formulations has rendered any direct MIP-based approach impossible. Up to now, the most effective exact algorithms for the SDVRPTW are branch-and-price-and-cut approaches using a path-based formulation. In this work, we propose a new and tailored branch-and-cut algorithm to solve the SDVRPTW. It is based on a new relaxed compact model, in which some integer solutions are infeasible to the SDVRPTW. We use known and introduce some new classes of valid inequalities in order to cut off such infeasible solutions. However, some integer solutions to the new compact formulation remain to be tested for feasibility. For a given solution, we built a generally sparse subnetwork of the original instance. On this subnetwork, all time-window feasible routes can be enumerated and a path-based residual problem is then solved in order to decide on the selection of routes, the delivery quantities, and herewith the overall feasibility. All infeasible solutions need to be cut off. For this reason, we derive some strengthened feasibility cuts exploiting the fact that solutions often decompose into weakly connected components. Computational experiments show that the new approach is able to prove optimality for several previously unsolved instances from the literature.

*Speaker

The Electric Autonomous Dial-a-Ride Problem

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Ride sharing is changing urban mobility by offering reliable and convenient on-demand services at any time. Given the constant increase in demand, ride-sharing businesses are currently planning to expand their portfolio to include Dial-a-Ride Transit (DART) by the use of electric Autonomous Vehicles (AVs). This novel type of service introduces new operational challenges. First, as the vehicles are electric, battery management needs to be considered during route planning. Second, DART is provided 24/7 and autonomous vehicles are not required to return to a specific depot. Providing multiple depots becomes a crucial feature since vehicles need to continuously wait and relocate around the urban network during the non-stop service. In this study, we present a new multi-objective Dial-a-Ride formulation for electric AVs (e-ADARP) which integrates tracking battery levels, decisions regarding detours to recharging stations, recharging times and decisions regarding destination depots with the classic Dial-a-Ride features. We formulate the problem as a Mixed Integer Linear Problem (MILP) and devise a Branch-and-Cut algorithm with new valid inequalities derived from e-ADARP properties. Large instances of the problem are decomposed to tractable sub-instances using machine learning techniques. Real data from Uber Technologies Inc. in San Francisco is employed for testing purposes.

*Speaker

Optimizing Real Time Operations of One-way Electric Carsharing Systems

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Carsharing is a mode of transportation which allows its users to rent cars for short periods of times. Although one-way systems are more attractive to their users, operators prefer to implement easy-to-operate and implement round-trip systems. Furthermore, round-trip systems provide the flexibility of early reservation which is not an option in most of the operating one-way systems. In these systems, users are usually allowed to reserve vehicles which are available at the time of reservation shortly (not longer than 30 minutes) before the pick-up time. With an additional feature of early reservations, one-way systems can attract more customers and increase their efficiency without requiring additional investment. In this research, our ultimate aim is to combine early and last-minute reservations for one-way non-floating electric carsharing systems. For this purpose, we developed a simulation framework which takes the demand and other system information as input. This simulator replicates a generic carsharing system including rental requests, movements of vehicles and relocation personnel. Furthermore, it allows developing different algorithms to decide on operational decisions that include vehicle (and personnel) relocation and rental decisions. We also developed a mathematical model which maximises the number of rentals served with minimum relocation cost without violating operational constraints. This mathematical model is integrated to this simulation framework to test the system performance in real time with the data from carsharing system in Nice, France.

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Optimal charging station placement in a free-floating electric car sharing system

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In recent years, free-floating car sharing systems have become a popular mode of transportation within urban areas, as they allow their customers similar flexibility to owning a car without the associated costs. Using electric vehicles allows the operator to operate in an environmentally-friendly way, while also improving efficiency.
These vehicles must, however, be regularly recharged to ensure that they do not run out of battery. Thus, a network of charging stations must be built within the system's area of operation, where cars can be recharged when they are not in use. Since building and maintaining these stations is costly, placing them effectively is paramount to the economic viability of any free-floating electric car sharing system.
We present integer linear programming formulations for solving the problem of finding optimal locations and sizes for charging stations within such a system. Given a limited budget, we want to place them in such a way as to maximize the amount of customer demand that can then be satisfied. We assume that customers are willing to walk a short distance to get to an available car at the start of their trip. They may end their trip anywhere within the system's operational area, but are incentivized by lower rental fees to return cars with low battery to a charging station close to their actual destination.
We analyze the performance of our algorithms on a set of benchmark instances that is based on both artificial and real-world data.

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Value Function Approximation-based Dynamic Look-ahead Policies for Stochastic-Dynamic Inventory Routing in Bike Sharing Systems

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We consider a station-based bike sharing system (BSS) where users can rent and return bikes spontaneously. Rental and return requests are uncertain and subjected to a spatio-temporal pattern. Service providers dynamically dispatch transport vehicles to relocate bikes between stations. The challenge is to balance the numbers of bikes and free bike racks at every station to satisfy as many requests as possible.
The considered problem is a stochastic-dynamic inventory routing problem (SDIRP). We model the SDIRP as a Markov decision process. The objective is to identify an optimal policy, minimizing the expected number of failed requests.
To solve the SDIRP, we draw on policies by means of approximate dynamic programming. We present dynamic look-ahead policies (DLA) to anticipate potentially failing requests in online simulations. The DLA simulates a limited time of the overall time horizon to evaluate feasible inventory and routing decisions. Due to the spatio-temporal request pattern, the lengths of suitable simulation horizons differ in the course of the day. To select suitable horizons for every hour of the day, we apply value function approximation (VFA). VFA carries out offline simulations and returns a sequence of suitable simulation horizons.
Our computational studies on real-world data by the BSS of Minneapolis (Minnesota, USA) point out, that the VFA-based DLA outperforms look-ahead policies with static simulation horizons as well as conventional policies from literature. Further, the sequence of simulation horizons reflects the temporal aspect of the request pattern.

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The Green Vehicle Routing Problem with Capacitated Alternative Fuel Stations

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This work addresses the problem of efficiently routing a set of Alternative Fuel Vehicles (AFVs), considering that, during their trips, some stops at Alternative Fuel Stations (AFSs) have to be planned. Every AFV leaves from a common depot and returns to it, after serving a subset of customers. Due to some forms of contract with the drivers, an upper bound is usually imposed on the duration of each route. The aim is to define the optimal routing of the AFVs in order to minimize the total traveled distance. This problem is known in the literature as the Green Vehicle Routing Problem (G-VRP). Several Mixed Integer Linear Programming (MILP) formulations have been already presented to model it. The G-VRP assumes that an unlimited number of vehicles may be simultaneously refueled at the same AFS. This hypothesis is not realistic, since AFSs typically have a very small number of refueling locations. To manage this issue, we propose an extension of the G-VRP that models the more realistic situation where a capacity is associated with every AFS, bounding the number of vehicles that can simultaneously refuel. The capacity constraint makes more challenging the scheduling of the stops at the AFSs, since now the AFSs become a shared resource of the problem. For this new version of the G-VRP, we propose a MILP formulation and a heuristic approach. Preliminary numerical results have been carried out on some benchmark instances, properly adapted to this extension of the G-VRP.

*Speaker

Exact algorithms for the traveling salesman problem with time-dependent service times

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The Traveling Salesman Problem with time-dependent Service Times (TSP-TS) is a variant of the well-known Asymmetric TSP (ATSP). In addition to the classical constraints of ATSP, in TSP-TS each customer requires a service time, whose duration depends on the time at which the service starts at that customer. The TSP-TS calls for finding a Hamiltonian tour (i.e. a tour visiting each customer exactly once) such that the total duration of the tour (i.e. the sum of the travel times and of the service times) is minimized.
Tas, Gendreau, Jabali and Laporte, in "The traveling salesman problem with time-dependent service times", European Journal of Operational Research (2016), proposed Mixed Integer Programming (MIP) formulations with a polynomial number of constraints. In this talk, we propose and solve exponential-size formulations that explicitly incorporate subtour elimination constraints. Additional valid inequalities, strengthening those presented in Tas et al. (2016), and an exact branch-and-cut algorithm are also proposed. Extensive computational experiments on benchmark TSP-TS instances with small, medium and large service times are reported.

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An evolutionary algorithm for the location-allocation-routing problem

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The problem addressed in this work focuses on a multi-echelon distribution system which consists of a central depot, a set of potential intermediate warehouses and a set of customers with known demand. Goods are supplied from the central depot to a subset of warehouses using a fleet of homogeneous vehicles. Customers are not served directly. Instead, each customer is allocated a warehouse where he/she goes to collect his/her goods. Therefore, the problem simultaneously handles the selection of the location of the warehouses which are visited, the design of the routes to serve them and the allocation of the customers to the selected warehouses. These are decisions which are interrelated and have a strong impact on the quality of customer service and on the costs of the distribution system. The aim of the model is to minimize the total distance travelled by all vehicles which serve the warehouses, while guaranteeing a good service to customers measured in terms of the distance they need to travel from their location to their allocated warehouse. An evolutionary algorithm is developed to solve the problem. Chromosomes provide the selected warehouses and the number of routes. For each chromosome, the algorithm uses a heuristic to construct feasible solutions. Uniform crossover and mutation are used to construct offspring. The fitness of a chromosome measures its quality by means of the objective function value of its associated feasible solution. Elitist survivor selection is applied. A computational experiment is carried out to demonstrate the performance of the algorithm.

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Solving Partially Dynamic Vehicle Routing Problems using Intelligent Multiagent System

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More recently, the availability of real-time traffic information has allowed their treatment and incorporation into route plan and execution. Thus the route processing provide more accurate data, including real time to support the dispatch and operation of vehicles. The emergence of mobile, embedded software components and devices with good and reliable communication performance and processing can help the driver to perform his assigned tasks and follow the paths in the best possible way. This article presents an actual computational model based on Intelligent Multiagent to deal with the Partially Dynamic Vehicle Routing Problem applied to services and products distribution in large metropolitan areas.The Intelligent Multiagents are software components with autonomy and cooperation to maintain the optimality of route plans over the unpredictability of the urban environment and urgent requests. The architecture of the Multiagent System is composed of a Central Supervisor Agent controlling several Executor Agents embedded in Mobile Apps, one for each route (vehicle/driver) and an Observer Agent (to observe traffic conditions of the urban network). After dispatching Executor Agents, new urgent requests are received by the Supervisor Agent that assigns each of them to the most suitable Executor Agent. In this case the Executor Agent deviates from its route, services the urgent request and in return, if necessary, reorder the remaining customers to ensure the optimality of the path. These autonomous agents interact with an urban environment represented by a real-time updated digital map obtained from the Google Maps APIs.

*Speaker

The location-routing covering problem

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In this presentation, we introduce, model and solve the location-routing covering problem (LRCP). The LRCP is a variant of the location-routing problem and the covering tour problem. The problem consists of routing a set of homogeneous vehicles from a set of opened facilities to a subset of visited customers while ensuring that each unvisited customer is covered by exactly one visited customer. This problem arises for example in the context of healthcare supply chains in underserved regions where community health workers (CHWs) are recruited directly in their community and each CHW is restocked by a supervisor. In that context, the problem consists of determining the density and location of CHWs as well as the density, location and routing of the supervisors. To solve this problem, different mathematical formulations each with a different set of variables and a different set of constraints. To compare the performance of the different mathematical models, computational results will be presented on real-life instances for an application in Africa.

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A Generally Applicable Ruin & Recreate Approach for Capacitated Vehicle Routing Problems

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The largest capacitated vehicle routing problem (CVRP) instances continue to remain unsolvable by exact mathematical algorithms, despite considerable academic progress and success over the previous decades. Such larger instances are, however, more representative of current real-world industrial challenges and they therefore necessitate the use of heuristics.
The present research introduces a single general ruin & recreate heuristic entitled Adjacent String Removal and greedy insertion with Blinks Ruin & Recreate (ASB-RR). Incorporated in a simulated annealing framework, ASB-RR proves capable of replacing current unwieldy and often unreproducible heuristics which are often over-saturated with both ruin methods and recreate methods. ASB-RR is not only capable of improving results in shorter computational times for numerous (Uchoa et al.) CVRP benchmark instances, but its general applicability has since been confirmed via its deployment across a wide variety of associated and derivative problems such as VRP with Backhauls, Simultaneous Delivery & Pickup, Open VRP and Cumulative VRP. The competitive computational results and consequent comparative analysis against state of the art heuristics resulting from experimentation across this suite of problems will be detailed and discussed.
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

Prioritized Routing and Scheduling for Home Healthcare Services

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In home healthcare services it is customary to visit the patients on a schedule. A Turkish company that sells medical nutrition products provides follow up services to its patients that are fed by tube or orally. Each nurse either visits a set of patients for whom she is responsible at home or calls them by phone on a specific day. In the current system, each nurse decides by herself how to follow the patients up in a given month. Thus, the managers cannot control whether the nurses visit the right patients in the right order. Patients can be prioritized depending on factors such as the last visit time, next prescription date and the severity of his/her condition. An important aspect of the priority parameter is that it is updated by time. As time progresses, the priority of an unvisited patient increases. We define an optimization problem that determines which patients to visit on each day of a multi-period planning horizon and in which order to visit them to maximize the total priority of visited patients and to minimize the total routing time. This leads to a multi-period orienteering problem with time-dependent prizes and time windows, which has not been studied before in the literature to the best of our knowledge. We develop a mixed integer programming model and solve it by Lagrangean relaxation to obtain upper bounds. We also develop a Simulated Annealing heuristic to generate near-optimal feasible solutions in short running times. We test these methods on real-life data.

*Speaker

On the Chinese Postman Problem with load-dependent costs

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We introduce an interesting variant of the well-known Chinese Postman Problem (CPP). While in the CPP the cost of traversing an edge is a constant (equal to its length), in the variant we present here the cost of traversing an edge depends on its length and on the weight of the vehicle at the moment it is traversed. This problem is inspired by the perspective of minimizing pollution in transportation, since the amount of pollution emitted by a vehicle not only depends on the travel distance, but also on its load, among other factors. We define the problem, study its computational complexity, provide two different formulations and propose two metaheuristics for its solution. Extensive computational experiments reveal the extraordinary difficulty of this problem.

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Production routing problem with emission minimization

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Integration of operational decisions of different functions of the supply chain has been identified as an important success factor in minimizing their total costs. Traditionally, supply chain optimization has merely concentrated on the economic aspect of the sustainability, neglecting its environmental and social aspects. However, with the growing concern towards green operations, the impact of short term decisions on reduction of carbon emissions could no longer be overlooked. Only recently some papers start to consider environmental issues in the integration of production and distribution decisions. Aiming to compare the effect of operational decisions not only on cost but also on emissions, in this talk, we reassess the well known production routing problem under new objectives. We study an integrated system dealing with production, inventory, and routing decisions, in which the commodity produced at the plant is shipped to the customers over a finite time horizon. We measure several metrics under different scenarios, namely when minimizing total costs, only routing costs, or minimizing only emissions. Each solution is evaluated under all three objective functions, and their costs and business performance indicators are then compared. We provide elaborated sensitivity analyses allowing us to gain useful managerial insights on the costs and emissions in integrated supply chains.

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Multi-Depot Inventory Routing Problem in the last-mile delivery: a case of study

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In this work a Multi-Depot Inventory Routing Problem (MDIRP) for last mile deliveries is presented. The MDIRP aims at optimizing the inventory at the customers by avoiding stock-out, while minimizing the last mile deliveries to the customers in a big city context. The MDIRP is Np-hard because it subsumes the classical Vehicle Routing Problems. The context of analysis is an urban space of high dimension (a big city) that is characterized by a huge complexity. The presence of several depots allows to face the problem in the big city context by splitting the urban space into districts and by solving a single depot Inventory Routing Problem for each district. A two-phase matheuristic algorithm is used for solving the problem. In the first phase a cluster of customers is built around each depot. In the second phase a route generation procedure is designed to build a limited number of feasible routes for each cluster. Computational results are presented on real case instances.

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Integrating Partner Objectives in Horizontal Logistic Optimization Models

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In this talk, a general solution framework is presented for optimising decisions in a horizontal logistic cooperation. The framework distinguishes between the objective of the group and the objectives of the individual partners in the coalition. Although the importance of the individual partner interests is often acknowledged in the literature, the proposed solution framework is the first to include these objectives directly into the objective function of the optimisation model. The solution framework is applied to a collaborative variant of the clustered vehicle routing problem, for which we also create a set of benchmark instances. We find that by only considering a global coalition objective the obtained solution is often suboptimal for some partners in the coalition. Providing a set of high quality alternative solutions that are Pareto efficient with respect to the partner objectives, gives additional insight in the sensitivity of a solution, which can support the decision making process. Our computational results therefore acknowledge the importance of including the individual partner objectives into the optimisation procedure.

*Speaker

On solvable cases of the 2-period-balanced-TSP and benchmark test problems

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We consider a 2-period-balanced-TSP, where n customers to be visited in two days: some of them have to be visited each day, i.e. twice within these two days. An additional constraint demands that the number of customers visited each day should be the same (we assume here that the number of customers is even). We generalise one of the well known polynomially solvable cases of the TSP to the case of the 2-period-balaced-TSP. We describe also a tool for generating benchmark test problems that can be used for testing heuristics for this NP-hard problem. One of earlier suggested heuristics is used to empirically evaluate the usefulness of this type of benchmark problems.

*Speaker

Vehicle Routing for a Food Service Marketplace

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With e-commerce revolutionising the Food and Beverages industry, there has been a surge of online food marketplaces world around, which allow customers to place orders from third party restaurants by listing their menus on its website, and offer logistics support to the restaurants. The success of such a marketplace depends on how it manages its delivery lead time and the total cost incurred to operate the fleet.
We demonstrate a vehicle routing problem with time windows and multiple pickups and deliveries at a food service marketplace using an illustrative case of a food technology start-up, considering the case of an aggregator cum restaurant with third party restaurants registered to it. The supply network offers a set of specialty products. The aggregator offers logistic support on behalf of the restaurants.

We consider a given set of open orders from different demand locations, delivery time windows, and current vehicle availability. The aggregator tries to minimise the total cost (and fleet travel duration) incurred to fulfil the orders within the time windows. We deploy Constraint programming to solve the multi-product, heterogeneous vehicle routing problem with time windows, pickups and deliveries.

The model helps decide the number of vehicles to be used, and the pickup and delivery schedules. It also accommodates for the traffic conditions in the routes.
To the best of our knowledge, this is the first paper that deals with vehicle routing problem at an online food service marketplace.

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A Lagrange Relaxation for the Orienteering Problem with Hotel Selection and Time Windows

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The Orienteering Problem with Hotel Selection and Time Windows (OPHSTW) is a recent variant of the Orienteering Problem (OP) in which a visiting tour starts in a given initial hotel and ends in a given final hotel. This tour is composed of a given number of trips, each limited by a time budget. Each trip starts and ends in one of the available hotels. Next to the hotels, a number of vertices with an assigned score can be visited within each trip respecting their time windows. The goal is to maximize the total score collected by visiting vertices in the tour. Various applications are considered for this problem such as tourist trip planning, military reconnaissance activity, and truck drivers with limited driving time. In this research, a Lagrange Relaxation (LR) method is implemented to 395 benchmark instances with known optimal solutions from the literature. In each iteration of the proposed LR method, a smart heuristic approach is used to tackle the sub-tour elimination constraints and obtain a feasible solution. The experimental results show that the solution method is able to improve the best known solution for larger instances of the problem.

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Driver and Vehicle Routing Problem

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We introduce a combinatorial optimization problem that consists of finding the optimal set of routes that must be performed by vehicles and drivers to minimize the overall performance cost. We model it as a vehicle routing problem with two depots. There are two types of routes. The drivers' routes start and end at the same depot. The routes of the vehicles start at a depot and end at the other one. All the routes must be performed by a driver and a vehicle at the same time. An important aspect of the problem is the synchronization of drivers and vehicles. The drivers can make a vehicle change only in a particular set of nodes. We propose a mixed integer programming formulation and design a branch-and-cut algorithm to solve the problem.

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An approach for an Inventory Routing Problem presented in the VeRoLog Solver Challenge 2017

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Our solver is based on dividing the problem into two separate algorithms dealing with finding schedules for the visits at customers and then computing routes for the pickup and delivery of tools based on the schedule.
We start with generating a population of mostly feasible candidate schedules. Scores are assigned to each candidate by including the routing and computing the objective value. A genetic algorithm is used to iteratively breed new generations while also introducing random mutations.

Since the genetic algorithm needs to be able to score a large number of schedules in a limited time-frame, we decided on a simple, but fast approach to finding routes. For each schedule we generate tours using a slightly modified parallel saving algorithm, which favors matching pickup and delivery requests. The tours are then assigned to vehicles using a best-fit packing heuristic reducing the number of required vehicles. Vehicle-routes are then further improved using 2-opt and 3-opt heuristics.
After a certain number of generations a candidate solution is found and the post-optimization stage is started where the routing of the best solution is further improved using variable neighborhood descent with move, swap, 2- and 3-opt operators.

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A pickup and delivery problem in two regions with fixed and flexible long-hauls

Alina-Gabriela Dragomir *† [1], Karl Doerner‡ [1]

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This work adresses a logistical problem occurring in and between two regions (cities) in a three stage setting. Packages have to be transported between and within those cites. Within a city they are transported by small short-haul vehicles. Between them, the packages are transported by long-haul vehicles (train, plane or truck) that operate either on a fixed or on a flexible schedule. In addition, we have time windows for the pickup and delivery nodes of varying size, depot opening hours, tour length restrictions for the short-haul vehicles, capacity restrictions for both the long-haul and short-haul vehicles, a limited number of vehicles at our disposal and the possibility of direct delivery of request at high costs and with additional vehicles if they cannot be served by our fleet. We propose a hybrid solution approach based on the savings algorithm, the pilot method and a commercial MIP solver. Preliminary computational results are presented and future extensions of the problem formulation and of the solution method are discussed.

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A Novel Formulation and a Column Generation Technique for a Rich Humanitarian Logistic Problem

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We address a problem which is inspired by the logistic challenges of food banks in Israel and in the US. The food bank determines a vehicle route in order to collect products from suppliers in the food industry and deliver them to welfare agencies, and simultaneously sets allocation quantities so as to balance considerations of effectiveness and equity. Previous work has focused on modeling a suitable objective function so that the problem can be formulated as a MILP, and on developing an LNS metaheuristic based on the special structure of a sub-problem. In this work, we further exploit this structure to present a new mathematical formulation of the problem. We substitute the "classical" site-based routing decisions variables, i.e., whether the vehicle should proceed from a certain site to another, with new variables which indicate whether the vehicle should proceed from a certain *sequence of sites* to another. These sequences are chosen in a way that guarantees that the allocation decision which they dictate, can be made independently of the other sequences that are chosen in the solution. We believe that this novel approach, which has not been used previously in the literature, to the best of our knowledge, has two main advantages: (1) It provides a tighter bound compared to the site-based formulation used in previous work; (2) It gives rise to a new solution methodolgy for the problem, based on column generation. Numerical experiments to assess the performance of these methods are currently underway.

*Speaker

A unifying software framework for vehicle routing and logistics.

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A wide range of open source tools and real world data are available to support those working on vehicle routing and logistics optimisation. Despite such tools being available there is still a requirement for a unifying software API to allow researchers and developers to access such tools and data with ease. We present a framework written in the Java API that provides access to data from sources such as Open Streetmap and public transport APIs, as well as facilities for scheduling events and for producing KML map overlays. By making use of Object Oriented software engineering techniques we can make data sources interchangeable and exploit common concepts such as locations and journeys. With multiple sources of data available an important underlying concept is that objects within the system have their data source identified. We believe that this framework provides a useful resource for those working within the field and encourage collaboration. The framework is open source and is available for all to download, use and modify.

*Speaker

The vehicle routing problem with time windows and a fragility constraint

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In this presentation we consider a new variant of the vehicle routing problem with time windows where the items (e.g., pallets or containers) delivered by a vehicle are positioned in stacks. Once the item has been placed, it cannot be moved, except for its delivery. Two types of items are considered: heavy or light. The *fragility* constraint forbids stacking a heavy item over a light one. We first consider the case of stacks of height 2. To solve this problem we develop different branch-price-and-cut algorithms. Some of them exploit theoretical results on the feasibility of a route subject to a fragility constraint. These theoretical results, as well as the branch-price-and-cut algorithms, are then generalized to the case of stacks of arbitrary height. Based on the Solomon's dataset for the vehicle routing problem with time windows, we generate a new dataset by varying several parameters such as the number of customers, the vehicle capacity, the ratio between the number of heavy and light items, the height of the stacks, etc. To assess the efficiency of our algorithm, we performed an extensive computational campaign. Preliminary results show that our algorithms are able to solve problem instances with up to 100 customers. Furthermore, the branch-price-and-cut algorithm featuring a bi-directional labeling algorithm to solve the subproblem in the column generation step seems to outperform the other algorithms.

*Speaker

On the solution of the rolling stock rebalancing problem

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In this talk, we deal with the Rolling Stock Rebalancing Problem (RSRP). In railways transportation, one of the objectives of the rolling stock planning is to match the train units stored at the shunt yards at the end of the daily operation with the train units required to perform the rolling stock plan on the following day. The scheduled plan is sometimes disrupted, and some stations may end up having a surplus or a deficit of train units at the end of the day. To solve the mismatch new empty trips can be scheduled. In this version of the RSRP we want to minimize the cost of these new empty trips while satisfying different sets of operational constraints imposed by the existing train timetables and the railway network. The complexity of the problem arises from the need to integrate decisions on the timetables of the new trains and the rolling stock units to reallocate. The literature on this version of the problem is quite scarce. We present a Mixed Integer Linear Programming formulation of the problem and show the computational results achieved on real-life instances provided by the main railway operator in the Netherlands.

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Exact solution of vehicle routing problems with multigraphs or road-network-type graphs

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In this presentation, we investigate the exact solution of vehicle routing problems when a route is characterized by several attributes, e.g., travel cost and travel time as in the VRPTW (Vehicle Routing Problem with Time windows). Recent works confirmed that the best solutions are missed using the standard modeling, where the road network is represented with a complete graph. Indeed, in this case, an arc (i,j) represents a specific path between i and j and all alternative paths, with different compromises betwwen the attributes are lost.

We explore two different representations of the road network that avoid restricting abusively the solution space: a representation as a multigraph and a representation reproducing the road network. For both cases, we develop branch-and-price algorithms. Experiments compare computationnally the two approaches.

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Introducing Fairness in Facility Location Problems

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We consider a plant location problem where a supplier will be locating facilities to serve a set of customers. We assume that the location costs are in charge of the supplier, whereas each customer pays the transportation costs between its position and the serving facilities. For the supplier, an effective service is then reflected by two goals: the facility location cost and the customer satisfaction. While the first goal is easy to formulate uniquely, the second goal can be characterized in different ways. In this talk, we assume that customer satisfaction is a matter of both fair allocation of transportation cost (system equity) and minimum total transportation cost (system efficiency). We then argue that both aspects are captured by the minimization of the sum of the k highest transportation costs among customers (k-sum), where k is an integer parameter whose value reflects the relative importance assigned to equity and efficiency. After discussing the properties of the selected measure, we show how to embed it into a compact bi-objective MILP model, where the first objective is location cost. We analyze heuristic procedures to build an approximation of the Pareto optimal solution set. We discuss computational results on benchmark instances, focusing on the trade-off between objectives in the obtained solutions.

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Multi-product Multi-vehicle inventory-routing problem considering weight and volume in a wholesale grocery chain.

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The Multiproduct multivehicle inventory routing problem (MMIRP) is a logistical problem that arises in the great majority of organizations, especially those in which more than one product is marketed, in many cases the packaging does not have the same volume and weight. The distributor decides what delivery strategy should be made given the demand and the inventory of the customers in a finite and discrete time horizon. The delivery strategy includes the time and the size of the deliveries to minimize the total cost of delivery. In the literature, we generally study a single homogeneous product with a deterministic but variable time demand that is delivered in a finite time horizon. This work focuses on the weight and volume restrictions that have to be charged to the vehicles in order to be taken from the distribution center to the customer in a mexican wholesale chain. This type of study is important because even though the weight restriction has been applied, many times by volume the transport vehicle can not take all the merchandise and leave something at the distribution center or vice versa. We formally define and shape the problem, and we solve it exactly. Demand was predicted with Holt - Winters models. Previously the combinations of the points of sale were made to solve previously the best routes between them so that given the necessary vehicles with the correct merchandise covering the restrictions of weight and volume, to cover the demand the itinerary is chosen.

*Speaker

New Modeling and Solution Approaches for the Vehicle Routing Problem with Stochastic Demands

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The Vehicle Routing Problem with Stochastic Demands (VRPSD) has been traditionally studied under the assumption of the detour-to-depot policy. Nevertheless, it is generally a consensus that such restocking policy is rather suboptimal and tends to be adopted very seldom in practical scenarios.
In this talk we present a new model for the single-vehicle VRPSD under the a priori optimization approach. Our model computes the optimal tour assuming the optimal restocking policy is to be used. We conduct tests on instances of up to 50 nodes, and verify the large suboptimality of the detour-to-depot policy, especially in high vehicle load scenarios.

When the instance size increases our model quickly becomes intractable. For this reason, we introduce an approximate branch-and-bound based solution method suitable for solving heuristically larger instances of the VRPSD. The heuristic finds the optimal solution of all instances solved to optimality. It also significantly improves the upper-bound obtained by combining the optimal Travelling Salesman Problem (TSP) solution with the optimal restocking policy, which in turn performs better than the optimal detour-to-depot solution.

We conclude by pointing out a few remarks of practical relevance. In particular, we discuss in which situations it generally pays off pursuing the optimal solution, and when the solution obtained by solving the corresponding TSP problem is good enough.

*Speaker

A matheuristic approach for solving the Integrated Timetabling and Vehicle Scheduling Problem

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The Integrated Timetabling and Vehicle Scheduling Problem (IT-VSP) is a generalization of the well-known Vehicle Scheduling Problem (VSP). In the IT-VSP the trips in the original timetables may be modified in terms of arrival and departure times in order to minimize a new objective function that considers both operational costs and passenger transfer costs. Starting from a base timetable, the allowed modifications include shifting the departure time from the first station of each trip and also the extension of dwell times at important stops where large flows of passengers are expected to transfer between different trips. We consider transfers between bus trips scheduled by the model, but also transfers to other fixed lines that intersect the lines considered in the IT-VSP. We present a MIP formulation of the IT-VSP able to solve small instances of the problem, and a matheuristic approach that uses the compact MIP to solve larger instances of the problem. The idea is to iteratively solve restricted versions of the MIP selecting at each step a subset of trips where modifications are allowed, while all other trips remain fixed. The performance of the proposed matheuristic is shown on a case study with real-life instances provided by the main service provider in the greater Copenhagen area. The effect of allowing dwell times is compared to previous approaches to the problem where trips are only allowed to be shifted in time.

*Speaker

SAT solving for complex routing and scheduling problems

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Most real-world applications in context of routing and scheduling involve special side constraints to model applied conditions and resource requirements. Especially temporal availability of staff members, working hour regulations, inter-route constraints, and other issues regarding interdependencies between resources, respectively synchronization between routes, lead to hard combinatorial optimization problems and specialized algorithms therefor. It is a hard task on its own to get valid solutions for such high-constraint problems. Achieving high-quality results fast is even more challenging. Simple or more specialized typical construction heuristics often fail to find valid solutions at all, while improvement heuristics evoke long running times as well as standard exact approaches. We propose the integration of satisfiability testing (SAT) to proof feasibility of such problems. For this purpose we describe a generalized SAT encoding for the problems under consideration, which subsequent are solved by state-of-the-art SAT solvers. In addition we outline optimization strategies to obtain high-quality, respectively optimal, solutions. Computational results are reported on different problem classes which illustrate the efficiency of integrating SAT in the solving process.

*Speaker

Neighborhood search approaches for a multi-trip vehicle routing problem with time windows

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We consider a multi-trip vehicle routing problem with time windows where each vehicle can perform several routes to serve the customers. Besides imposing a time window at the depot, we also assume that the working time of each vehicle may not exceed a maximum duration. The pursued objective is the minimization of the total working time. In this context, starting early to ensure the satisfaction of time window constraints has a negative impact on the objective function and on the maximum allowed working time constraint. Thus, vehicle start times are explicit decision variables. We compare two large neighborhood search approaches. The first one combines vehicle routing heuristics with bin packing techniques aimed at assigning routes to vehicles. The second one makes use of specific multi-trip operators designed to tackle simultaneously the routing and the assignment aspects of the problem. We show that the proposed multi-trip operators are more suitable for constrained instances with tight time windows. An automatic configuration tool is used to find high quality results. Moreover, it allows us to gain knowledge about the behavior of algorithmic components. We also question the impact of commonly employed heuristic components.

*Speaker

The electric vehicle routing problem with partial charge, nonlinear charging function, and capacitated charging stations

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We study the electric vehicle routing problem with partial charge, nonlinear charging function, and capacitated charging stations (E-VRP-NL-C). Decisions in the E-VRP-NL-C concern not only the sequence in which the customers are to be served, but also where and how much to charge the batteries in each route. The special features of the problem are that: 1) the function describing the relationship between the time spent charging the vehicle and the amount of charged energy is nonlinear and 2) a maximum number of EVs can simultaneously charge at each charging station (CS). We propose different MILP formulations for the E-VRP-NL-C and study the efficiency of these continuous-time models when running on a commercial solver. We also introduce a *route first-assemble second* approach to tackle the E-VRP-NL-C. In the routing phase the method uses an iterated local search embedding a variable neighborhood descent scheme. It combines simple components from the literature and components specifically designed to consider charging decisions and the limited number of chargers available at each CS. In the assembling phase the method builds the best possible solution from the routes that are part of the local optima found during the first stage. We adopt a decomposition method to exactly solve this phase.

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An new bidding process for combinatorial transportation auctions

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In horizontal collaborations, carriers form coalitions in order to perform parts of their logistics operations jointly. By exchanging transportation requests among each other, they can operate more efficiently and in a more sustainable way. This exchange of requests can be organized through combinatorial auctions, where collaborators submit requests for exchange to a common pool. The requests in the pool can be grouped into bundles either by the auctioneer or by the carriers themselves. While in the literature it is mostly assumed that bundling and bidding is done by the carriers, our computational study shows that bundles built by the auctioneer can yield significantly higher collaboration profits, while the number of traded bundles can be decreased. The gap in solution quality gets even more obvious, as the pool of offered requests is increased. However, even if the number of traded bundles is decreased by offering auctioneer bundles, the carriers have to give their bids for the offered bundles. Typically, a bid is based on the carrier's marginal profit, which is the difference of the profits including and excluding the bundle in the tour. Hence, for each bid, an NP-hard routing problem has to be solved. To decrease this enormous computational effort, we develop two approximate bidding strategies. Each of them is assessed in regard of solution quality and computational time. One of the strategies decreases the average computational time by 20%, while only little loss in solution quality can be observed.

*Speaker

A backlog management approach to reserve capacity for emergency demand: the case of service dispatching in power distribution utilities

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The attendance of emergency services in electric utilities involves the well-known vehicle routing problem in its dynamic form. By knowing gradually these emergency requests in such a way that vehicles are following their pre-established routes, the question that arises from this context is how much time of the workday will be subtracted by addressing these emergency services. In addition, when considering pre-established routes in the context of a power distribution utility, there are several levels of importance related to the services previously routed. Assuming the use of a vehicle routing algorithm with time windows and on site service to construct the pre-established routes, the appropriated management of the service backlog may reserve a certain amount of time on the workday in such a way that this amount is proportional to the number of hours to be used on the attendance of emergency services. Moreover, this reservation is timely dependent: when observing the past request information, one may note that the emergency demand is highly dependent of the day of the week and of time of the day. This work focuses on the development of mathematical programming approach, based on mixed integer linear programming to rationing the backlog when reserving capacity for emergency demand, being this level determined by a forecasting method based on time series.

*Speaker

Sequential search for the multi-depot vehicle routing problem

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Defining rich neighborhoods while maintaining efficient marginal updates of intermediate solutions plays a key role in producing successful heuristics. The sequential search paradigm has proven to be a worthy competitor to the lexicographic search paradigm when tackling single depot vehicle routing problems. The lexicographic search produces a search tree of a neighborhood by expanding move possibilities across the lexicographic ordering of edges contained in the current solution. As the possibilities are explored, segments of path tested for the gain criterion are longer by construction. The idea of the lexicographic search is that once infeasibility is observed, the longer routes remaining in the exploration must also be infeasible and the search can be halted. In contrast, the sequential search halts the exploration of the search tree via a distance sorted neighbor list such that the gain criterion is utilized during the local search. In both cases, the search tree is therefore explored exhaustively although the sequential search is more malleable when it comes to incorporating gain criterion goals because the latter is innately part of the paradigm. The seminal paper is used as a starting point for the multi-depot vehicle routing problem study. The behavior of both search paradigms is studied on classical moves such as 2-opt, 3-opt, or-opt, string exchange, swap and relocation. The analysis is based on benchmark instances from the literature.

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Optimization of urban delivery systems with drones

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Delivery of goods into urban areas constitutes an important issue for logistics service providers. In order to increase the efficiency of their logistics activities and to improve the environment impact, Amazon and La Poste have launched in December 2016 unmanned drone delivery. Delivery by drones offers new possibilities, but also proposes new challenging routing problems. How to optimize the total delivery process time by combining vehicles and drones efficiently? Two kinds of problems have been described in the literature : vehicles and drones combination with synchronisation (a drone is launched from a vehicle while it delivers a customer and the vehicle takes it back at its next delivery point) and without synchronisation (drones deliver customers from a depot).

Here, we consider the problem without synchronisation. We propose an original resolution approach based on dynamic programming. It consists in an iterative two-steps heuristic. The first step builds a giant tour, either by solving a TSP with all the customers at the first iteration or by perturbing the previous giant tour. In the second step, the giant tour is optimally splitted in order to determine what customers are delivered by drones and what customers are delivered by vehicles (in the order defined by the giant tour). The objective is to minimize the makespan, i.e. the latest return time of vehicles and drones to the depot.

The results obtained are very promising. The proposed heuristic is applied on a literature benchmark test of 240 instances. We find better solutions for 224 instances.

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Multi-criteria tourist trip planning

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Plan a cycling-tourist trip over several days taking into account tourism features (ie greenways, points of interest, ...) or specific bike features (ie secure roads, distance, ...) can be a difficult task.
In collaboration with a French company ("La compagnie des Mobilités"), the aim of our research is to develop efficient methods for solving this problem in a short computation time. The problem can be defined as follows. From cyclist preferences, the goal is to find a route from predefined starting and arrival points, that can be follow by the cyclist in a given number of day N. This route should include N-1 stops at not predefined hotels and can pass by some points of interest to visit. Each point is characterized by a duration of visit, a time window where the site is open and a entrance charge. The cyclist preferences are a daily earlier departure time from the starting point or hotels, a daily maximum distance to travel, a daily maximum time that cyclist spent cycling and visiting, and a total maximum cost of the trip. Several criteria to evaluate a solution have to be taking into account: minimize the total traveling distance, maximize the safety of the roads, and maximize the tourist attraction related to the points of interest and the roads.The objective is to propose a set of non-dominated solutions satisfying all the constraints.
We will present an exact and an approximate methods for solving this problem, called the "Multi-Objective Orienteering Problem with Hotel Selection".

*Speaker

An exact method for bi-objective vehicle routing problems

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We propose an extension of the single objective exact algorithm of Baldacci et al. (2008) to generate the complete Pareto front of a bi-objective VRP. The resulting algorithm combines the column generation and the branch-and-bound methods.

The algorithm requires the set of non-dominated points of the LP-relaxation to define a lower bound of the problem. Each point is combined with a direction in which the solution optimizes the problem. The algorithm also needs an upper bound representing feasible solutions of the initial problem. For each direction, the associated gap between the corresponding lower bound point and the closest upper bound point is computed. Then, all routes having their parametrized cost within this gap are generated and solving the resulting VRP provides a Pareto optimal solution.

Afterwards, every pair of consecutive Pareto optimal solutions previously found defines a reduced area where other optimal solutions could be. Those are generated successively by calculating their most efficient direction, lower bound and gap.

The algorithm is applied to a bi-objective VRP with time-windows to minimize two different costs on each route. Computational results will be compared with a classical bi-objective technique.

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Correlated Orienteering for Planning Emergency Surveillance Flights of Unmanned Aerial Vehicles

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Flight plans of unmanned aerial vehicles (UAVs) equipped with optical remote sensor systems often need to ensure the complete coverage of a designated region. More recently, UAVs have been utilized for surveillance tasks in case of emergencies such as gas leaks or fires. In this scenario, the time available for collecting information is limited and it is essential to focus on the most relevant areas during the flight.
In this talk, we present an approach for planning the route of an UAV for surveying potentially contaminated areas after the breakout of a fire. As the vehicle is required to stop when taking images, this corresponds to a discrete routing problem. The objective is to maximise total route utility. The utility of performing a measurement at a point in space is determined by either its temperature or the concentration of a contaminant. Such measurements are typically spatially correlated between neighbouring areas, which allows making predictions about unobserved points. In order to improve the route by taking into account both direct as well as indirect observations, we model the planning problem as a Correlated Orienteering Problem (COP).
For solving the COP we present a Constraint Programming based Large Neighbourhood Search. We evaluate the approach on benchmark instances as well as on a use case in firefighting. The results indicate that the approach yields good solutions within the available time span, and that it is robust towards different utility measures.

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Extended Formulations and Branch-and-Cut Algorithms for the Black-and-White Traveling Salesman Problem

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In this paper we study integer linear programming models and develop branch-and-cut algorithms to solve the Black-and-White Traveling Salesman Problem (BWTSP) is a variant of the well known Traveling Salesman Problem (TSP).
Two strategies to model the BWTSP have been used in the literature. The problem is either modeled on the original graph as TSP using a single set of binary edge variables and with additional non-trivial hop and distance constraints between every pair of black nodes (see {Ghiani2006}) or as a sequence of constrained paths composed of white nodes connecting pairs of black nodes (see {Muter2015}). In this paper, we study and develop an intermediate approach based on the observation that it is sufficient to guarantee the required distance (and hop) limit of the path from a given black node to the next black node without explicitly stating which one it is. Thus, instead of stating the two constraints (after adding appropriately defined variables) for each pair of black nodes, they are stated for each black node only (that represents the source of each path). Based on this idea we develop several variants of position- and distance-dependent reformulations together with corresponding layered graph representations. Branch-and-cut algorithms are developed for all proposed formulations and empirically compared by an extensive computational study. The obtained results allow us to provide insights into individual advantages and disadvantages of the different models.

*Speaker

The vehicle routing problem with locker boxes

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Direct-to-consumer deliveries show an ongoing increase due to the fact that people prefer to order online nowadays. This trend comes along with new challenges, as for example the problem of delivery failures that occur when customers are not at home at the time of a delivery. Additional delivery attempts or dropping the parcels at any arbitrary station causes inefficiencies and inconveniences for both the logistics provider and the customer.
To deal with these changes, it is necessary to consider innovative aspects when designing an efficient logistics systems. In this work, we introduce so called locker boxes to the network, which leads to the vehicle routing problem with locker boxes (VRPLB). We assume that locations and configuration of the locker box stations are already decided. Locker box stations are constrained by capacity. The access to the boxes is not restricted to any opening hours, whereas a delivery to a customer's private address can only happen within a certain time frame. We consider the number of successful home deliveries as a measure for customer satisfaction and will present two variants for taking this into account in the model.
We use randomly generated instances for computational experiments. Both models are implemented as mixed integer programs and small instances are solved with Gurobi. A set covering method is used to solve larger instances heuristically. Adaptive Large Neighbourhood Search (ALNS) serves as a metaheuristic approach. Finally, we combine ALNS with set covering, yielding a hybrid ALNS for the VRPLB.

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Alternative Paths for Reliable Vehicle Routing in City Logistics

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Due to varying traffic volumes and limited traffic infrastructure in urban areas, travel times are uncertain and differ during the day. In this environment, city logistics service providers have to fulfill deliveries in a cost-efficient and reliable manner. To ensure cost-efficient routing while satisfying promised delivery dates, information on the expected travel times between customers needs to be considered appropriately.
Typically, vehicle routing is conducted on an abstract level, relying on direct connections between customers, to determine a desirable sequence of customer visits. These direct connections are usually precomputed using shortest path algorithms. Most approaches merely consider a single (shortest) path, based on a single cost value (e.g., distance or average travel time). When concentrating on travel times, their variation (e.g., due to congestion) is therefore ignored. To incorporate information on travel time variation, it might be of value to consider alternative paths and more sophisticated travel time models such as Interval Travel Times. Exploiting the high connectivity of urban road networks and available travel time information allows for more efficient and reliable routing.
In this work, we investigate the incorporation of alternative paths into city logistics vehicle routing. For this purpose, different approaches for the computation of paths are considered with regard to deterministic and stochastic travel time models. Experiments are conducted within an exemplary city logistics setting. Combinations of different path computation and customer sequencing approaches are evaluated and discussed to investigate the additional value of incorporating more complex travel time models.

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Bidirectional Labeling in Column-Generation Algorithms for Pickup and Delivery Problems

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For the exact solution of many types of vehicle routing problems, column-generation based algorithms have become predominant. The column-generation subproblems are then variants of the shortest-path problem with resource constraints which can be solved well with dynamic programming labeling algorithms. For vehicle routing problems with a pickup-and-delivery structure, the strongest known dominance between two labels requires the delivery triangle inequality (DTI) for reduced costs to hold. When the direction of labeling is altered from forward labeling to backward labeling, the DTI requirement becomes the pickup triangle inequality (PTI). DTI and PTI cannot be guaranteed at the same time. The consequence seemed to be that bidirectional labeling, one of the most successful acceleration techniques developed over the last years, cannot be effectively applied to pickup and delivery problems. In this paper, we show that bidirectional labeling with the strongest dominance rules in forward as well as backward direction is possible and computationally beneficial. A full-fledged branch-and-price-and-cut algorithm is tested on the pickup and delivery problem with time windows.

*Speaker

Which comes first, delivery or sales?

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We deal with a synchronized tactical planning of sales territories and corresponding delivery routes for 3PL /4PL providers. Such a planning is challenging in FCMG markets where Traditonal Trade is still strong compared to Key Accounts. In such markets, 3PL /4PL providers have exclusive distribution agreements with several brends. As the rule of thumb, each brend insists on a salesforce that sells only its products. On the other hand, the delivery of products from different brends can be consolidated. The brends are *compatible* if such consolidation is possible. The lists of the shops of two compatible brends usually overlap to a great extent.
The planner of sales teritories for a single brend usually has complete freedom to organize territories for his/her salesforce. A single salesperson thus gets a territory that is often split into subterritories, where each subterritory can be handled during a single working day. Goods that are sold during a working day are either delivered during one or two working days. All subterritories of the salesforce related to a particular brend and assigned to a particular day can be identified with the daily list of shops in them. Based on the daily lists of shops from all its brends, 3PL/4PL provider plans its delivery routes. Since the planning of sales for different brends is not synchronized, it results in more visits and consequently in more kilometers and more vehicles engaged.
We propose a model for the sychronized planning for compatible brends and present first computational results.

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A bi-objective two-echelon vehicle routing problem with synchronization and customer-to-echelon assignment

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Cargo bikes are an important means of transport in the city of the future. They are environmentally friendly, quiet and perfectly suited for deliveries in the inner-city. However, due to the lower loading capacity and operating distance, they are inefficient for longer distances, such as the ones from a depot on the outskirts to the final customers in the inner city. Therefore, an idea is to introduce transshipment points close to the inner city where goods are transferred between trucks and cargo bikes.
We study a two-echelon vehicle routing problem (2eVRP) with synchronization. In the classical 2eVRP, vehicle routing is performed on two echelons. At transshipment points, the so called satellites, loads are transferred from first echelon vehicles, which supply the satellites, to second echelon vehicles, which supply the final customers. In our problem, customers are not preassigned to the second echelon, and the decision of whether to visit a customer on the first or second echelon has to be taken.
In our bi-objective problem external (social and environmental) as well as economic costs are minimized. As solution method, we use a combination of exact and heuristic methods. Computational experiments on artificial and real world data will be presented.

*Speaker

A Matheuristic for the Multi-Compartment Vehicle Routing Problem with Multiple Periods

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In this presentation, an extension of the multi-compartment vehicle routing problem (MCVRP) is considered, in which a planning horizon of not only one but multiple periods is taken into account. The problem is inspired by the real-world application of glass waste collection from public containers. In each of the regarded periods, the containers are filled by a certain amount of glass waste and they must be emptied before their capacity would be exceeded. To collect the glass waste, a fleet of vehicles with multiple compartments is available, where each compartment can be used to collect exactly one type of glass waste. Thus, different types of glass waste cannot get mixed during transportation and an efficient recycling process is supported. In addition to the typical assignment and sequencing decisions in (multi-compartment) vehicle routing problems, for each container a visiting schedule needs to be determined. For solving this problem, a matheuristic has been developed and implemented. The algorithm uses a tabu search framework, in which the defined neighborhood structure is searched by an integer program. Extensive numerical experiments have been conducted in order to evaluate the performance matheuristic, to gain insights into the problem structure, and to determine the managerial value of considering multiple periods simultaneously. The corresponding results will be presented.

*Speaker

Branch-and-Price-and-Cut for the Clustered Vehicle-Routing Problem with Soft Cluster Constraints

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The clustered vehicle-routing problem (CluVRP) is a variant of the classical capacitated vehicle-routing problem in which the 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 presentation considers the CluVRP with soft cluster constraints (CluVRPSC). Customers of same clusters must still be part of same routes, but do not need to be served contiguously any more. We present an exact branch-and-price-and-cut algorithm, compare different solution methods for the subproblem, and discuss branching strategies and the addition of cutting planes. First, the subproblem is solved as an elementary shortest path problem with resource constraints by labeling algorithms. Second, a mixed integer programming based branch-and-cut algorithm is developed. Both approaches are supplemented by heuristic approaches for partial pricing. To the best of our knowledge, this branch-and-price-and-cut algorithm is the first exact approach for the CluVRPSC.

*Speaker

Another look at snow removal

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Planning urban snow removal is a difficult, infrequently occurring optimization problem, concerning complicated routing of vehicles. Clearing a street includes several different activities, and the tours must be allowed to contain subtours.

Our earlier research in this area has produced the following results:
A large intractable time-indexed MIP-model, including all details such as different vehicles, precedence requirements, turning penalties and environmental aspects.
Some solvable relaxations of the total model, yielding lower bounds.
Heuristic solution procedures for the k-Chinese postman problem, to find a good allocation of streets to identical vehicles, also addressing the question of the number of vehicles.
Optimization approaches for the map matching problem, i.e. transferring a number of GPS-positions to a tour on the edges of a digital map.
A detailed ATSP-based solution procedure for the (over) zealous snow remover problem, i.e. the problem facing a single vehicle, based on a reformulation to an asymmetric traveling salesman problem in an extended graph, plus a heuristic for finding feasible solutions.

The methods have been implemented and tested on real life examples.

In this talk we give an overview of the whole picture, including all the parts mentioned above, and discuss what is missing for making the picture complete.

*Speaker

Vehicle routing problem with arrival time diversification

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We propose a novel method to generate sufficiently unpredictable routes by varying the arrival time at each customer, while minimizing transportation costs. By removing the previous arrival time slots at each customer from the solution space, the problem becomes a Vehicle Routing Problem with Multiple Time Windows (VRPMTW) in which every customer has a set of time windows in which it is still available for service. Because of the reformulation into a VRPMTW with a rolling horizon, our approach is easier, more efficient and more powerful than existing methods. Since waiting times are not allowed a new method is proposed to check if a route is time window feasible. To allow time window violations during the local search, four different penalty methods are proposed and compared in terms of solution quality and computational time. The routing problem is solved using an iterated granular tabu search which finds new best-known solutions for all benchmark instances from the literature. The proposed method reduces average distance with 28% and computational time with 91%. A case study is performed on data from a Cash in Transit company that transfers valuable goods to banks and ATMs. For security and legal regulations they have to use varying routes and computational experiments show the savings potential of the proposed solution approach and quantify the trade-off between arrival time diversification and transportation costs.

*Speaker
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Vehicle Selection for a Multi-Compartment Vehicle Routing Problem

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This paper addresses the selection of single and multi-compartment vehicles for the delivery of grocery products. The transport of grocery products requires to keep required temperatures for particular product segments (e.g., deep frozen, fresh, ambient). Retailers thereby used to rely almost exclusively on single-compartment vehicles (SCV) to transport products with one particular temperature zone. Due to recent technological advances retailers now have the option to use multi-compartment vehicles (MCV) for the distribution instead. MCV possess the ability to transport several temperature zones jointly on the same truck by splitting the loading area into different temperature-specific compartments. For retailers this imposes a selection between different vehicles. This choice is associated with different costs dependent on the corresponding vehicle types. More precisely, costs for loading, unloading and transportation have to be distinguished between the vehicle types and the corresponding routing. In literature either the use of SCV or MCV has been considered for the distribution without a distinction between the vehicle dependent costs and the possibility to use both vehicles in the same distribution fleet to achieve a cost optimal fleet mix. We therefore identify all decision relevant costs within a case study and present an extended MCVRP for the vehicle selection that takes into account vehicle dependent costs. We solve the problem with a Large Neighborhood Search and provide insides on the benefits of using SCV and MCV jointly in grocery distribution. Further, the approach is applied to a real life case to evaluate the economic impact of our extended model.

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Route design for mixed fleet of hydrogen and conventional vehicles

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In this study, a new variant of green vehicle routing problem named as hydrogen and mixed fleet based green vehicle routing problem with recharging station (H-MFGVRPRS) is considered. The study is motivated from the global concerns about environmental sustainability challenges and subsequent CO2 limit imposed for the businesses. Associated with real-life scenarios, a pragmatic energy consumption method and its CO2 emission models of the vehicles is considered as non-linear function of vehicles travel distance. The models incorporate the realistic variation of vehicle speed and cargo load on the arc while calculating CO2 emission. Overall, it is a new GVRP of a mixed fleet and heterogeneous vehicles consists of fuel cell hydrogen vehicle and conventional internal combustion vehicle with alternative refuel stations (AFSs). For the problem, new datasets are generated and utilized for computation experiments in this study. The problem is mathematically formulated as mixed integer programming (MIP) and a meta-heuristic algorithm is designed to solve the problem.

*Speaker

A Benders Decomposition Approach for Solving the Electric Vehicle Routing Problem with Soft Time Windows

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The Electric Vehicle Routing Problem with Time Windows (EVRPTW) is a variant of the VRP where battery electric vehicles (BEVs) are used in order to service customers with time windows. A BEV has a limited travel range due to its battery charge capacity and may need to be recharged at recharging stations. EVRPTW aims at minimizing the number of capacitated vehicles and total travelling costs. In this study, we model the Electric Vehicle Routing Problem with Soft Time Windows (EVRPSTW) by allowing vehicles to visit customers beyond their time windows by a given tolerance, which enables early and late servicing with some penalty costs. EVRPSTW challenges the distribution task of public services and private organizations in a context with heavy traffic, which servicing customers within their time windows is severe. Moreover, the hard time windows can strongly increase the vehicle number necessary to serve all customers, which leads to very high vehicle acquisition costs. Therefore, the flexibility in time windows enables big savings in the investments on vehicle fleet, since the possibility to serve customers out of their time window range may reduce the vehicle number. We formulate this problem as a mixed integer linear program and solve the small instances using CPLEX. To solve the larger problems we develop a Benders decomposition approach. We carried out a computational study to investigate the benefits of soft time windows and test the performance of the proposed approach using benchmark instances from the literature in terms of solution times and quality.

*Speaker

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On asymmetric multi-depot multiple traveling salesmen problem

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We consider multi-depot multiple asymmetric traveling salesmen problem (MmATSP) where each tour starts and ends at the same depot. The problem can be modeled in several ways with different variables. We analyze strengths and limitations of the compact linear integer formulations: the corresponding linear programming relaxations are compared and their non-dominant relations are explained by deriving additional valid inequalities. Also, we propose novel constraints to formulate the depot fixing feature (sometimes referred as path elimination constraints) and consequently novel formulations. Another particular feature we study is lower and upper bound restrictions on the number of nodes visited in a tour. Our results can be directly applied to relevant multi-depot vehicle routing problems as well.

*Speaker

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On the effects of day-by-day planning on the global objective in Inventory Routing

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ORTEC Inventory Routing is a vendor managed inventory solution that minimizes the long-term costs involved in distributing products to multiple customers, while preventing stock-outs at those customers. Currently, trips for the distribution are constructed daily, based on the daily cost per volume as the (short-term) objective, as a way to minimize the total cost per volume over a rolling horizon, the long-term objective. We discuss some negative effects of using this short-term objective on the long-term objective, and ways to reduce some of these effects.

*Speaker

Methods for Corporate Mobility as a Service

Sebastian Knopp *† [1], Benjamin Biesinger [1], Miriam Enzi [1], Bin Hu [1], Matthias Prandtstetter [1]

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Many companies provide individual cars to certain employees in order to fulfill their mobility needs including private and business trips. This can result in a large underutilized fleet of vehicles with combustion engine. For such settings, the project SEAMLESS aims at developing novel corporate mobility services while striving for multiple goals. In order to reduce CO2-emissions, the usage of battery electric vehicles, public transportation, or bicycles should be fostered. However, the flexibility offered by conventional vehicles must remain available in case of need. Thus, operating a mixed fleet of company vehicles in a cost-effective manner is important. Also, other mobility services such as taxis or rental cars should be considered, e.g., for coping with peak hours. Now, bringing the emerging concept of "mobility as a service" to this corporate context results in a system where users request transportation services instead of reserving specific cars. Decisions on the fulfillment of individual transportation requests are delayed in order to increase the number of options available for company-wide mobility planning. We propose a solution approach that first determines a set of possible mobility offers for each transportation request. This facilitates the inclusion of different route planners and allows to include information from third party mobility providers. Then, assuming each vehicle is assigned to a fixed depot and each mobility offer covers a fixed time interval, this leads to a variant of an interval scheduling problem. We present solution methods for the problem at hand and report initial results of computational experiments.

*Speaker

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A hybrid solution approach for the 3L-VRP with simultaneous delivery and pickups

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A vehicle routing problem with three-dimensional loading constraints and simultaneous delivery and pickups is introduced (3L-VRPSDP). Sets of different three-dimensional (cuboid) items have to be delivered to customers. At the same time, items have to be picked up from the customer locations and brought to the depot. This approach requires the integration of three-dimensional packing problems into the VRPB so that packing constraints such as stability requirements or LIFO constraints can be considered.
A particular challenge of the problem is to transport delivery and pickup items simultaneously on the same vehicle. In order to avoid any reloading effort during a tour, we consider two different loading approaches of vehicles: (i) loading from the back side with separation of the loading space into a delivery section and a pickup section and (ii) loading at the long side.
A hybrid algorithm is proposed for solving the problem consisting of an *Adaptive Large Neighbourhood Search* for the routing and different packing heuristics for the loading part of the problem. The solution approach was tested for newly generated instances for the 3L-VRPSDP and well-known instances form the literature for the one-dimensional VRPSDP. The corresponding results will be presented.

*Speaker

Path Problems with Additive and Multiplicative Objectives

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A problem of finding a path between two vertices of a directed multigraph is studied. Each arc is associated with two numbers which can be viewed as the survival probabilty and the length, respectively. The quality of a path is evaluated by two functions, one of which is the product of the arc probabilities and the other is the sum of the arc lenths. We prove NP-completeness of the decision version of this problem, in which there is a lower bound on the multiplicative function and an upper bound on the additive function. We also develop approximation algorithms for the optimization versions of the studied problem, and evaluate their worst case performances. One algorithm is based on approximate computing of logarithms of the arc probabilities, and another is a fully polynomial time approximation scheme (FPTAS).

*Speaker

Routing of Multi-Section Vehicles for Delivery of Multiple Products

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There are several clients (unloading terminals) having given demands for different products. The products are stored at loading terminals. The product transportation is realized by vehicles located at several depots. There are given loading-unloading times, compatibility constraints between vehicles and terminals, and time windows, in which vehicles and terminals are available. Vehicles can include several sections of various capacities. There can be restrictions on the order of changing products carried in the sections. For each vehicle type, the cost of moving a unit of total mass per distance unit is given. Terminals and depots are nodes of a transportation network. The problem is to select vehicles, to determine their feasible routes and feasible loading/unloading plans such that all the demands are satisfied and the total transportation cost is minimized. A route of a vehicle starts and finishes in the depot of this vehicle. The route can include visiting any client or loading terminal several times. We suggest a solution approach that builds partial routes and loading/unloading plans. A complete solution is combined of these parts in an optimal way via solving an Integer Linear Programming problem, or by applying our heuristic approaches.

*Speaker

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Forming, Scheduling and Routing Field Service Teams for Multi-Skill Tasks with Priority Levels

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In this research, we study the multi-skill workforce scheduling and routing problem that exists in all service operations that provide services in customer premises. The problem originates from a real-life operational problem, faced by the electricity distribution companies on a daily basis, requiring efficient assignment of field service personnel to tasks. The problem aims to assign the tasks at different geographical locations with different priorities and skill level requirements to teams of technicians who have different skills. In this research, a mathematical model that forms the teams of personnel, assigns the tasks to the teams according to their skill requirements, and determines the daily routing schedule of the teams is developed. The model has two prioritized objectives. At the first priority level, the objective is to minimize the makespan of the tasks subject to the condition that each task is completed before any other task of lower priority. At the second priority level, the objective is to minimize total daily operational costs, including travel costs, overtime costs, and penalty costs of late tasks. A multi-phased heuristic is proposed for large-scale realistic problems. In the first phase of the heuristic, the teams are formed through a team building procedure. In the second phase, a greedy-based approach is applied to assign tasks to the teams in accordance with their skills and to identify the daily routes of teams. In the third phase, the solution is improved though local search techniques. The effectiveness of the heuristic is assessed using realistic problem instances.

*Speaker

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Flexible Time Window Management for Attended Deliveries

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With the ongoing boom in e-commerce, many retailers offer tight delivery time windows to fulfill customers' expectations of high-quality delivery. After choosing products on an e-grocer's website, for example, customers conclude their booking with selecting one of the offered time windows, which are often as tight as one hour. While customers usually prefer tight delivery time windows, it is well known that these can cause high costs of delivery, because they restrict the underlying routing problem heavily. However, adapting the length of the offered time windows to the current flexibility of the route plan might alleviate this problem.

In this presentation, we investigate flexible time window management to enable more effective routing of attended deliveries with limited transportation resources. Extending customer acceptance mechanisms from the literature, we vary the length of time windows in the course of the booking horizon, considering that the acceptance of an order request can restrict the ability of accommodating future requests significantly. We make the length of a time window depend on customer status (premium/non-premium), time of request relative to the booking horizon (early/late), as well as spatio-temporal routing characteristics (proximity to current routes).

We investigate the impact of these ideas on the number of served customers given the demand structure of order data from an e-grocer in Berlin, Germany. To this end, we build routes iteratively and analyze the trade-off between a large number of high-quality delivery options and the retailers' need to serve as many customers as possible.

*Speaker

A Branch-and-cut algorithm for the Periodic Rural Postman Problem with Irregular Services on Mixed Graphs

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In this paper, we deal with an extension of the rural postman problem in which some links of a mixed graph must be traversed once (or a specified number of times) over a given time horizon. These links represent entities that must be serviced a number of times in some sub-periods of a given time horizon. The aim is to design a set of least-cost tours, one for each period in the time horizon, that satisfy the service requirements. We refer to this problem as the periodic rural postman problem with irregular services (PRPPIS).
Some practical applications of the problem can be found in road maintenance operations and road network surveillance. In order to solve the PRPPIS, we propose a mathematical model and a branch-and-cut algorithm. In the solution framework, constraints ensuring connectivity and other valid inequalities are identified by using specific separation procedures. Some valid inequalities consider the particular nature of the PRPPIS. We show the effectiveness of the solution approach through an extensive experimental phase.

*Speaker

Air cargo rescheduling for demand fluctuations considering transshipments

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Demand for air cargo transportation is very difficult to forecast due to its high volatility. This can be explained by the following factors: i) there is a reduced number of clients who transport large volumes; ii) orders are usually placed on relatively short notice; iii) cargo booked to travel often arrives partially, past its deadline, or in the last minute; and iv) there are no penalties in place for clients cancelling an order. This uncertainty can lead to significant operative inefficiencies, generating losses to the airline. In this work we propose and discuss a model for re-optimizing aircraft itineraries and order routing, considering the last-minute demand realizations. This model, which admits transshipments, takes into account the costs involved in changing the itineraries. We propose and model three different ways to evaluate this particular cost, as a function of the additional number of i) crews; ii) trips between airports; and iii) trips between airport by aircraft. Our model was tested using real-life data provided by our partner in the industry, consisting of a network of fourteen airports and a planning horizon of three days. Three different demand scenarios were constructed, with different disruption levels. Our experiments show the applicability of our methodology, which yields an increase in load factors when compared against applying the original schedule to the disrupted scenario. We also show that modeling with transshipments has a positive impact in the solution, which increases with the magnitude of demand disruptions.

*Speaker

A heuristic for a bi-objective large scale waste collection problem

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In the last few years, the application of decision making to logistic problems has become crucial for public organizations. The search of efficient decisions might contribute in the achievement of different profits for a company, such as cost reduction, service improvement or duty schedules to mention a few. In the particular case of waste collection service, this task involves a set of economic, social, labor and environmental aspects, which implies a big effort from these companies that must provide a good service. Additionally to the problem's constraints, there is a need for optimizing different objectives that might come into conflict with each other. Therefore, we need to resort to a multiobjective approach to deal with this problem. As it is customary in multiobjective optimization, we do not have a unique solution, and we are seeking for a good approximation of the set of efficient solutions. In this paper, two different objectives are considered: to minimize the overall travel cost and to balance the driven routes. The resolution process has two steps: first, the bi-objective problem is transformed, using a reference point, into a mono-objective problem; and then, a metaheuristic strategy is applied. In particular, we consider the hybridization between a Greedy Randomized Procedure and Path Relinking. We explore different designs within both methodologies. The performance of this method is analyzed with its application to solve a real waste collection problem from a southern region of Spain.

*Speaker

Robust solutions for the Inventory-Routing Problem with uncertain travel times

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We assess an inventory routing problem (IRP) where a supplier distributes a single product to multiple customers under uncertain travel times. The travel times are independent and symmetric random variables that take values in an interval around their nominal value. Based on the concepts of 'The Price Of Robustness' of Bertsimas and Sim, we develop a robust optimization model for the problem that allows to control the degree of conservatism of the solution. We demonstrate how the valid inequalities that exist for the IRP can be adapted for the robust IRP (RIRP). Furthermore, we present a Benders' decomposition-based matheuristic to solve the problem effectively. Experimental results confirm the success of this approach compared to other robust optimization techniques.

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Lifted compact formulations for the Capacitated Vehicle Routing problem

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We present lifted polynomial length formulations that can be obtained using Reformulation and Linearization Techniques (RLT) from an initial ordered path-based formulation. The tightest formulation that can be derived using this process turns out to be equivalent to the strongest multi-commodity flow formulation presented in the literature by Letchford and Salazar-Gonzalez. In order to further strengthen the formulation, three sets of polynomial size valid inequalities are proposed. The first set is retried using precedence relationship between customers from the Traveling Salesman problem, the second set is obtained applying RLT on precedence constraints and the third set exploits the possible incompatibilities of the customers on the basis of their demands and of the capacity load of the vehicles. Finally, we present computational results with the aim of showing the tightness of the proposed formulation and the impact of the valid inequalities.

*Speaker

An Open Source Tool for Generating Arc Routing Instances from Real Street Data

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Optimization algorithms for vehicle and arc routing problems often rely on a set of benchmark problems to validate and demonstrate performance. Ideally, these benchmark problems are reflective of the real-world street networks on which practitioners will be solving the problem. However, with few exceptions, these instances are artificially generated to try and approximate real networks. Even if special attention is paid to ensure that relevant parameters fall within practical ranges, there is significant variety between street networks of different cities, for example. Open Street Maps is an open, user-driven map database which allows software developers to query it for map data. We develop and present a software tool that allows users to generate arc routing problem instances directly from this map data. The tool allows the ability to curate (prune edges or vertices or mark them as required) the resulting network either by hand, or according to configurable parameters. The instances generated in the tool can then be exported for use by researchers. In addition, the tool offers a visualization capability which can produce images of routes overlaid on the graph.

*Speaker

Improving a city road network for the Multi-Depot Vehicle Routing Problem

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In this research, a number of Multi-Depot Vehicle Routing Problems, in which only a subset of the customers has a demand, are considered in an incomplete network. We will propose two solution approaches to determine the best single improvement or best set of improvements of this incomplete network, such that the total travel time of the vehicles in these routing problems is minimized. This problem originates from the situation in a number of (Dutch) cities where a large part of the logistics within the city area are performed by one transport company. In this case, this company will be able to suggest its most beneficial improvements to the network to the traffic manager. Favoring this transport company will reduce the traveled vehicle kilometers within the city area. In this research, three possible network improvements are considered: (re-)opening pedestrian zones for vehicles, widening existing roads and converting existing roads into one-way roads with a higher speed. The first approach is a Three-Phase Heuristic, which consists of a construction phase, an analysis phase and a testing stage. The second approach is an Adaptive Large Neighborhood Search (ALNS). This ALNS consists of a unique set of destroy and repair methods. The performance of our heuristic is evaluated on a set of benchmark instances based on a realistic road network with a varying number of customers and vehicles. Additionally, the solution quality is compared to that of solutions obtained using exact solution techniques.

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The Multi-Objective Capacitated Vehicle Routing Problems with Multiple Trips

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The Multi-Objective Capacitated Vehicle Routing Problems with Multiple Trips (MO-MTCVRP) will be defined as the Capacitated Vehicle Routing Problems with Multiple Trips where the objectives are: minimization of the number of vehicles, of the total travel cost, and of the maximum latency (accumulate visiting time for the last customer).
The MO-MTCVRP deals with the transportation and distribution activities in humanitarian logistic operations in a natural way, as a multi-objective vehicle routing problem with multiple trips. Since the fleet of vehicles in a disaster scenario is often reduced, and the capacity of the vehicles is limited, then the need for multiple trips is more than justified.

Additionally, if we focus on the objective functions, we need to take the importance of reducing costs, that is, the minimization of the number of vehicles and of their total travelling cost, and it is also crucial to provide a fast response in a disaster situation, that is, to minimize the maximum latency, i.e., the minimization of the waiting time of the last affected victim in the disaster area, rather than the total waiting time, as is usually carried out in other logistics operations.
The model under consideration (MO-MTCVRP), is clearly not only useful in this context, but it can also be extended or adapted to other real-world situations, as medical transport operations. For the purpose of producing high-quality solutions, a Multi-Start Algorithm with Intelligent Neighborhood Selection is designed and then compared with one of the reference in the literature, to prove its superiority.

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Owning or sharing autonomous vehicles: comparing different ownership and usage scenarios

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Emerging challenges, such as finite oil supplies, rising gas prices and traffic congestion, going in hand with environmental concerns are the reason for new transport innovations, like autonomous vehicles, which will play a major role in future mobility systems. Regarding autonomous vehicles (AVs), two ownership models are being considered for future transportation systems. These are: autonomous vehicles as a public service or privately owning them. Furthermore, they can be used in a private or shared mode. As such, we study the different cases of using autonomous vehicles and the potential use of such vehicles in a ride-sharing application. In the first case, AVs can be used as a public service. In such case, we consider that there is a fleet of such vehicles located on specific locations (depots). AVs are invoked from their stations to satisfy mobility demands appearing in an urban area such that one single AV can serve multiple demands before getting back to a depot. On the other hand, privately owned AVs cannot just bring their owners from their homes to their work locations in the morning and bring them back in the evening while providing ride-sharing opportunities to other users, but they can also serve other users when their owners do not need them (e.g. while they are at work). Extending work on vehicle sharing by [Stiglic et al., 2015], we propose different approaches for planning AV trips aiming at studying and comparing the different ownership and usage scenarios for autonomous vehicles in an urban context.

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Evaluation of methods for construction of robust supply vessel schedules with discrete-event simulation

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Supply vessel planning problem arises in offshore oil and gas logistics, where a fleet of vessels provides cargo deliveries to offshore installations on a periodic basis from an onshore supply base. The objective is to define an optimal fleet composition and a least-cost weekly sailing plan of scheduled vessels' voyages. The problem is defined as a fleet-sizing and periodic routing problem with multiple time windows at installations and voyage duration constraints. Weather conditions change dynamically and may significantly influence vessels' sailing and service times, resulting in sailing plan infeasibility. The planners need vessel plans with sufficient robustness to offset the impact of weather conditions and avoid use of additional vessels. Known approaches for construction of robust vessel schedules consist of generation of shortest duration voyages and solution of a set covering model. In some approaches, voyage slacks are incorporated during voyage generation phase based on planners' experience. In other approaches, shortest generated voyages are simulated over multiple replications of wave height evolution to compute voyage robustness measure or to assign voyage duration. In this study, we evaluate robustness of vessel schedules constructed by different robustness approaches with the developed discrete-event simulation model. It simulates weekly sailing schedules repetitively over seasonal horizon over multiple replications of weather scenarios. Multi-site multivariate seasonal sea state modeling is based on nonparametric numerical resampling and intra-day hind-cast metocean data. Experiments are conducted on real-based instances from an oil and gas company. We examine the impact of various instance characteristics on robustness of weekly sailing schedules.

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The Traveling Purchaser Problem with time-dependent quantities

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The Traveling Purchaser Problem (TPP) looks for a tour visiting a subset of markets to satisfy a positive discrete demand for some products at minimum traveling and purchasing costs. The problem is known to be NP-hard in the strong sense, and finds application in different real contexts. Frequently, as a static problem, the TPP lacks of realism: different purchasers may compete for the same resources, and the products quantity supplied in the markets may reduce during the day. We study a variant of the TPP where product quantities in the markets are time-varying by a constant positive consumption rate. The problem is analyzed in a single-day horizon, with fixed product prices and daily stock replenishment. Although in real contexts the product consumptions can be dealt with stochastic processes, we consider a deterministic linear decrease of the quantities over time. We show that such an approximation can safely represents a conservative estimation to the real consumption when the selected line slope is chosen steep enough. We propose a compact formulation for the problem, and strengthen it with connectivity constraints. A new branching strategy and a primal heuristic, enforcing the bounding operations, have been embedded into a branch-and-cut framework. The branching rule exploits a simple valid inequality and the presence of necessary markets. The resulting method outperforms CPLEX 12.6 when used to solve the proposed model. Algorithms have been compared on standard TSPLIB instances modified to include products and quantities decreasing at different rates of consumption.

*Speaker

A generalized formulation and solution approach for stochastic routing problems

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We introduce a generalized framework for solving various classes of stochastic vehicle and inventory routing problems as well as other probability-based routing problems with a time-horizon dimension. Demand is assumed to be stochastic and non-stationary, and is forecast using any forecasting model that provides expected demands over the planning horizon, with error terms from any empirical distribution. The optimization methodology is heuristic, based on Adaptive Large Neighborhood Search (ALNS). In this work, we provide a detailed mathematical formulation of the proposed framework, discuss possible conceptual applications, explore in detail several specific problem classes, and demonstrate that probability-based routing problems over a planning horizon can be seen through the lens of stochastic inventory routing. The numerical experiments demonstrate the suitability of our approach and the efficiency of the optimization framework. The optimization results are corroborated by simulation runs.

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Metaheuristic approaches for the multi-period vehicle routing problem with synchronization constraints and refuelling

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In the context of home health care services, patients might need to be visited multiple times by different healthcare specialists or the services given by a health care specialist must be performed in a certain order over a set of days. In other words, each home health care patient has unique needs and combinations of multiple services are used to meet those needs at her/his preferred location. In order to tackle this specific routing and scheduling problem, we study the multi-period VRP with synchronization constraints. This problem is a variant of the VRP and consists of finding a set of vehicle routes to serve a set of patients who may require several synchronized visits over a set of days. Moreover, each patient must be served within a pre-specified time window in a multi-period planning horizon. Furthermore, due to the limited fuel tank capacity, a vehicle also requires refuelling at fuel station in order to visit the rest of patients along its route of the day. In this research, we name this variant of the VRP as the MP-VRPSynch with Refuelling (MP-VRPSynch-RV).
We present an integer linear-programming formulation for the MP-VRPSynch-RV and propose three population-based Hybrid Artificial Bee Colony metaheuristic algorithms. These variants include Demon algorithm, Old Bachelor Acceptance rule, and Record-to-Record Travel mechanism. To evaluate our proposed metaheuristics, we generated new test instances and used a set of single-period VRPSynch instances from the literature. The results show that our proposed algorithms produce high-quality solutions and outperform the current state-of-the-art-algorithm.

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Revisiting the Balanced VRP: A Comparative Study of Alternative Workload Metrics

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Real-life optimization problems often have conflicting objectives, and so there has been growing interest in multi-objective models and methods for tackling such problems. Objectives concerning equitable workload allocation and/or balanced resource utilization in VRP contexts have been considered by researchers and practitioners alike. Despite many practical applications reported in the literature, there has been only limited discussion about relevant metrics for modeling workload, and about functions for measuring its equitable allocation.
Based on a recent survey and analysis, we observed that the theoretical literature has thus far focused almost exclusively on a narrow and problematic definition of equitable workload, modeled by the range of tour lengths. Yet papers reporting on applications include interesting cases in which other definitions of workload are more appropriate, e.g. the number of stops in the small package delivery sector, service times in service technician routing, and load/demand in groceries delivery. Various equity functions have also been proposed besides the range of workloads.
In this contribution we discuss a comparative study of alternative workload metrics beyond tour length. We also consider the impact of different equity functions for measuring balanced allocation of these workloads. By analyzing Pareto-optimal solution sets of bi-objective VRP models, we provide insights into how the choice of workload metric and equity function affects the trade-off solutions identified. Our observations also generalize to constraint-based approaches. We hope that by placing more emphasis on broader definitions of workload and equity, existing theory and methodology can be generalized to a wider range of balanced VRPs.

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An update on VRP-REP: the vehicle routing problem repository

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The Vehicle Routing Problem Repository (VRP-REP) is an open data platform for sharing benchmark instances and solutions of vehicle routing problems. With VRP-REP, users can upload/download instance and solution files; plot instances and solutions in their web browser; link instances and solutions to publications; track the best solutions for instances over the years; access open-source code for solution verification; and contribute with their own solution verifiers. VRP-REP was launched during the 2014 VeRoLog conference in Oslo. Since then, the platform has grown fast: it accounts today for more than 250 users from more than 60 different countries (including practitioners from world-leading companies). Thanks to the efforts of its contributors, the data shared through the platform has also grown, and the functionalities have expanded. In this talk we review the platform's evolution over the last three years and present its forthcoming developments.

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An integrated framework for bus driver rostering and re-rostering

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The driver rostering problem in public transit companies aims at assigning daily crew duties to each driver defining a sequence of workdays and days-off, the driver schedule, to be in force during a pre-determined rostering horizon. A roster is the set of all driver schedules, together with the particular work shifts that drivers must work on. The rosters must comply with labor regulations, drivers' union agreements and meet the demand for transport in specific urban areas, while minimizing costs and balancing the workload among drivers. During real-time control, absences of drivers call for an adjustment in the current roster, the re-rostering problem. Absent drivers must be substituted by reassigning daily crew duties to drivers, from the first day of drivers' absences, eventually, until the end of the rostering horizon. The resulting new roster should minimize the dissimilarities to the current roster so as to reduce the inconvenience of changing the previously assigned schedules besides ensuring workload demand, rostering constraints and maintaining the equilibrium of the roster. In this talk, the rostering and re-rostering problems are formulated in a multilevel acyclic network through integer multi-commodity flow/assignment models. Taking advantage from the network and model characteristics, a decompose-and-fix heuristic is used to solve the rostering problem. This heuristic is easily adapted to solve re-rostering problems, by penalizing changes in crew duties previously assigned to drivers through the objective cost function, leading to an integrated framework for solving (re)rostering problems. Computational experience with instances derived from real world data is presented.

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A Hybrid Approach for the Travelling Salesman Problem with General Time Windows

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In urban distribution of supplies to restaurants, short travel and service times as well as low delivery volumes enable logistics providers to serve a large number of customers per day. We consider an application where a driver is responsible for an area of customers for which no feasible route might exist if hard time windows were enforced. Instead, restaurants specify delivery time preferences, taking into account their opening hours and their rush hours during which service is not desirable. This is a special case of the Vehicle Routing Problem with General Time Window, which we define as the Travelling Salesman Problem with General Time Windows (TSP-GTW).

In a TSP-GTW, we model preferences as piecewise linear penalty functions, which may comprise multiple preferred intervals, penalties for early or late delivery and intervals where service is forbidden. The objective in our case is to find a tour that minimizes in a hierarchical order (a) total penalty cost, (b) number of customers with nonzero service penalty, and (c) total route duration.

We present a solution approach for the TSP-GTW combining a Constraint Programming model, a regret based route construction heuristic and a dynamic programming approach for determining minimum service cost. In order to minimize route duration, we iteratively enhance this approach with customer sequences from solving the TSP-TW with artificially increased zero penalty time slots using dedicated TSP-TW approaches. We successfully evaluated this hybrid heuristic on artificial and on real-world instances from a food distributor in Paris (France).

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An optimization model for integrating production and distribution planning in furniture companies

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We propose a mixed integer programming model that integrates production and distribution planning in Brazilian small furniture companies, in which the manufacturer has one production line and a small fleet of heterogeneous vehicles to make deliveries. Our formulation properly represents the problem and can be used to support the planning of production and distribution operations in small companies. A set of random instances is used to evaluate the performance of the model in terms of both solution quality and computational effort. In order to show the benefits of coordinating production and distribution operations, we compare our model with a two-step procedure that follows the common practice of furniture companies. In such a procedure, the integrated model is decomposed into two smaller subproblems, representing production and distribution decisions, respectively. These two subproblems are then solved sequentially in order to find a feasible solution to the problem. Numerical experimentation using a general-purpose solver showed that the integrated model can be used to solve instances with up to twenty customers and five products, whose size is considered realistic for small companies. Results also pointed out that integrating production and distribution decisions allows us to find solutions with lower total cost than those obtained by the sequential procedure. Still, solving the integrated model requires a higher computational effort.

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Quality-oriented scheduling procedures for the dial-a-ride problem

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A dial-a-ride system is an application of demand-dependent, collective people transportation. Users request a trip between an origin and destination of choice. A time window is imposed on the departure or the arrival of the user and his ride time (the time spent in the vehicle) is limited. The service provider attempts to develop efficient vehicle routes and schedules, respecting these requirements and the technical constraints of a pickup and delivery problem.
Solution algorithms invoke a scheduling procedure to assess the time feasibility of routes. Due to the maximum ride time constraint, serving each node at the earliest possible time is not effective. Postponing a pickup may reduce the ride time of the user involved. Cordeau and Laporte (2003) apply the forward time slack principle to eliminate constraint violations whenever possible. However, their procedure ignores the quality of the schedule. Parragh et al. (2009) modify the forward time slack approach to minimize the total ride time of all users, at the expense of occasional incorrect infeasibility declarations.
Our work introduces a scheduling procedure that minimizes the total user ride time according to a different strategy. Starting from a schedule with minimal ride times for the given time windows, potential travel time shortages are eliminated while keeping ride time increases as limited as possible. Extensive computational tests on different sets of benchmark data show that the proposed procedure is fast and fails on fewer routes than Parragh et al. (2009). In addition, feasible schedules exhibit smaller deviations from the optimal solution.

*Speaker

A generalized formulation for vehicle routing problems

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In the vehicle routing literature, different types of formulations have been proposed to model a variety of routing problems. Most of these formulations can be classified into one of two classes: vehicle flow formulations on the one hand and set partitioning formulations on the other. Vehicle flow formulations have the advantage of being compact models that can straightforwardly be solved by commercial optimization packages. However, the models typically have many constraints and weak relaxations. Set partitioning models commonly lead to stronger relaxations, but have a huge number of variables. As a consequence, these models require sophisticated solution methods, commonly based on column generation with complicated pricing problems. In this paper, we develop a generalized formulation for the capacitated vehicle routing problem. This formulation is based on the concept of partial vehicle routes, which we refer to as p-steps. These p-steps visit a fixed number of customers and take the limited vehicle capacity into account. We show that the vehicle flow formulation and the set partitioning formulation are special cases of our general p-step formulation. Varying the fixed number of customers to be visited in a p-step allows us to study the transition from vehicle flow to set partitioning models. We study this transition theoretically and perform computational experiments to analyse the strength of the relaxations. Finally, we explain how the generalized formulation can be adapted to include time windows.

*Speaker

A Multi-objective Dynamic Vehicle Routing Model for Food Rescue and Delivery

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The not-for-profit food rescue organizations play a vital role in alleviating hunger in many developing and developed countries. They rescue surplus food from the business sector and re-distribute to welfare agencies supporting different forms of food relief. In practice, the food rescue and delivery problem is dynamic, and changes when the operation of routes is in progress. The supply of food providers is uncertain until observed upon the driver's arrival. Moreover, new pickup requests arrive randomly over time and there is no deterministic nor probabilistic information on their location and supply until they arrive. In such instances, routes must be reconfigured dynamically while executing the current plan. Furthermore, the routing model must consider, the perishability of products, level of fairness in the distribution, etc., in addition to the operational cost, which are highly relevant to the operational policies of food relief logistics. In this study, we define and model an integrated allocation-routing problem that fairly allocates the uncertain surplus food among the welfare agencies with minimum wastage accounting for the perishability of products, and designs effective vehicle routes. We propose and implement a Tabu Search heuristic solution algorithm for this food relief logistics problem. The performance of the proposed approach is first evaluated in static conditions and then the other assumptions and developments are added gradually and the changes are examined. We design and evaluate various test scenarios which comprise different occurrences of the dynamic events to illustrate the efficiency and effectiveness of the proposed approach.

*Speaker

A decomposition scheme for service network design of bike sharing systems

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We propose a service network design formulation to address the redistribution problem in station-based bike sharing systems. Due to spatial and temporal characteristics of user demand, e.g., commuting, such systems require bike redistribution among stations to ensure both bikes and free racks when and where required. Our formulation, which takes the form of a MILP, aims to produce a cost-efficient redistribution plan, which is defined in terms of services. A service is described by a vehicle movement between two stations, the number of transported bikes, and time interval. Such services are scheduled into master tours, which are regularly operated by load vehicles. For an adequate representation of redistribution decisions, a master tour does not only indicate a chronologically ordered sequence to visit stations, but also the necessary handling time to pick-up or deliver bikes at such stations. In order to produce good-quality solutions for large instances, we propose an iterative solution method which combines hierarchical decomposition, metaheuristics, and exact optimization techniques. Each iteration of our decomposition scheme consists of 1) a dynamic transportation problem determining services to be operated, and 2) a single-commodity pick-up and delivery problem determining the schedule of such services into tours. The tours are stored in a pool, which is finally used to provide guidelines for efficiently exploring the search space of the original service network design problem. We demonstrate the efficacy of our solution methods with an extensive computational study on a new set of challenging instances.

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Design and Incentive Decisions in Humanitarian Supply Chains

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During humanitarian relief operations, designated facilities are established by the authorities (for example, cities or local communities), to which the affected population will arrive to receive relief goods (water, food, etc.). The authorities typically instruct the affected population regarding which facility they should visit. However, at times of crises, uncertainty and lack of information, these instructions are often not followed, which may cause some facilities to be congested, while others to be under-utilized.
In this work, we investigate how the authorities should invest in incentivizing the population to follow their instructions. These decisions need to be combined with those concerning the supply chain design, i.e., which facilities to establish, and how to allocate existing resources to them. A key factor in deciding on such investments is the population behavior, and in particular its cooperation level, which may vary between communities. We model this behavior and incorporate it in a mathematical formulation, building on previous research on humanitarian supply chain design which includes a humanitarian objective function as well as equity constraints.
We develop solution methods to solve the resulting problem. Our preliminary results concerning the level of investments that are needed to provide an efficient supply chain design indicate that a small investment in some communities is typically sufficient to significantly improve the overall system performance.

*Speaker

The capacitated routing problem with profits and service level requirements

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Inspired by a real-life case we propose the Capacitated Routing Problem with Profits and Service Level Requirements (CRPPSLR). The CRPPSLR extends the class of Routing Problems with Profits by considering customers requesting deliveries to their service points. Moreover, each customer imposes a service level requirement (SLR) specifying a minimum bound on the fraction of its service points being delivered. A customer-specific flat-rate financial penalty is incurred by the Logistics Service Provider (LSP) when this requirement is not met. The CRPPSLR consists of finding vehicle routes maximizing the difference between the collected revenues and incurred transportation and penalty costs in such a way that vehicle capacity and route duration constraints are met. A fleet of homogeneous vehicles is available for serving the customers. We design a branch-and-cut algorithm and identify valid inequalities that have been effectively used for the Capacitated Vehicle Routing Problem and for other Routing Problems with Profits. Moreover, a matheuristic which produces promising starting solution structures is developed and used as a pre-processing step of our branch-and-cut solution framework. A real-life case study in cash distribution highlights the relevance of the problem under consideration and computational results illustrate the performance of the proposed solution approach under different input parameter settings.

*Speaker

Loading Constraints for a Multi-Compartment Vehicle Routing Problem

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Little attention has so far been paid to multi-compartment vehicles routing problems with flexible compartments. Practice shows that many retailers use these technical advanced vehicles in their distribution. Multi-compartment vehicles (MCV) offer the possibility to deliver various product segments jointly and therefore can reduce the number of customer stops. Besides classical routing decisions, the configuration of each truck becomes an essential part in tour planning when using MCV. This requires defining the segment mix, compartment sizes, and the combinations of different orders and therefore customers on vehicles. As orders of one segment can only be loaded jointly and as the orders cannot be rearranged on the loading area during the tour, customers and segments need to be sequenced so that no blocking during unloading occurs. Routing and loading layout planning are interdependent for MCVs. Our work addresses the problem to obtain feasible MCV loading and cost-optimal routing. An MCVRP is formulated that takes into account loading constraints. We present a specialized packing problem to account for loading constraints. It is integrated into a branch-and-cut algorithm and a Large Neighborhood Search (LNS). The tailored LNS iteratively solves the routing and packing problem. In numerical studies we show that the proposed LNS reaches the optimal solution for small instances and can be applied efficiently to larger problems. Additionally, we perform tests on larger instances to derive general rules for the influence of loading constraints. To conclude the numerical experiments, a case study was analyzed with an European retailer.

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Vehicle routing for trunk delivery applications

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The growth of the e-commerce sector with the ever-increasing push towards online-shopping poses a major supply chain challenge for many companies. Usually, last-mile delivery; i.e., the delivery of goods to the consumers is the most expensive and inefficient part of the supply chain. Year-over-year growing sales volumes, huge number of delivery locations, and the aggressive service levels promised to customers drive companies to seek innovative strategies to increase the efficiency of last-mile delivery operations. Among these is the trunk delivery service introduced recently by Amazon, Audi and DHL. Motivated by the interest in trunk delivery services, we study a variant of the vehicle routing problem, called the vehicle routing problem with roaming delivery locations (VRPRDL), in a dynamic setting. In the static version of the VRPRDL, each customer has an itinerary specifying one or more locations with corresponding time windows where the customer's order can be delivered to the trunk of his/her car, and customer itineraries are assumed to be known with certainty and remain unchanged throughout the day. We consider a dynamic version of the problem where there may be deviations from the original customer itineraries that can render the planned delivery schedule infeasible or suboptimal. We propose a rolling horizon approach to solve the problem in which the delivery routes are re-optimized every time there is an itinerary change using the branch-and-price algorithm we developed for the static VRPRDL. We perform a computational study to test the efficiency of our solution approach and report the results.

*Speaker

A path-based Mixed Integer Linear Programming formulation for the Green Vehicle Routing Problem

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The Green Vehicle Routing Problem (G-VRP) is a variant of the classical Vehicle Routing Problem (VRP) in which Green Vehicles (GVs), such as those with alternative fuel propulsion, are considered. Since GVs are characterized by a limited driving range, one or more stops at Refueling Stations (RSs) may be required along their trip. The goal of the problem is to serve a set of customers exploiting a fleet of identical GVs and minimizing their total travelled distance. Each vehicle leaves from the depot and returns to it. A maximum limit is imposed on the route duration. We propose a path-based Mixed Integer Linear Programming formulation for the G-VRP. In classical VRPs, paths enumeration techniques cannot be adopted due to the exponential number of feasible paths. On the contrary, in the G-VRP, given the GV autonomy constraints, the number of feasible paths is somehow limited. We generate all the feasible paths between the depot and each RS and between two RSs. We also introduce some rules to a priori exclude dominated paths from the feasible set. Such a feasible set is given in input to a Set-Partitioning formulation with the aim of selecting a subset of paths that, properly combined, compose the solution routes for the G-VRP. Computational results, carried out on benchmark instances, show that our approach is much faster than every exact method already presented in the literature, and it is also suitable to detect the optimal solutions in almost all the test cases.

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Efficient routes in a Periodic Inventory Routing Problem

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In this work, a mixed-integer linear programming formulation for a Periodic Inventory Routing Problem, based on routes variables, is presented. In particular, a product has to be shipped from a supplier to a set of customers over a innite time horizon. Given the plan periodicity, the problem is to determine a periodic shipping policy that minimizes the sum
of transportation and inventory costs at the supplier and at the customers per time unit. Due to the difficulty to solve a formulation with all the possible feasible routes, the aim of this work is to find the minimal set of routes that allows to have the best possible worst-case performance ratio, allowing to solve the problem with a lower number of integer variables ensuring the quality of the solution over a threshold.

*Speaker

Two-phase hybrid algorithm for the vehicle routing problem with scarce, reusable resources

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This work presents a hybrid algorithm for the vehicle routing problem with scarce, reusable resources. The proposed methodology allows to decompose the problem in two phases. Firstly, a Mixed Integer Programming-based procedure is developed to provide multiple assignments for pickups and deliveries of a set of tools within a planning horizon. Secondly, a heuristic algorithm is put forward to obtain routes that satisfy the scheduled pickups and deliveries, relying on savings and local search procedures. The methodology is devised to address the VeRoLog Solver Challenge Part I (All-time-best). Results are validated on the challenge platform for the available instances, for which feasible solutions are consistently obtained within reasonable CPU times, achieving high ranking positions in the challenge.

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Collaborative vehicle routing with excess vehicle capacity in urban last-mile deliveries

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Consolidation of transport flows in logistics is one of the key ways for sustainability in urban transportation. The load factor for trucks in Europe is around 50% and a similar trend is seen in other parts of the world as well. In this paper, we introduce a novel collaborative vehicle routing strategy between logistics carriers where one (external carrier) offers the other (focal carrier) the possibility to piggyback on its routes by using its unused capacity. The number of nodes whose demand can be redirected from the focal carrier to the external carrier is constrained by the excess capacity in the vehicles of the external carrier. It is observed that the excess capacity in the external carrier routes varies from day to day, hence it is not always cost-feasible to consolidate demands of customer locations. There is a fixed cost per trip to move items from focal warehouse to external warehouse, which offsets the savings obtained by collaboration and also adds another dimension of complexity to the problem. The decision to collaborate is very ad-hoc and depends on the instance characteristics. We developed a heuristic inspired from the Knapsack problem to generate good quality initial solutions very fast. We also implemented a local search to improve the initial solution by defining some problem specific neighborhoods. For the benchmark instances, the local search heuristic provides solutions with a very small optimality gap ($<$ 0.1%). Our experiments show potential savings in total distance traveled using this collaborative strategy under different scenarios.

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Some recent research on electric vehicle routing

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Goods distribution with electric vehicles has become a hot topic in the last few years. We discuss some of the most recent research done in the field of electric vehicle routing and introduce a new 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. We also discuss how the battery can be modeled in a way that allows realistic non-linear charging functions to be used, as well as how to integrate certain battery health considerations.

*Speaker

The Glider Routing and Trajectory Optimisation Problem

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Unmanned Aerial Vehicles (UAVs) are increasingly popular. Their use can be cost-effective and they can perform missions in locations inaccessible by terrestrial vehicles. UAVs are suitable, for example, for disaster assessment. Detailed pictures of the areas affected by a disaster can be taken quickly. While the utilisation of powered UAVs has been investigated, routing unpowered UAVs such as gliders has not been broadly studied. Gliders are much cheaper, they glide for long distances without the need for batteries, and they do not require a pilot or landing strip. On the other hand, specialised control systems to optimise their trajectories have to be utilised. We define the Glider Routing and Trajectory Optimisation Problem (GRTOP) as the problem in which a fleet of gliders is required to fly over a set of waypoints subject to operational constraints, such as the influence of wind. Motivated by a flooding assessment application, we present a Mixed-Integer Second-Order Cone Programming (MISOCP) formulation for the GRTOP. Preliminary results show that this formulation is able to provide solutions for small instances based on real world flooding maps.

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A strategic and tactical facility location problem with mobile equipment

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A large majority of facility location problems in industry aim at locating production plants or logistics facilities over a strategic time horizon. Sizing decisions determine the overall capacity installed at each capacity. One strong characteristic is that the installed capacity is generally not very flexible.
In this research, we model the problem of locating logistics platforms and planning a set of tasks. A characteristics feature is that some tasks require the use of mobile equipement, i.e. some machines that can be moved from one logistics platform to another. The problem includes strategic decisions (select a subset of candidate platforms to be opened) and tactical decisions (locate the mobile equipment).

We consider a time horizon of a few months, decomposed into several time periods, typically weeks. The company has a large set of intermittent customers, with a deterministic but variable demand during a subset of time periods. The objective function to be minimized is the sum of the fixed set-up cost of platforms, production, inventory and delivery costs and the cost of moving the mobile resources from one platform to another.
The model the problem as a mixed integer linear program (MILP). We first solve it with IBM Ilog Cplex 12.6. Then, for large-sized instances, we develop a Large Neighborhood Search meta-heuristic. We present numerical experiments for a case study in the sector of civil engineering.

*Speaker

An improved Branch-Cut-and-Price algorithm for heterogeneous vehicle routing problems

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This work considers a family of VRP variants that generalizes the classical Capacitated Vehicle Routing Problem by taking into account the existence of a number of vehicle types differ by capacity, costs, depot allocation, or even by the set of customers that they can visit. Those problems are very important in practice, since fleets are likely to be heterogeneous in most real-world situations.

The proposed Branch-Cut-and-Price algorithm combines several state-of-the-art techniques known to be efficient for routing problems : bi-directional ng-path based labeling algorithm to solve the pricing subproblems, generation of limited arc memory rank-1 cuts with up to 5 rows, reduced cost fixing of arc variables, enumeration of elementary routes, automatic dual price smoothing stabilization, and multi-phase strong branching with pseudo-costs.

To improve the master problem relaxation, we additionally generate homogeneous extended capacity cuts. We computationally show that these cuts, even in the presence of rank-1 cuts, are important for solving difficult instances of the problem. Other contributions include pricing subproblem dependent memory for rank-1 cuts, and the concept of " enumerated mode " for pricing subproblems.

The proposed algorithm was tested on a set of standard instances of the problem, including multi-depot and site-dependent variants. The dimension of instances that can solved to optimality was doubled in comparison with the state-of-the-art algorithm by Baldacci and Mingozzi (2009). Several best-known solutions were improved.

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Arc Routing in Money Collection

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When routing money collection additionally to the total collecting time minimization, avoiding robberies is also a major concern and so the tours cannot somehow be anticipated. This problem is faced by a Portuguese company when the safes of the parking meters need to be collected.
The safes are spread over the streets so Arc Routing is a natural approach. Although some studies for node routing problem exist, references on arc routing regarding the safety issue could not be found. We called this new problem Dissimilar Arc Routing Problem (DARP).

DARP is defined on a mixed graph. Edges represent narrow two way streets that may be served by only one traversal. Arcs are large two way streets that need to be served each direction, or one way streets. The nodes are street crossings, dead-end streets and a depot, where every tour must start and end. The links that represent streets with safes to be collected are named as tasks. Services should be performed on a daily basis and a planning time horizon of five working days is on focus. The problem aims at finding a set of dissimilar tours, one tour for each day, which minimizes the total time.

To impose dissimilarity, tours are divided into periods, and it is avoided that a same task is scheduled for the same period in different tours. We present a mixed integer programming formulation and a matheuristic. Computational experiments are reported.
Keywords: Arc Routing; Dissimilar Arc Routing; Integer Programming Formulation; Matheuristics.

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Aesthetic considerations for the Min-Max K-Windy Rural Postman Problem

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The aesthetic quality of routes is a feature of route planning that is of practical importance, but receives relatively little attention in the literature. Several practitioners have pointed out that the visual appeal of a proposed set of routes can have a strong influence on the willingness of a client to accept or reject a specific routing plan. While some work has analyzed algorithmic performance relative to traditional min-sum or min-max objective functions and aesthetic objective functions, we are not aware of any work that has considered a multi-objective approach. This work considers a multi-objective variant of the Min-Max K-Windy Rural Postman Problem, discusses several formulations of the problem, and presents computational experiments with a heuristic algorithm.

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Branch-and-Price Algorithm for Team Orienteering Problem with Time-Dependent Rewards

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The Team Orienteering Problem with Time-Dependent Rewards (TOPwTDR) is an extension of the classical Team Orienteering Problem, where the profit associated with each customer is a function of time, e.g. linear decreasing, exponentially increasing, etc. The objective of the TOPwTDR is to maximise the total collected profit by finding vehicle routes, which visit each customer at most once within a prescribed time limit. The TOPwTDR has been considered previously in the literature under the assumption of decreasing profits.
We apply Dantzig-Wolfe decomposition and solve exactly the TOPwTDR with a Branch-and-Price algorithm. For solving the pricing problem we propose a modified labelling algorithm, which on the first stage uses heuristics to find columns to enter the reduced master problem. As dominance rules are very weak due to time-dependency of the profits, we employ reduced costs bounding to reduce significantly the search space of the pricing problem. Two of such bounds are implemented, and we further speed up the algorithm by using a set of accelerating techniques. We complete the methodology with a branching scheme compatible with the proposed column generation procedure.
Computational experiments are conducted on the classical TOP instances found in the literature, slightly modified according to the nature of the problem. The results demonstrate effectiveness of the method and show a positive impact of the proposed accelerating techniques.

*Speaker

Stochastic programming approach for the coupled problem of pre-positioning and distributing resources for disaster response under uncertain demand and travel times

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Resource allocation and planning for disaster preparedness and response are essential to prevent loss of life and economic impacts as well as to efficiently provide relief in a timely manner. We consider the problem of locating and allocating resources for disaster response, as well as its relationship with resource distribution in a set of uncertain disaster scenarios. In this sense, we propose a model in which different realizations of a network are obtained for each of a set of scenarios representing possible disasters in the context of a large urban concentration. Each disaster realization leads to different travel times along network edges (e.g., due to road closures) and a different demand for resources and services at nodes. A two-stage stochastic programming approach is proposed in which the first stage addresses the location/allocation of resources for disaster response while the second stage concerns the distribution of these resources by means of a vehicle routing problem. Besides typical installation and distribution costs, we incorporate the expected delay in distribution and the expected unsatisfied demand as possible risk measures. The proposed hybrid methodology uses an optimization approach that allows disaster preparedness policies to be obtained and evaluated in terms of both risk measures and logistical aspects (e.g., costs).

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Scheduling synchromodal freight transport using Approximate Dynamic Programming

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We study the problem of scheduling services and transfers for freight in a synchromodal network, over a multi-period horizon, considering probabilistic knowledge about new freights that arrive each period and their characteristics, and considering transport durations of more than one period. In a synchromodal network, any service (i.e., transport mode and schedule) and any transfer hub can be used to transport a freight to its destination within its time-window. Furthermore, transport plans are dynamic and can be changed at any period, given that period's circumstances. We model this stochastic optimization problem as a Markov decision process and propose a heuristic based on Approximate Dynamic Programming (ADP) to solve it. Since the transport, revenues, and costs are spread over multiple time periods, the one-step look-ahead behavior of traditional ADP designs can make the algorithm flounder and end in a local-optimum. To avoid this, we investigate the inclusion of policy exploration using constructs from Bayesian exploration. The contribution of our investigation is threefold. First, we show how balancing exploration and exploitation decisions using the Value of Perfect Information (VPI) in different ways can lead to substantial improvements over traditional ADP designs. Second, we provide insights on the performance gains of scheduling transport using our hybrid ADP with VPI design instead of common practice heuristics, for different transport network settings. Finally, we discuss our experience merging VPI into ADP, and specify directions for further research of ADP in scheduling multi-period transport processes such as the ones in synchromodality.

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Optimizing a reverse logistics system for plastic waste collection: the Netherlands case-study

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Recyclable waste collection systems are often characterized by a logistics setup which is typically municipality-driven. This means that each system is responsible to collect a certain number of municipalities and the municipalities' boundaries are also the boundaries for the system's intervention area. Given this type of operation, there is some room for improvement if a broader approach is followed where the boundaries of each individual logistics system are broken and a global collection setup at the country level is followed. The present work explores this challenge and for that takes as case study the plastic packaging waste collection of Netherlands. Such system consists of 10 different companies, involving a total of 49 depots and 8 sorting stations. Currently, each one of the 370 municipalities is served by the closest depot and inter-municipality collection is not allowed. Moreover, all routes must start and end at the same depot, i.e., only closed routes are allowed. Aiming at optimizing this reverse logistics system, a mathematical model is developed to define the optimal service areas for each depot and the optimal collection routes. The municipality-driven setup is broken while promoting a higher integration by allowing inter-depot routes. The problem is modelled as a Multi-Depot Vehicle Routing Problem with Inter-Depot Routes. The objective function is to minimize the total distance, including the distance from the collection sites to depots and from these to sorting stations. A solution method based on a hybrid approach combining mathematical models with heuristics is devised to solve the real problem.

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Route Planning of Electric Freight Vehicles by Considering Internal and Environmental Conditions

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Despite the advancements in battery technology, range anxiety still poses crucial limitations in logistics operations performed with electric vehicles (EVs). Accurate route planning by taking into account various conditions that effect energy consumption is of critical importance for operational efficiency. In this study, we extend the Electric Vehicle Routing Problem with Time Windows (EVRPTW) by considering different internal and environmental factors. In EVRPTW, EVs may need to visit stations for recharging their battery. Recharging may start and end at any battery state of charge, and its duration is proportional to the amount of energy transferred. The energy is consumed proportional to the distance traveled. In our case, the energy discharged during the trip depends on additional factors such as load carried, road gradient, on-board auxiliary systems, and ambient temperature. The impact of the first two factors has been addressed in the VRP literature. The last factor may increase the energy consumption due to cabin heating or cooling. In addition, battery efficiency reduces in cold temperatures. Furthermore, we consider recuperation which recovers the excess kinetic energy through a regenerative braking system. This may save significant energy particularly when a loaded EV moves downhill. Incorporating these factors in modeling makes the problem more complex; yet, neglecting them may result in a feasible solution to the model inapplicable in real business environment. We formulate this problem as a mixed integer linear program and solve small instances using CPLEX under different scenarios. Our goal is to present managerial insights to both researchers and practitioners.

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Small parcel routing in a crowdsourced physical internet

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We envision a new logistic process for delivering parcels by crowdsourcing curriers. It is based on a network of automatic service points, which are used as a drop-off, pickup, and intermediate transfer points. The system offers the occasional curriers monetary rewards for stopping by the service points and for transferring parcels between them during their regular trips. In this talk, we will present an online routing algorithm that matches parcels to occasional curriers. Parcels can be transferred to their destination in several legs by several different occasional curriers, hence the term physical internet. The economic viability of the proposed method is demonstrated via a simulation study that is based on realistic data about car journeys and small parcel shipments. The ratio between the rewards paid to the occasional curriers and our conservative estimate of the time needed to handle the parcels is well above the average hourly wage while the average cost of delivering a parcel is significantly lower than the price of parcel delivery service in the same market.

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The Multi-Depot Vehicle Routing Problem with vehicle interchanges

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This work introduces a new variant of the Multi-Depot Vehicle Routing Problem. In this problem, capacity constraints on the vehicles and length constraints on the routes of the drivers are imposed. To favor a better utilization of the available capacities and drivers working times, it is allowed to combine pairs of routes at predefined interchange locations, where two drivers can exchange their vehicles so that, even if each driver must return to his home depot at the end of the journey, vehicles can follow paths from one depot to another one. The objective is to minimize the total operational costs.

The main difficulty in formulating the MDVRPVI is the need for synchronization of the pairs of routes interchanging their vehicles. This requires considering explicitly the direction in which routes are performed. We propose a first MIP formulation of the MDVRPVI, based on the classical three-index vehicle flow formulation of the CVRP. Although, as it is well known, this type of formulations present awkward symmetry problems, this first formulation allows us to obtain optimal solutions to small instances of the MDVRPVI. Moreover, we study the problem structure and analyze the effect of allowing vehicle interchanges on the solution structure and cost. In order to solve larger instances, a two-index flow formulation has been performed. Additionally to the well-known subtour elimination constraints, other families of constraints need to be included to forbid pathological solution structures, such as, paths starting and ending in a different depot where a pair of routes are interchanged.

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On-Line Management of a Multi-Layered Personal Transit System

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A Multi-Layered Personal Transit System (MLPTS) is an innovative last-mile on-demand public transit system consisting of convoys of electric vehicles. Each convoy is composed of a human-driven head vehicle followed by one to several cabins that can autonomously travel short distances at the proximity of stations. That is, cabins can attach and detach from head vehicles as they pass nearby stations while heads cycle non-stop in the system. A passenger completes his/her entire journey on-board the same cabin, while the cabin may switch between several heads along its path. These features generate strong dependencies between the head-cabin-passenger layers. Namely, passenger movements are restricted by cabin movements, which in turn are restricted by head movements. Operationally, this results with a complicated routing and assignment problem. In this study, we introduce the MLPTS planning problem and examine various on-line operational policies. For this purpose, we developed a detailed event-based simulation that consists of several operating modules, including passenger assignment, vehicle routing, empty cabin relocation, etc. Specifically, we formulate a static head routing problem as an MILP and solve it using Benders decomposition. Through simulation, we compare the results to some benchmark routing policies and demonstrate the effectiveness of our solution.

*Speaker

Solving the Multi-Depot Vehicle Routing Problem with Sustainability Indicators

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Transport activities have relevant negative impacts on the social, economic and environmental context, which are reflected by some indicators such as accident rate, gross domestic product or emissions of greenhouses gasses. The growing concern about developing more efficient towns has led to a trend towards sustainability issues and smart cities, in which a number of technologies provide enough information to create smart sustainable cities. Thus, the traditional design of routes needs to be changed to incorporate sustainability criteria into the decision-making. For instance, the information systems reveal the state of roads in real-time, which may help to reduce congestion, waiting times and unnecessary stops that increase the negative impacts. A large part of the academic advances related to vehicle routing problems is focused on the environmental impacts ignoring negative direct effects on the population welfare. In contrast, this work presents a powerful algorithm based on the VNS metaheuristic that integrates the sustainability dimensions as decision criteria to provide smart solutions to a rich vehicle routing problem with multi-depots. The algorithm has been tested in realistic instances and compared against a state-of-the-art algorithm. Our experimental results show how the social, environmental and economic impacts vary according to the decision criterion.

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Integrating Logistics Optimization into Traffic Management Policies

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In an urban area, traffic managers aim to implement transport policies which are efficient, safe and sustainable. To achieve this goal, they must assess the costs and benefits of the possible measures and deploy optimization techniques to determine the best actions to be taken. However, the costs and benefits depend on how the users of the transportation network will respond to the measures. Therefore, their decision processes must also be understood and predicted.
Traffic assignment models represent, in this context, an attempt to anticipate how road users would be scattered in a traffic network given the demand rates (measured in number of vehicles per unit of time) between pairs of origin and destination points. These models assume that each user chooses the route that minimizes the costs of his/her trip, and the expected flows are calculated based on the network equilibrium.

In reality, however, there are different classes of users in a transportation network, and not all of them are trying to minimize the costs of a trip from one point to another. Logistic companies, for instance, have many other concerns when defining their routing schemes. Intricate logistic models have been developed to aid their decision processes.
Integrating these optimization models provides a good opportunity to enhance traffic management policies in a way to benefit all involved stakeholders. The analysis carried out in this paper demonstrates an improvement in traffic and logistics performance when the specific goals and requirements of logistic operators are explicitly taken into account.

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Orienteering with synchronization constraints in a telescope scheduling problem

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EMIR (Espectrógrafo Multiobjeto Infrarrojo) is a common-user, wide-field, near-infrared camera-spectrograph operating in the near-infrared wavelengths 0.9—2.5 um, using cryogenic multi-slit masks. From a Operations Research perspective, this device is a multiprocessor machine which is able to process several task in parallel. Each task is the observation of a specific region in the sky. In order the improve the performance of the instrument by covering as many targets as possible within the use time windows, exacts algorithms, based on the resolution of a variation of the well known Orienteering Problem, are proposed to provide with an optimal schedule.

*Speaker

A branch-and-price algorithm for an Inventory Routing Problem for Bike Sharing Systems

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Success of bike sharing systems depends on the operators' ability to provide an adequate level of service. To this end, operators commonly deploy a fleet of vehicles to redistribute bicycles so that customers do not find stations empty or full. The problems of handling station inventory and routing the fleet have been widely explored in the literature, yet not frequently together. Moreover, most studies focus on the single time-period case (modelling night rebalancing) with only a handful dealing with the multi-period case (day rebalancing).
This work proposes an inventory routing model for the day rebalancing problem as well as an exact resolution approach based on branch-and-price.

The model describes the evolution of station inventory as function of both users' and vehicles' activity, instead of having "ideal" levels provided as input (as commonly found in the literature). The routing component follows a "prize collection" approach where the vehicles are routed to perform the most valuable operations in the available time. The objective is to minimise unsatisfied demand.

The model is decomposed in a formulation suitable for resolution via column generation: a master problem that handles inventory and a subproblem that generates feasible pickup and drop-offs patterns. The column generation is embedded in a branch-and-price algorithm.
The proposed approach was tested on instances obtained from real data from a European capital as well as on randomly generated ones. All have dimensions comparable to those presented in literature. Results show the effectiveness of the proposed method and offer some insights for operational planning.

*Speaker

Collaboration through shared-customers in last-mile urban delivery

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Collaboration has been recently explored in many ways to reduce costs of different transportation systems, or to provide an improved service using the same available resources.
In this work, we focus on last-mile delivery when several carriers operate in the same urban area and customers may have demand of service for more than one carrier.
Collaboration is considered among carriers for the service of the shared customers to reduce the overall operational costs. First we study the savings that can be theoretical obtained by allowing collaboration. Then, two formulations are proposed and computationally compared. Optimal solutions are analyzed and compared to the case when no collaboration exists. Extensive computational experiments will be presented with different sets of benchmark instances.

*Speaker

The Periodic Vehicle Routing Problem with Driver Consistency

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The Periodic Vehicle Routing Problem is a generalization of the classical VRP in which routes are determined for a planning horizon of several days. Each customer has an associated set of allowable visit schedules, and the objective of the problem is to design a set of minimum cost routes that give service to all the customers respecting their visit requirements. In this paper we study a variant of this problem in which we impose that each customer should be served by the same vehicle/driver at all visits. We call this problem the Periodic Vehicle Routing Problem with Driver Consistency (PVRP-DC). We present different integer linear programming formulations for the problem and derive several families of valid inequalities. We solve it using an exact branch-and-cut algorithm, and show computational results on a wide range of randomly generated instances.

*Speaker

Solving a Rich Vehicle Routing Problem Arising in the Steel Industry

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We study a variant of the capacitated vehicle routing problem inspired by a real world problem setting that occurs in steel producing factories. Steel slabs are heterogeneous items that appear at locations at certain release times and need to be transported to other specified locations within the factory before a certain due time. Every steel slab is assigned a profit representing its production value. We are given a fleet of standard vehicles and a fleet of truck and trailer type vehicles. The trucks serve as towing vehicles for trailers and they cannot hold any steel slabs of their own. Meisel F. and Kopfer H. (2014) have already contributed to similar problem settings where a truck pulls a trailer and a trailer is used for holding cargo. Our work additionally takes into account that both the standard vehicle and the trailer can carry several slabs at once up to a capacity limit. Also, our model allows slab transshipments among vehicles. The input is such that not all slabs can be delivered in time during the considered time horizon. Therefore, the objective function is organized in a lexicographic fashion: first, maximize the throughput-related profit; second, minimize the fleet size; third, minimize travel times. We propose a Mixed Integer Programming (MIP) representation of the problem. For solving large scale problems, we develop a Large Neighborhood Search (LNS) algorithm. As this work is motivated by a problem faced by our industrial partner, we also compare our results to their provided solutions revealing significant improvements.

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User-based relocation strategies in free-floating car-sharing systems

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Free-floating car-sharing (FFCS) systems provide a promising way to reduce the traffic volume in cities sustainably. However, the efficiency of FFCS systems, measured by the daily operation time of the vehicles, is still very low. This is mainly due to a spatial (and temporal) mismatch of demand and available vehicles. For FFCS systems, active relocation derogates the operators profit significantly and causes additional traffic and emissions. In this course, environmentally friendly and cost efficient relocation strategies for FFCS systems are still missing. In this context, matching demand and supply by slightly changing the drop-off point of cars by incentivizing user behavior seems to be a promising option. Against this background, we introduce the Car-Sharing Relocation Problem with flexible drop-offs (CSRP-FDO) that accounts for relocating vehicles in FFCS fleets by utilizing the price sensitivity of users to change their drop-offs in a spatial or a temporal fashion. The CSRP-FDO is used to find an optimal relocation strategy for a given fleet with vehicle requests, using user price sensitivity most beneficially. We model the CSRP-FDO as a k-shortest disjoint paths problem and employ the Suurballe algorithm to solve large sized instances. We present new benchmark instances for the CSRP-FDO to assess the competitiveness of our algorithm. Furthermore, we present a case study based on real world data to derive managerial insights on user-based relocation strategies. In this context, we highlight the benefit of different modes of user-based relocation focusing on the reduction of both, temporal and spatial mismatches.

*Speaker

Optimizing Domestic Road Freight Operations of a 3PL Carrier in Turkey

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This study is inspired by a complex real-world problem faced by a third-party logistics (3PL) provider in Turkey. The aim of the study is to develop a methodology to optimize the planning of daily domestic road transport operations of the company. Three types of facilities exist: pick-up locations, delivery locations and cross-dock centers. Both Full-truckload (FTL) and less-than-truckload (LTL) operations are considered within the problem context. Currently, these operations are planned separately and manually by on-site planners located at different facilities. The algorithms developed in this study will help the 3PL company shift towards centralized and automated planning.

The company owns a heterogeneous vehicle fleet and also utilizes long-term contracted and on-the-spot hired vehicles to fulfill transportation orders. Different types of vehicles have different cost structures and load capacities. The problem is represented on a time-space network and time windows are imposed on both pick-ups and deliveries, while synchronization requirements arise at cross-docks. Certain rules and regulations such as working hours of drivers, maximum number of facilities visited and distances between the stops are taken into account when defining feasible routes. These rules depend on the type of the vehicle assigned to the route.

We propose a construction algorithm that generates routes considering all predefined rules. The resulting set of routes is then inserted into a comprehensive mixed-integer linear programming model to find the least-cost assignment of orders to routes and vehicles satisfying all problem constraints. We test and validate our model using real-life data of the 3PL company.

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Promoting inconsistency in security related routing problems by clustering

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Based on the most recent literature dealing with consistency, security aspects and surveillance tasks with respect to vehicle routing problems, we provide a formulation, a definition and a way to measure inconsistency as well as a suitable meta- and mathheuristic that is able to solve the problem given the restrictions from a real world application. As suitable characteristics for diversification in terms of inconsistency we present two possibilities: time of service and route diversity. Those two were selected since those are suitable for a wide range of problems. Time inconsistency is a necessary in patrol problems while route inconsistency is important in cash in transit problems.
One important restriction needs to be considered for the solution; the companies cannot control the actual routing drivers use to visit all stops, only the clustering and the time window realization can be controlled. Taking this information into account the clustering had to be used to ensure the route inconsistency and diversity. A two-stage solution process consisting of clustering and routing operations is applied (exact ones as well as heuristic ones). The models and heuristics performance were tested on classic instances for the vehicle routing problem as well as real-world instances from an Austrian security service provider.
With the method at hand we are able to generate good quality solutions for the Solomon instances as well as for the two newly created case studies.

*Speaker

Solving the static vehicle sharing rebalancing problem

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Given a set of stations where vehicles can be parked, associated with excess or deficit values, we search the routing and loading instructions of a set of carriers that will correct these excesses and deficits. We address the static case and we do not consider transshipments, which corresponds to the non-preemptive case. The tours should respect carriers capacity and timespan constraints, and minimize a multicriterion value composed of the number of carriers, the sum of carriers tours durations and the carried vehicles indisponibility time. Lower bounds can be computed either by solving a min-cost assignment problem, which determines how many vehicles are to be moved from a station to another, or by solving a min-cost flow problem. We propose two heuristic approaches to compute feasible solutions. One consists in solving the min-cost assignment resulting in a set of Pickup and Delivery requests, then solving the related PDP. The approximation ratio for this strategy, when focusing on minimizing the carriers riding time, increases with the capacity of the carriers. Thus, the two subproblems are combined in a local search scheme allowing to improve the solution. The other heuristic consists in solving a min-cost flow problem from which the carriers tours are derived, and computing loading instructions on these tours thanks to another flow model. The heuristics were launched on random instances. Results were compared to the lower bounds and the obtained gap ranges from 1% to 30%, depending on the instance size and the heuristic being used.

*Speaker

Continuous Time Inventory Routing

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We consider the following inventory routing problem. A company supplies a single product to its n retail locations from a single production facility with infinite production capacity over a finite planning horizon T. Each retail location i has a storage capacity Ci and consumes product at a rate of ui per hour. The company deploys a fleet of m vehicles, each with capacity Q, to serve its retail locations, i.e., to deliver product at the retail locations. It is assumed that the delivery of product at a retail location is instantaneous. The vehicles are available at the depot at time zero, can make multiple trips, but have to be back at the depot at time T. The travel time tij as well as the cost of travel cij between two locations i and j (either the depot or a retail location) are known and given. The goal is to minimize the cost of supplying the retail locations, i.e., ensuring that the retail locations do not run out of product at any time during the planning horizon. As product is consumed at retail locations at a constant rate and deliveries can be made at any time during the planning horizon, we refer to this variant of the inventory routing problem as the *continuous time inventory routing problem* (CIRP). We explore mixed integer programming formulations for the exact and heuristic solution of instances of the CIRP.

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Strategic planning of electric logistics fleets: A robust location-routing approach

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The main source for noxious emissions and noise as well as 20% of European greenhouse gas emissions are caused by transportation activities. Electric commercial vehicles (ECVs) can contribute significantly to reduce these negative effects of transportation. However, for mid-haul transportation, recharging options en-route have to be considered while designing electric logistics fleet networks in order to keep ECVs competitive to internal combustion engine vehicles and thus, attractive for practitioners. Against this background, we present the robust electric location routing problem with time windows and partial recharging considering uncertainties in customer demand, time windows and customer locations. We discuss an adjustable robust counterpart (ARC), focusing on a non-adjustable component (siting charging stations) and an adjustable component (routing of ECVs). Since robust reformulation techniques are not sufficient to solve large sized instances, we present a hybrid of (parallelized) adaptive large neighborhood search and dynamic programming elements to solve large-sized instances by an adversarial approach. We derive new benchmark instances incorporating different degrees of uncertainty in underlying customer patterns. Results show the benefit of a robust modeling approach against different deterministic modeling approaches that aggregate the customer pattern uncertainty (partially) within the instance derivation.

*Speaker

The Benefits of Flexible Fulfillment Center Assignments in Attended Home Delivery

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Attended home delivery in narrow time windows is the prevailing service model in internet grocery retailing. E-grocers typically serve their customers from one or more dedicated e-fulfillment centers. To simplify planning, each fulfillment center is often responsible for a fixed delivery region. In this contribution, we investigate the benefits of allowing flexibility in the assignment customers to fulfillment centers from a routing perspective. The underlying routing problem can be characterized by a multi-depot vehicle routing problem with time windows. We analyze the advantages of a flexible assignment as compared to a decomposed planning per fulfillment center by using a new exact mixed-integer programming model and a state-of-the-art heuristic. In addition, we investigate the impact of different factors on this benefit and the associated solutions.

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The Romaing Salesman Problem: Application to Election Logistics

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We introduce the Roaming Salesman Problem (RSP) as a multi-period variant of the Prize-Collecting Traveling Salesman Problem (PCTSP). On a directed graph with static arc costs and time-dependent node rewards, RSP finds the best *closed or open tour* for each day of a planning horizon. The objective is to maximize the net benefit defined as the sum of rewards collected from the visited cities minus the normalized traveling costs. The salesman is not required to visit all cities, which makes the problem selective. He can also visit the same city more than once. Moreover, he can stay overnight in any city and resume his tour there the next day. This means there is no unique central node as is the case in the PCTSP. Several applications ranging from the trip planning of marketing associates to the scheduling of wholesaler purchases can be modeled as such. In our study, RSP is adapted to seek the most impactful rally schedule for a politician during a 30-day campaign before elections. The problem involves 81 cities in Turkey each associated with a base reward. The reward collected from a visited city is linearly depreciated with the meeting date and the recency of the preceding meeting in that city. We propose a comprehensive MILP formulation which captures many real-world aspects of this election logistics problem. Different scenarios are analyzed that may arise during the rally planning. We also develop a greedy heuristic for constructing the initial solution, and implement it on our data sets.

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Tiered-Facility Vehicle Routing Problem with Global Cross-Docking

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The collection and delivery of pathological specimens within the transportation network of a national laboratory service requires several novel model features that are not usually considered in the vehicle routing literature. One such feature is the processing capabilities of the pathological laboratories, which are segregated into several tiers based on their associated processing capabilities.
Another novel feature arises due to the often rural locations of clinics and the large distances between these clinics and laboratories capable of processing the pathological specimens. These difficulties may be alleviated by the incorporation into the vehicle routing model of the possibility of cross-docking of pathological specimens at certain locations.

The aforementioned features, along with several other features, lead to the introduction of a new type of vehicle routing problem, referred to as the *tiered-facility vehicle routing problem with global cross-docking* (TVRPGC). A formal mathematical model for this problem is formulated and validated in the context of a small-hypothetical test instance using a mixed integer linear programming solver.

Although conceived within the context of pathological specimen collection, the model also has several alternative applications such as that of a national postal service and other organisations that incorporate consolidation centres within their distribution network.

The combinatorial complexity of the mathematical model calls for the development of an approximate solution methodology. Two approximate solution methods are described and the results obtained via these methods are compared within the context of a real problem instance pertaining to the operations of the National Health Laboratory Service of South Africa.

*Speaker

Fairness Aspects of Selective Customer Acceptance Mechanisms in Dynamic Vehicle Routing

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In many logistics service applications, customers request service dynamically during the service time horizon and may be served on the same day. For the service provider, these requests are stochastic and due to working hour limitations, usually not all customer requests can be accepted for same-day service. The problem to be discussed in this presentation is a dynamic vehicle routing problem with stochastic customer requests. Decisions are made about service acceptances and routing. The objective is to maximize the expected number of customers accepted for same-day service. Solution approaches can be classified as being either selective regarding the customer acceptance or as being non-selective. Non-selective approaches accept every feasible request. Selective approaches may decline same-day service although an acceptance would be feasible to save time for further acceptances later and enable more overall acceptances. In this presentation, we analyze the impact of the customer acceptance mechanism on the objective function and the coefficient of variation of rejection probabilities ("unfairness") within the service area. To this end, we model the underlying dynamic vehicle routing problem with stochastic requests as a Markov decision process and compare two solution methods. While the non-selective approach accepts requests if they can be feasibly inserted in the tour, the selective approach applies methods of approximate dynamic programming to anticipate future requests and the impact of current decisions. We show that selective customer acceptance mechanisms improve the objective value at the cost of a higher unfairness compared to non-selective customer acceptance mechanisms.

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The two-region multi depot pickup and delivery problem

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Motivated by the increasing complexity of transportation networks and the problems faced nowadays by big and small transportation companies, we define the two-region pickup and delivery problem. A region in this setting refers to an area where customers and depots are located, but no direct transportation between customers belonging to different regions is allowed. The problem structure consists on a set of pickup and delivery requests to be served between two regions. Pickup and delivery locations of each request lay in different regions. Therefore, they can not be served on the same intra-region route, and a long distance transportation must exist between the clusters for the requests to be serviced. A set of depots exist in each cluster for consolidation between transportation modes. Hence we face a problem where two interrelated decisions are to be made. The problem is studied for a planning horizon of several days. The objective is to minimize the total cost of the planning, both for long and short distance transportation. We make use of the structure of the problem to design two different approaches of an adaptive large neighbourhood search algorithm, each one focusing in a different decision. We obtain results over a set of self-generated instances for both approaches applied individually and for a third approach where they are combined. Results show a better performance of the combined approach for all instances.

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Exact and heuristic algorithms for the inventory routing problem with logistic ratio

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We study the Inventory Routing Problem with Logistic ratio (IRP-LR), a variant of the classical IRP where the goal is to minimize the average cost per unit delivered. The problem has been recently introduced in the scientific literature (Archetti et al., 2016), although the logistic ratio is commonly used in practice as a performance measure. The adoption of the logistic ratio gives rise to a fractional objective function. An exact algorithm for the IRP-LR, which consists in solving a sequence of IRPs with a linear objective function, is presented. The algorithm stops when an optimality condition is satisfied. Different acceleration techniques to speed-up the exact algorithm are proposed. A descent heuristic algorithm based on the same scheme and on an early stopping condition is also presented. Computational tests are performed on the same instances introduced in Archetti et al. (2016). The results show that the exact algorithm dramatically improves the one proposed in Archetti et al. (2016) and that the acceleration techniques remarkably help in improving its performance. The exact algorithm is also tested on new and larger instances, showing that the algorithm is able to solve to optimality instances with 50 customers and 3 periods or 30 customers and 6 periods in one hour of computing time. Moreover, the heuristic is able to find high quality solutions in a short computing time. Archetti, C., Desaulniers, G., Speranza, M.G. (2016), Minimizing the logistic ratio in the inventory routing problem, to appear in EURO Journal on Transportation and Logistics, DOI 10.1007/s13676-016-0097-9.

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The time window assignment vehicle routing problem with time-dependent travel times

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We introduce the time window assignment vehicle routing problem with time-dependent travel times. It is the problem of assigning time windows to customers before their demand is known and creating vehicle routes adhering to these time windows after demand becomes known. The goal is to assign the time windows in such a way that the expected transportation costs are minimized. We develop a branch-price-and-cut algorithm to solve this problem to optimality. The pricing problem that has to be solved is a new variant of the shortest path problem which includes a capacity constraint, time-dependent travel times, time window constraints on both the nodes and on the arcs, and linear node costs. We develop an exact labeling algorithm and a tabu search heuristic that incorporates a polynomial time algorithm designed to optimize the time of service on a given delivery route. Furthermore, we present new valid inequalities which are specifically designed for the time window assignment vehicle routing problem with time-dependent travel times. Finally, we present numerical experiments to illustrate the performance of the algorithm.

*Speaker

Vehicle repositioning within a city

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Nowadays, almost every worldwide operating car rental company provides the service of delivering vehicles to customers and picking them up after the rental period. The use of vehicle trailers for this purpose within a city is in most cases too expensive and very time-consuming. This poses new challenges for planning departments, as the determination of a set of routes for the vehicle repositioning problem exhibits special characteristics and is not yet covered by the literature on vehicle routing. For instance, a vehicle that is on the way to a customer may make a detour in order to give other drivers a ride to different customer locations. This may lead to constellations in which no shuttle is required to deliver and pick drivers up. This research is the result of a joint project with a large car rental company dealing with the afore mentioned repositioning problem. To tackle this problem, we developed a mixed integer linear program and a specialized Adaptive Large Neighborhood Search.

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A new mixed integer programming formulation for the vehicle routing problem with drones

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Growing Urbanization, increasing online purchases, and higher customer requirements in terms of speed, flexibility, and costs of home deliveries are challenges to every company related with the last mile. Technological advances have paved the way for urban parcel delivery by unmanned aerial vehicles (UAV). With the promise of cost-reductions and time-efficiency, a large number of companies has begun to redirect some of their resources to develop drone based delivery systems. Yet, the limited range and capacity of UAVs remain a challenge. This makes the possibility of pairing drones with well-established means of transportation highly attractive. However, the optimization problem arising in joint delivery by truck and drone has only recently been considered in the literature. To contribute to this field of research, we enhance the mixed integer programming model of the flying sidekick traveling salesman problem developed by Murray and Chu as well as expand it by multiple vehicle-drone pairs to the vehicle problem with drones. Furthermore, we introduce valid inequalities to strengthen the linear relaxation and, consequently, speed up the solution process. Extensive numerical studies with small test instances from the literature as well self-generated slightly larger instances with up to 15 customers are performed to demonstrate the influence of different assumptions on the objective value and to show the limits of the current solution procedure. Moreover, we compare the actual savings obtained by using truck-drone tandems instead of solely trucks with the theoretical savings proposed by Wang, Poikonen and Golden.

*Speaker

A branch and price algorithm for the resource constrained vehicle routing problem

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In this study, we consider a variation of the vehicle routing problem where the customers require different types of resources. The problem is motivated by an application for a Home Health Care service provider. In this problem, services are provided by a limited number of personnel (nurses and health care aids). Each patient requires either a nurse or a health aid or both depending on their conditions during a strict time window. The personnel are transported to patients by vehicles that can carry at most two people. We assume that a health aid cannot be substituted by a nurse and vice versa. The problem can be generalized to cases where customers require different resources at different levels. In this study, a Branch and Price algorithm is implemented to optimally solve the problem. The problem is formulated as a set-partitioning problem and decomposed into a master problem and three pricing sub-problems which are elementary shortest path problems with time window. The master problem is optimally solved through column generation algorithm and embedded in a branch and bound structure. Initial results are reported for random instances generated based on Solomon's benchmarks.

*Speaker

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The Twin Robot Routing Problem

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This paper introduces the Twin Robot Routing Problem (TRRP) in which two robots must be scheduled and routed to pick up, and deliver products at specified locations along a rail. The robots are initially located at the opposite ends of the rail and must preserve a minimum safe distance from one another (i.e., a non-crossing restraint must be respected). The objective is to minimise the makespan, defined as the time required to complete all operations and for both robots to return to their starting positions. The paper presents a proof of NP-Hardness of the TRRP, as well as two mixed integer linear programming models. A genetic algorithm is then developed, in which a linear-time heuristic and a dynamic algorithm are proposed to evaluate the quality of solutions. Extensive computational results demonstrate the limits of the mathematical models, the effectiveness of the genetic algorithm, and the savings obtained by using twin robots instead of a single one.

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Asymmetry matters: Dynamic Half-Way Points in Bidirectional Labeling for Solving Shortest Path Problems with Resource Constraints Faster

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With their paper "Symmetry helps: Bounded bi-directional dynamic programming for the elementary shortest path problem with resource constraints" [Discrete Optimization 3, 2006, pp. 255–273] Righini and Salani introduced bounded bidirectional dynamic programming (DP) as an acceleration technique for solving variants of the shortest path problem with resource constraints (SPPRC). SPPRCs must be solved iteratively when vehicle routing and scheduling problems are tackled via Lagrangian relaxation or column-generation techniques. Righini and Salani and several subsequent works have shown that bounded bidirectional DP algorithms are often superior to their monodirectional counterparts since the former can mitigate the fact that the number of labels increases strongly with the path length. Bidirectional DP has become a quasi-standard for solving SPPRCs with general resource extension functions. In computational experiments, however, one can still observe that the number of forward and backward label extensions is very unbalanced despite a symmetric bounding of a critical resource in the middle of its feasible domain. We exploit this asymmetry in forward and backward label extensions to reduce the overall workload by introducing a so-called dynamic half-way point, which is a dynamic bounding criterion based on the current state of the simultaneously solved forward and backward DPs. Experiments with the standard and the electric vehicle routing problem with time windows as well as the vehicle routing and truck driver scheduling problem confirm that dynamic half-way points better balance forward and backward labeling and reduce the overall runtime.

*Speaker

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A real-world inventory routing problem for waste collection

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With more than ten million tonnes of waste produced every day in the world, waste logistics management has become a major cost reduction and optimization challenge. In this talk, we present a new inventory routing problem that arises when a (waste) collection company wants to collect from a set of voluntary drop-off containers placed in public spaces or industrial sites. These containers are dedicated to various products (cardboard, glass, paper, household waste) that are randomly filled by consumers throughout the studied horizon and must be collected before overflowing. A heterogeneous fleet of vehicles is used to perform this service. Each vehicle has its own cost structure (fixed cost, linear distance and duration costs) and product capacity. All vehicles must start and end their trip at a central depot and can empty their content at a set of intermediate outlets (facilities) in order to continue their tour or collect a different product. Each location (containers and outlets) must be served within one of its multiple time windows. We address the deterministic case of this real-world routing problem over a fixed planning horizon (typically a week). To solve it, we propose an Adaptive Large Neighborhood Search (ALNS) method and apply our approach on benchmarks from the literature and real data from a French waste transport and logistics company.

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Combining pickups and deliveries in vehicle routing – An assessment of carbon emission effects

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This paper studies the effect on carbon emissions of consolidation of shipments on trucks. By utilizing existing vehicle capacity better, one can reduce distance and thereby carbon emission reductions. Our analysis determines the emission savings obtained by an individual transport provider who receives customer orders for outbound deliveries as well as pickup orders from supply locations. The transport provider can improve the utilization of vehicles by performing the pickups and deliveries jointly on vehicles instead of using separate trucks. We compare a basic set-up, in which pickups and deliveries are segregated and performed with separate vehicles, with two consolidation set-ups, namely mixing (pickups and deliveries may be mixed freely on a single vehicle) and backhauling. In our model we assume that the transport provider minimizes costs by use of a Vehicle Routing tool, where we choose the industrial solver Spider. To compare carbon emissions for the three set-ups, we use a carbon assessment method that uses the distance driven and the average load factor.
We find that emission savings are relatively large in case of small vehicles and for delivery and pickup locations that are relatively far from the depot. However, if a truck visits many demand and supply locations before returning to the depot, we observe negligible carbon emission decreases or even emission increases for consolidation set-ups, meaning that in such cases investing in consolidation through joint pickups and deliveries may not be effective.

*Speaker

Combining Parametric and Non-Parametric Value Function Approximation for Dynamic Customer Acceptances in Home Delivery

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We consider a dynamic customer acceptance problem motivated by home delivery applications. During a capture phase, customers request delivery. The dispatcher must decide whether or not to accept the request given the limits on driver working hours and vehicle capacities. Accepted deliveries made during a delivery phase. The objective is to maximize the expected revenue. To solve this stochastic, dynamic decision problem, we introduce a novel method of value function approximation (VFA). VFAs are offline methods that seek to approximate a reward-to-go given a problem's state. Conventionally, VFAs are either parametric or non-parametric. Parametric VFAs (P-VFAs) approximate the functional form of a value function based on a set of state features. Non-parametric VFAs (N-VFAs) approximate individual values for each feature setting without assuming a functional form. Both types of VFAs have advantages and shortcomings. While P-VFAs provide fast and reliable approximation, the approximation is often inaccurate due to the choice of functional form. N-VFAs allow an accurate approximation, but require significant computational effort. Further, N-VFAs may provide unreliable approximation due to the curses of dimensionality. To combine the advantages and to alleviate the shortcomings of the two forms of VFA, we present a novel method, meso-parametric value function approximation (M-VFA). This method adaptively combines P-VFA and N-VFA. For a variety of instance settings based on data of Iowa City, Iowa, USA, we show how M-VFA is able to combine the advantages and alleviate the shortcomings of P-VFA and N-VFAs leading to accurate but reliable approximation and excellent policies.

*Speaker

A Routing Problem for Restoring Interdependent Infrastructure Systems

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Fast restoration of infrastructure (power, water, gas, telecommunication, transportation) systems is crucial in the aftermath of a disaster. Restoration requires sending repair teams to major inoperative components of each system. In practice, restoration operations are carried out independently, i.e., a repair team for a power system visits a set of power network components uninformed about the routing plans for the gas system. However, functionality of these systems are dependent, i.e., a compressor in a gas network cannot function if power from a connected electricity network component is down. So, even after a component is *repaired*, it may not be *operational* until a component in the other system is repaired.
Such operational interdependencies complicate the repair process in terms of finding a prioritization in visiting system components under limited resources. In a decentralized decision making process where each system uses a separate team to visit its network components, such interdependencies would be overlooked. This would lead to inefficient routes, causing a delay in the operational time of the overall system.
In this ongoing study, we model these systems as a network of networks and consider a central decision making process when selecting routes for a set of repair teams. In this approach, interdependencies are modeled implicitly in an integer program as operational synchronization of network components.

*Speaker

Managing Disruptions in the Multi-Depot Vehicle Scheduling Problem

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We consider two types of disruptions arising in the multi-depot vehicle scheduling; the delays and the extra trips. These disruptions may or may not occur during operations, and hence they need to be indirectly incorporated into the planned schedule by anticipating their likely occurence times. We present a unique recovery method to handle these potential disruptions. Our method is based on partially swapping two planned routes in such a way that the effect on the planned schedule is minimal, if these disruptions are actually realized. The mathematical programming model for the multi-depot vehicle scheduling problem, which incorporates these robustness considerations, possesses a special structure. This special structure causes the conventional column generation method fall short as the resulting problem grows also row-wise when columns are generated. We design an exact simultaneous column-and-row generation algorithm to find a valid lower-bound. The novel aspect of this algorithm is the pricing subproblem, which generates pairs of routes that form recovery solutions. Compromising on exactness, we modify this algorithm in order to enable it to solve practical-sized instances efficiently. This heuristic algorithm is shown to provide very tight bounds on the randomly generated instances in a short computation time.

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Convex Resource Allocation and Ship Speed Optimization

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We study a convex resource allocation problem in which lower and upper bounds are imposed on partial sums of allocations. This model is linked to a large variety of applications, including production planning, lot sizing, ship speed optimization, stratified sampling, support vector machines, portfolio management, and telecommunications.

We introduce a gradient-free divide-and-conquer algorithm, which uses monotonicity arguments to generate valid bounds from the recursive calls, and eliminate linking constraints based on the information from sub-problems. These principles are quite unusual: the algorithm is not based on greedy steps and scaling, or even flow propagation, as it is often the case for this family of problems. It also does not need strict convexity or differentiability, and improves upon the best known complexity for this problem, producing a solution to the integer version of the problem (or an epsilon-approximate solution to the continuous version) in linearithmic time as a function of the problem size.

Our experimental analyses confirm the practical performance of the method, which produces optimal solutions for problems with up to one million variables in a few seconds. Promising applications to the support vector ordinal regression problem, for machine learning, are also investigated.

*Speaker

Efficient Move Evaluations for Time-Dependent Vehicle Routing Problems with Route Duration Constraints

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We consider the Vehicle Routing Problem with Time Windows, time-dependent travel times and in which route duration is constrained or minimized. This problem arises in many real world transportation applications, for instance when modeling road traffic congestion and driver shifts with maximum allowed working time. To obtain high quality solutions for instances of 1000+ requests, (meta-) heuristics are needed, which typically rely on some form of Neighborhood Search. In such algorithms, it is crucial to quickly check feasibility and exact objective change of local improvement moves. Although constant time checks based on preprocessing are known for both the time-dependent VRPTW, and the VRPTW with duration constraints, the combination of the two is significantly harder, leading to quadratic time complexity in the number of requests. We show how preprocessing can be used to decrease the move evaluation complexity from quadratic to linear time. Furthermore, we introduce a new data structure that reduces computation times further by maintaining linear time move evaluation complexity even when the neighborhood is searched in non-lexicographic order. We support our complexity results by presenting numerical results of various benchmark instances.

*Speaker

A multiple ship routing and speed optimization problem under time, cost and environmental objectives

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This work studies a multiple ship routing and speed optimization problem under time, cost and environmental objectives. This problem considers (a) fuel consumption as a function of payload, (b) fuel price as an explicit input, (c) freight rate as an input, and (d) in-transit cargo inventory costs. Given a set of cargoes, each of which with a specific weight needs to be transported form pickup port to destination port, the aim is to find the optimal routes and the optimal speed on each leg of the route for a fleet of ships. The alternative objective functions are minimum total trip duration, minimum total cost and minimum emissions. A heuristic branch and price algorithm, where the pricing problem is solved heuristically, as well as a constraint programming model are developed for this problem. Computational results of different problem variants were compared and the sensitivity of the input was analyzed.

*Speaker

The Pickup and Delivery Problem with time windows, split loads and transshipment - A branch-and-cut solution method

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We address a generalized version of the well-known pickup and delivery problem with time windows. In this version the constraint that each customer is visited by exactly one vehicle is relaxed. Furthermore, transshipment of load from one vehicle to another is allowed at specific locations. However, it induces costs. The fleet of vehicles is heterogeneous and multiple depots may be present.

The objective is to find a set of feasible vehicle routes that serves all customers, such that the sum of travel costs and transshipment costs is minimized.

We present a solution method based on Benders decomposition.

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A Memetic Algorithm for the Bi-Objective Hub Location-Routing Problem

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The bi-objective Hub Location-Routing Problem is an extension of the Hub Location-Routing Problem (HLRP) which copes with hub facility locations, routes vehicle tours and plans the inter-hub transportations to satisfy the suppliers-clients transportation demands. Besides the classic economic goals, we consider the impact of environmental factors , revealing the conflicting relations between minimizing costs and CO2 emissions. We present a bi-objective model of the Capacitated Single Allocation Hub Location-Routing Problem (CSAHLRP) for less-than-truck load (LTL) transport under the assumption of independent collection and delivery processes. To solve the bi-objective problem, a memetic algorithm (MA) combined with a steady state non-dominated sorting genetic algorithm (NSGAII) is developed to capture the trade-off between minimizing total cost and CO2 emissions and exhibit approximations of the Pareto front. The proposed bi-objective algorithm uses the NSGAII to sort and rank the population obtained with the memetic algorithm into different non-dominated levels. Instead of ranking all the individual solutions for each new generation, an efficient non-dominance level update (ENLU) method is employed to only update the necessary solutions each time by adding a new solution and eliminating an inferior solution if it is necessary, thus reducing the computational time effectively. Two different local search strategies are consecutively implemented on the hub location and vehicle routing parts, based on a crowded comparison operator. A computational experimentation is conducted and the results are compared with those that are obtained by the corresponding single-objective models, both with CPLEX and the MA.

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Solving the one-commodity pickup and delivery location-routing problem by simulated annealing

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This research studies the one-commodity pickup and delivery location-routing problem (1-PDLRP), a variant of the location-routing problem. The problem has many applications, such as repositioning bicycles in a public bike-sharing system. In 1-PDLRP, there are a single commodity, a set of potential depots, and two types of customers, namely pickup customer and delivery customer. A fleet of vehicles with fixed capacity is used to fulfill the demand of customers. The demand of a delivery customer can be supplied by either the product stored at the depot or collected from the pickup customers in the same route. The goal is to find a set of routes that fulfill all customer demands at a minimum total cost, consisting of depot opening cost, vehicle fixed cost, and vehicle traveling cost. A mixed integer linear programming model and a heuristic approach based on simulated annealing (SA) are developed for 1-PDLRP. The results of computational experiments indicate that the proposed SA heuristic performs well on solving 1-PDLRP.

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Optimizing Link Strengthening Decisions to Improve Post-Disaster Road Network Accessibility

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We study a pre-disaster investment problem to strengthen the links of an urban disaster-risk-prone highway network structurally. The goal is to improve the expected post-disaster accessibility. Given the marginal survival probabilities of the links, we propose a new link failure dependency model to predict the post-disaster status of the network. We generate a family of joint probability distributions for the random surviving network by means of a control parameter with varying levels of spatial and structural correlation. We show that the probability of any network realization can be computed using a Bayesian network but the computational effort becomes immense as the problem size increases. Using the proposed dependency model in a sampling algorithm and three dissimilar path generation methods for the selection of reliable and short routes, we estimate the expected weighted average distance between the supply and demand points. We minimize this accessibility measure and decide on the links that should be strengthened in a two-stage stochastic programming framework. A tabu search heuristic is proposed to solve the two-stage stochastic program and tested in a case study of Istanbul under earthquake risk. Sensitivity analyses are conducted to derive insights for the decision-makers.

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A multi-move decent algorithm for the No-Split Multi-Compartment Capacitated Arc Routing Problem

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The No-Split Multi-Compartment Capacitated Arc Routing Problem (MC-CARP) is an extension of the CARP arising in different applications such as waste collection where different waste types exist at each edge and the fleet of vehicle is multi-compartmented. The aim of the MC-CARP is to find a set of least cost routes that service the demand for each waste type at all required edges without exceeding compartment capacities, with the condition that when a vehicle visits an edge it either picks the totality or none of its demands. We propose a heuristic approach to solve the MC-CARP, consisting of a multi-move descent algorithm that combines traditional CARP local search moves with optimal edge orientation choice and ejection chains. The algorithm iteratively chooses at random a set of moves and computes all the savings obtained from the search of the whole move neighborhood. The savings are then plotted on an alternate moves graph where each MC-CARP edge is transformed into a node and an edge is added between every two nodes presenting a positive saving. A shortest path algorithm is subsequently run on that graph to determine the set of multi-moves that bring the largest saving to the current solution. The algorithm has been tested on a large set of instances obtained from real-life waste collection companies across Denmark, varying in sizes between 25 to 11656 nodes and 18 to 8584 required edges, and in the number of waste types on each edge (2 to 4). Preliminary results thus far are promising.

[*]Speaker

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Scheduling Deliveries in Retail: a Case Study

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Scheduling deliveries in retail involves the consideration of a wide range of factors, including delivery team structures; delivery teams remuneration scheme; delivery teams preferences and limitations; time windows, assigned to deliveries; vehicle capacities; loading and unloading times; restrictions imposed by the depot; permissible working hours; etc. The delivery schedule, produced as a result of the optimisation procedure, must be analysed by the allocators who are responsible for the actual allocation of deliveries. This imposes the restriction on time available for optimisation. The talk is concerned with the experience gained in the process of developing an optimisation software for the above mention problem. Several models and optimisation procedures are presented together with the results of their comparison by means of computational experiments. The experiments were conducted in the real production environment, using the real-world data. The presented optimisation procedures include integer programming based algorithms, implemented using IBM ILOG CPLEX, as well as metaheuristics and constructive heuristics. Base on the obtained experience and knowledge, the talk suggests some directions of further research.

*Speaker

Planning City Logistics in a maritime urban area

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This study is motivated by a problem of City Logistics arising in maritime urban areas. Consider a fleet of inbound containers at a port. Containers are filled with pallets, which must be delivered to their final destinations in the landside. Containers cannot be opened in the port because of the lack of space, and/or this operation is too costly or disallowed. Freight distribution is organized in a two-tiered structure: in the first tier, containers are moved from the port to satellites, where pallets are transhipped in smaller and environment-friendly vehicles, which move pallets to their final destinations in the second tier. In this study, each container is allowed to be unpacked at a satellite only. The planning of operations involves determining which routes are served by vehicles and which containers or pallets are carried in each echelon. We present a mathematical formulation for this problem and discuss possible solution methods. Some computational tests on realistic instances will be presented.

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Optimal resolution of the transport problem from a flow into a RCPSP with routing

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The problem consists in defining a solution of the RCPSPR (Resource-Constrained Project Scheduling Problem (RCPSP) with Routing), considering both the scheduling and the routing addressing the transportation of resources between activities. The scheduling sub-problem can be solved considering the flow between activities to define the precedence constraints between activities and also the location of the transport operation. Commonly, disjunctive graphs have been tuned to model simultaneously both scheduling operations and transport operations addressing the proper coordination between transport operations and scheduling operations. Definition of a solution requires: 1) definition of assignment of vehicle to transport operation; 2) definition of disjunctions between transport operations assigned to the same vehicle; 3) computation of the earliest starting time of both scheduling and transport operation with a longest path algorithm.

This approach falls into the set of indirect resolution scheme but not falls into the category of split approaches. The contribution consists in the definition of an exact algorithm to solve optimally the routing problem considering a flow between activities. Such approach is the first step to define an indirect based resolution scheme where a local search and a metaheuristic could be based on the investigation of the search space defined only by the flow between activities. Our experiments carried out on 18 instances proved the method is strongly efficient.

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Decomposition and heuristics methods for the Pollution-Routing Problem with stochastic speed limits.

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Reducing pollution is an arising challenge faced by governments and organizations. An important portion of the overall gas emissions are caused by the transportation sector, and more specifically, road transportation. These emissions are affected by numbers of parameters, including loads and speeds of the vehicles. As an extension to the VRP with time windows, the pollution routing problem (PRP) has focused on minimizing a comprehensive cost function that includes gas emissions. It is assumed in the PRP that speeds limits on the route legs are fixed and known in advance. Such an assumption is strong and does not reflect reality where speed limits are affected by various uncertainties such as congestion or weather conditions. The PRP with stochastic speed limits is a variant of the PRP where the speed limits are considered as stochastic. It was shown that considering stochastic speed limits can save up to 7.9% of the total cost when tested on instances with 10 customers. In order to tackle larger and more realistic instances, we will introduce in this talk new resolution techniques for the PRP with speed limits. In these approaches, decompositions techniques and heuristic approaches are used to generate good quality solutions or optimal solutions for large instances. The techniques proposed will be tested on the PRP-lib instances available and compared to existing results for the same set of instances.

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A Metaheuristic Approach for the Two-dimensional Loading Vehicle Routing Problem with Heterogeneous Fleet

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In this work, we present a metaheuristic approach for the 2L-HFVRP with sequential loading constraints. This problem combines two well-known NP-hard problems: the heterogeneous fleet vehicle routing problem (HFVRP) and the two-dimensional sequential loading problem (2D-LP). The proposed approach for the considered problem uses a set of initial solutions generated by a specialized constructive algorithm, trying to get an initial population based on a set of good solution for a TSP problem. A Genetic Algorithm (GA) was developed to manage the search process. Prins' auxiliary graph is used to encode each chromosome. Meanwhile, the feasibility of the solutions regarding the loading constraints is checked by a reactive GRASP algorithm. The GRASP verifies if, for a route, the demand of the customers can be loaded considering sequential loading constraints (multi-drop constraints). Five different crossover methods SJX, PMX, OX, CX, and OBX were implemented. In this case, after applying the crossover methods, the algorithm checks the packing feasibility of the new offspring. The best individuals can be mutated with a randomized shaking procedure. Therefore, the population is updated if better solutions are found. Finally, the proposed approach shows good quality results on benchmarking instances, improving some of the best-known previous solutions.

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A heuristic approach for the vehicle routing problem with scarce, reusable resources

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This work presents an efficient methodology for the vehicle routing problem with scarce, reusable resources (VRPSRS), in the context of the VeRoLog Solver Challenge Part II (Traditional). The proposed methodology rapidly produces an initial scheduling of the pickups and deliveries of tools within a planning horizon that is obtained by solving a Mixed Integer Programming (MIP) model. The solution generated is used to feed a routing-based heuristic algorithm that aims at finding a feasible solution for the VRPSRS. The routing algorithm is comprised of a randomized constructive strategy that prioritizes the Pickup First-Delivery Second types of routes, and a local search procedure to improve obtained solutions by means of intra- and inter-route neighborhood structures. Results are validated on the challenge platform for the available instances, suggesting that the proposed methodology requires low CPU times to achieve high-quality solutions.

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