VeRoLog 2022 conference

8th meeting of the EURO Working Group on Vehicle Routing and Logistics Optimization

12-15 June 2022

Abstracts

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The truck-porters routing problem

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The truck-porters routing problem (TPRP) arises when undertaking deliveries within urban areas where vehicle access to some customers is impossible. Thus, some of the deliveries are undertaken by porters who walk to the customers, while a truck is driven to perform deliveries to the other customers. In the TPRP, a single truck and a limited number of identical porters are available at the depot. For the customers, some must be visited by the truck, some must be served by a porter, and the remainder can be visited either by the truck or by a porter. Porters are limited by the total weight of items that they can carry and by a total working time constraint. However, a porter can revisit the depot to collect further items for delivery. The TPRP problem consists of designing a set of minimum-cost routes, where each route starts and ends at the depot and satisfies capacity and travel time constraints. We introduced two mixed-integer programming formulations for this problem and several families of valid inequalities which are used within a branch-and-cut algorithm. A tabu search algorithm is designed and used for the separation procedure. Our branch-and-cut algorithm is tested on randomly generated instances. Computational results show that it solves to optimality instances with up to 19 nodes within a reasonable amount of computational time. Furthermore, for larger size instances, we propose a variable neighbourhood search heuristic for the TPRP problem.

*Speaker

A Large Neighborhood Search approach for the Daily Drayage Problem with Time Windows

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Drayage operations where empty and full containers are moved on the hinterland, are the least optimal of all the container supply chain. This incurs huge gain losses for truck companies, large delivery delays and terminals congestion causing in turn, an increase in carbon emissions. The Daily Drayage Problem with Time Windows can be seen as a generalization of the Pickup and Delivery Problem with Time Windows, since multiple containers need to be picked-up and delivered upon request between multiple locations (depots where empty containers are stored, industrial customers and terminals) while respecting the associated time windows. However, the particularity and difficulty of the problem resides in the additional time constraints that interfere while executing a composite request. A composite request can be either an import mission, a full container trip from terminal to customer followed by an empty container trip from customer to depot/terminal, or an export mission translated by an empty container trip from depot/terminal to customer followed by a full container trip from customer to terminal.
While drayage operations optimization is studied in the literature, many of these studies make simplifications that affect the real world application of their solutions (such as, considering a homogeneous fleet of trucks, a single container size and a star network where all trucks start their journey from the terminal). In our study, we model the problem by taking into consideration real world constraints through a real world network starting from the yard, the standard containers sizes and a heterogeneous fleet of trucks. Additionally, we consider all related time constraints including precedence constraints, and we introduce customer treatment times that correspond to the maximum time needed by a customer to fill or empty a container after its reception.
In this study, we propose a Mixed Integer Program formulation where the experiments have been conducted on real data provided by a transport company in the region of Marseille-Fos, France. For 28 missions, an optimal solution was found in less than a minute. Since a Mixed Integer Program formulation cannot scale on large instances (50 missions), we develop a Large Neighborhood Search heuristic to solve the problem efficiently when applied on data of different transport companies. This heuristic depends mainly on removal and insertion operators. It follows the classical scheme that uses destroy and repair operators, completed with simulated annealing and local search. Detailed experimental results will be presented in the conference.

*Speaker

Evaluating ride-hailing strategies under varying environmental conditions

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Mobility-on-demand represents a comfortable and flexible alternative to classic public transport or personal cars. Over the past decade, ride-hailing services continued to gain popularity among both the public as well as researchers in the logistics area. Most ride-hailing and taxi-dispatching strategies tackle the task of assigning the best available vehicle to each open request and repositioning the idle vehicles to different parts of the service area in anticipation of future requests. Various approaches have been introduced which rarely get compared to each other, since the underlying problem is not defined uniformly as in other well-known vehicle routing problems. Additionally, most of these approaches may require specific problem settings in order to produce high-quality solutions. In this study, we first propose a new set of assignment and repositioning strategies. Afterwards, we identify important environmental conditions like the supply/demand ratio, the reward/cost ratio, the maximum customer waiting time, the stochasticity of the environment (regarding travel times, request arrivals, etc.), and the optimization goal. Based on the famous New York taxi cab dataset, we analyze the effect of these features on the quality of our proposed strategies as well as of well-known approaches from the literature. From the results, recommendations can be derived, in which environment specific classes of approaches might be beneficial and – more importantly – which approaches should be used in a given real-world setting.

*Speaker

Two-Stage Stochastic Programming for Consistent Pickup and Delivery Routing

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An increasing number of shops offer fast local delivery within the city to compete with the online giants. The distribution of parcels from shops to customers is often lacking consolidation opportunities. Many individual delivery vehicles are on the streets, often operating cost-inefficiently with low vehicle fill rates. Thus, shops start collaborating on urban delivery by using shared vehicles. These vehicles visit stations of the city daily at predefined times to pick up or drop off parcels. Stations may either be selected stores or micro-hubs close to the shipments' origins and destinations. Whenever an order comes in, the corresponding store brings it to the next station, where it is picked up by a vehicle and dropped off at the station closest to the order's destination – if it is feasible with respect to the vehicle's consistent daily routing schedule. Creating effective schedules for the vehicles is therefore very important. Additionally, as daily demand varies, the schedules need to flexible with respect to order uncertainty in time and space.

In this work, we model the problem as a two-stage stochastic program. On the first stage, the vehicle schedules are determined. On the second stage, the realized orders are routed. The goal is to satisfy as many orders as possible with the shared vehicles. We solve the problem by investigating two different scenario-based solution approaches, a Progressive Hedging Algorithm, and a Multiple Scenario Approach (MSA). For both methods, the second stage is solved via Gurobi for each scenario. Among those solutions, MSA chooses the best one according to a consensus function. In Progressive Hedging, the solutions are combined to iteratively produce a feasible average first stage solution via penalty terms. To assess the methods' performance, we further consider the optimal solution without consistency constraints as an upper bound and a practically-inspired heuristic solution as benchmarks. The MSA outperforms the other methods for the vast majority of instances. Notably, we find that Progressive Hedging is outperformed by the MSA in all and by the fixed solution in most of the investigated cases.

*Speaker

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A branch-and-price algorithm for a routing problem with inbound and outbound requests

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We present a new problem arising in the context of non-emergency transportation of patients. We consider a hospital (the depot) and a set of patients with a medical appointment. Patients require either to go from home to hospital (inbound request) or from hospital to home (outbound request). The problem can be addressed as a Pickup and Delivery Problem, but the fact that all transportation requests are connected to the depot also allows to tackle it as a special Multi-Trip Vehicle Routing Problem. We adopt with standpoint and call it the Multi-Trip Vehicle Routing Problem with Mixed Pickup and Delivery, and Release and Due dates (MTMPD-RD).
Formally, the MTMPD-RD is stated as follows. A homogeneous fleet M of K vehicles of capacity Q is available to serve a set N of transportation requests to/from a single hospital (the depot). We distinguish two types of requests: inbound and outbound requests. Inbound requests consist in transporting patients from their home to the hospital, while outbound requests consist in transporting patients from the hospital to their home. With each request i are associated a release date r_i (time at which the patient is available at the pickup location), a due date d_i (latest time at which the patient can be dropped off at the delivery location), and a service time s_i at customer location. Service time is also spent at the hospital, when inbound customers are dropped-off and when outbound customers are picked-up.
To solve the MTMPD-RD, we propose a specialized branch-and-price algorithm. Seen as a multi-trip VRP, the problem raises a complex time and vehicle capacity management but we adopt this standpoint and demonstrate computationally that our approach outperforms a classical branch-and-price algorithm based on the Pickup and Delivery Problem modeling. In addition, we compare our approach to an approach in which the constraint on the fleet size would be relaxed first (which would allow applying a mono-trip branch-and-price), followed by a post-assignment of trips to vehicles. Finally, we show how our algorithm can be adapted to the solution of the Vehicle Routing Problem with Simultaneous Pickup and Delivery and Time Windows (VRPSPDTW), and obtain new optimal solutions on benchmark instances.

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Route network design for a population-wide CoVid-19 testing program

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The CoVid-19 pandemic that the world has experienced during the last years, has originated a wide range of logistics problems. These problems vary from prevention, testing, treatment, and supply challenges. In this article, we study one of the most recent testing strategies applied by national governments. This strategy is related to gargling tests which, due to pooling techniques, can be used to perform regular mass PCR-testings. However, in order to provide these PCR-based testing results in short time, an efficient logistics network must be developed. The City of Vienna has initiated such a population-wide testing program, and by this creates an excellent opportunity to investigate such logistics networks. All citizens in Vienna are encouraged to pick up CoVid-19 gargle tests from their closest, or most convenient, supermarket or retailer and perform the gargling tests at home. Then, used testkits can be returned to the retail stores and gas stations, from where they are picked up and delivered to a laboratory. We present a mathematical formulation that resembles the real-world problem related to the pick up of CoVid-19 gargle tests from these retailers and gas stations, which are spread all over the City of Vienna. We formulate the problem as a multi-period vehicle routing problem where the customers require consistency in the arrival times at the locations. Furthermore, it is possible to reduce the service times at the locations by increasing the number of drivers on each vehicle from one to two drivers. On the other hand, the laboratory where the gargling tests are processed, demand a progressive arrival of the vehicles, which eases the working schedule. By considering the arrival spread of the vehicles to the laboratory, and balancing the vehicle loads, the laboratory will not experience idle times or high accumulations of gargling tests to process. To solve this problem, we propose a heuristic method that combines a cheapest insertion constructive heuristic with an adaptive large neighborhood search to obtain template routes. The method is used to optimize the pick ups of the testkits. Then, depending on the amounts of tests of each day, these routes can be adjusted to minimize the overall logistics costs. An extensive

*Speaker

The energy minimizing truck-drone delivery problem

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Last-mile delivery constitutes a significant part of the supply chain. With the rapid development in e-commerce and the growing application of Unmanned Aerial Vehicles (drones), more focus has been shifted towards implementing a truck-drone delivery system due to the positive impact this integration has on operational cost, delivery time, and fuel consumption. This study presents the Energy minimizing Truck-Drone Delivery Problem (ETDDP) where drones are released from certain launch points or directly from the depot to serve a number of customers. A single truck constrained by predetermined time windows is routed across the launch points to transport the drones and packages and to function as a platform for take-off and landing. Contrary to previous drone delivery and vehicle routing problems, a nonlinear mathematical formulation is proposed where the speed of the drone and the truck are considered decision variables, and the diesel consumption components of the truck along with the energy consumption components of the drone are optimized jointly. This is achieved by converting diesel to energy, which leads to a reduction in the greenhouse gas emissions and the operational cost resulting from the diesel consumption of the truck, and the energy consumed by the drone which is reflected on the drone range. A second-order cone programming (SOCP) reformulation of the model is provided, along with two extensions. In the first one, we aim to minimize total cost which includes the cost of diesel and energy consumption along with the driver cost, while the second extension considers the consumption components of an electric truck in place of the diesel-based one. Finally, multiple parametric analyses are conducted to validate the model.

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Driver Routing and Scheduling in Long-Distance Bus Networks

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The liberalization of the European long-distance bus market caused a rapid growth in demand for intercity coach travel in recent years, resulting in a competition between numerous private coach companies. In this highly competitive environment, a coach company only survives by keeping operational cost at a minimum. In this context, driver wages continue to be a major cost share. Accordingly, efficient scheduling and routing that allows to keep the number of drivers as low as possible remains a crucial planning task. Related problems have already been studied for airline crew scheduling, railway timetabling, truck driver scheduling, and urban bus services, but research on driver scheduling in long-distance bus networks is still scarce. Against this background, we study driver routing and scheduling in long-distance bus networks. While our problem resembles a truck driver routing and scheduling problem, it bears several additional characteristics, e.g., drivers may be exchanged between buses en routes. These exchanges may take place at arbitrary intermediate stops such that our problem contains additional synchronization constraints. We present a mathematical model for this problem defined on a time-expanded multi-digraph and derive bounds for the total number of drivers required. Moreover, we develop a matheuristic that converges to provably optimal solutions and apply it to a real-world case study for one of Europe's leading coach companies. We demonstrate that our solution approach outperforms the standalone MIP implementation in terms of solution quality and runtime. Compared to current approaches used in practice, we can improve results by up to 56%. Furthermore, we evaluate the impact of driver exchanges and show that their consideration can lead to savings of up to 75% compared to solutions without driver exchanges.

*Speaker

Network Design Modelling for Decarbonization of the Norwegian Freight Transportation System

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In this work we consider the problem of how the Norwegian freight transportation system can be decarbonized during the upcoming decades. The problem entails assigning flow of goods between major Norwegian cities to optimal modes and fuels, ensuring a solution with minimal system costs that complies with the emissions constraints the Norwegian government has committed to through the Paris Agreement. Decarbonization is achieved through increased usage of sustainable fuels, which are discussed in terms of their technical maturity, existing and needed infrastructure, costs and suitability for the Norwegian market. Investments in infrastructure allow for a greater usage of certain modes and fuels. The problem is modelled as a strategic multimodal freight transportation network design model with elements from energy system modeling. We test our formulation on a case study based on data from the Norwegian Institute of Transport Economics, with the aim of giving decision support for the Norwegian government in policy-making regarding decarbonization of freight transport.

*Speaker

A Column Generation Heuristic for the Dynamic Rebalancing Problem in Bike Sharing Systems

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In this work we develop a column generation heuristic for the dynamic rebalancing problem in bike sharing system. The primary objective is to minimize the number of violations in the system, measured as congestions or starvations at stations, by performing rebalancing actions with service vehicle. We solve the problem using a rolling horizon approach, and test it using a discrete-event simulator. We construct an extensive case study based on the bike sharing system in Oslo that contains up to 158 bicycle stations. We test different versions of the column generation heuristic and find that it can generate good solutions for all scenarios within acceptable solution times. The developed simulation framework allows for a range of different analyses targeting amongst others solution structures, the effect of route re-generation, the number of service vehicles and bikes in the system and geo-fencing.

*Speaker

Canadian Prize Collection Problem: Assessing the impact of a disaster event

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This talk introduces the Canadian prize collection problem and demonstrates its application for assessing the impact of a disaster event on a region, which can arise in either a military or a humanitarian logistics context. The key difference between the Canadian prize collection problem and the "standard" prize collection problem is that some edges are obstructed. These impassable edges are not known a priori; rather, they are discovered by the vehicle as it traverses the network. Three heuristic solution approaches are developed for this problem, a prize-collection focused method, a shortest path focused method, and a hybrid method. These three heuristic solution approaches are implemented on a case study that is aimed at assessing the impact of a hurricane event in the DC-NYC-Boston area. The case study is evaluated at four probability levels of edge obstruction and consider a wide range of available budgets. Results indicate that the shortest path heuristic approach outperforms the prize collection heuristic in most cases for smaller budgets. Also, the shortest path heuristic performs increasingly well compared to the prize collection heuristic as the probability of edge obstruction increases.

*Speaker

Routing and scheduling challenges in operating integrated mobility systems: A Large Neighborhood Search heuristic for the static case

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This research focuses on the integration of different transportation modes, more in particular, the integration of timetabled public transport (PT) and dial-a-ride (DAR) services. This integration allows passengers to travel by a combination of these two modes and results into a more flexible and efficient mobility system. Users can submit a single transportation request for their entire trip, indicating their service requirements (e.g., time windows, maximum trip duration, ...). The routes and schedules of the demand-responsive DAR services are planned by a mobility provider. They must be aligned to the PT timetables to allow efficient transfers and take into account the users' service level by avoiding large detours and long waiting times during transfers. From the perspective of the mobility provider, the exploitation of such an integrated mobility system leads to challenging routing and scheduling problems on the operational level. The ultimate aim of the mobility provider to is generate efficient real-time solutions in response to all user requests by optimally combining and aligning the available transport modes with each other while minimizing their operational costs and the total trip times of the users. From the users' perspective, it is important that the proposed solutions are of high quality (e.g., attractive travel times) and reliable (e.g., low risk of missed transfers). In this talk, the static and deterministic case of the corresponding problem will first be modelled through a mixed-integer linear programming (MILP) formulation. Given the PT timetables, a DAR fleet and a set of customer requests, the aim of the proposed model is to serve all requests in a feasible manner while minimizing a weighted sum of the distance traveled by all DAR vehicles (operational cost) and the duration of all customer trips (service quality). Second, the design of a Large Neighborhood Search (LNS) framework for this problem will be discussed. To incorporate the trade-off between the operational costs and service level in the optimization process, a tailored scheduling subprocedure is presented which minimizes the sum of the users' trip durations for a given route. Next, we will discuss experiments on artificial instances, which confirm that the integration of PT and DAR indeed has a strong potential to reduce the operational cost of the service provider while still offering a high-quality service. Finally, the next steps in this research (e.g. incorporation of dynamic events, risk reduction in the initial planning) will be discussed.

*Speaker

Dynamic demand splitting rules 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 highly challenging combinatorial optimization problem. In this variant of the VRP, each customer must be visited in a certain time window by one or more vehicles that together serve the customer's complete demand.
Over the last decades, the SDVRPTW was mainly tackled by exact solution methods, which solve relatively small instances in comparatively long runtimes. To our knowledge, there are no metaheuristics that provide high quality SDVRPTW solutions in short runtimes.

In this work, we develop a performant metaheuristic to solve the SDVRPTW based on a Granular Tabu Search for solving the classical VRPTW. To address the possibility of split deliveries, we capitalize on the approach of Chen et al. (2016). The authors proposed to transform the SDVRP to CVRP instances by splitting customers with a predefined splitting rule. For example, the rule (50/20/10/5/2/1) imposes that a customer with demand 53 is split into one with demand 50, one with demand 2 and one with demand 1. For each customer, the partial customers have the same location as the original customer, and the sum of their demands equals the demand of the original customer. Then, a CVRP solver can be used to obtain solutions that can be interpreted as SDVRP solutions in a post processing step.

We extend this idea and allow to dynamically adjust the splitting rule in our algorithm. Instead of using a single rule, we modify the splitting rule in a local search framework. To that end, we define neighborhood operators that modify the splitting rule, e.g., by increasing or reducing the values of the splitting rule or by combining two values into one. A long-term memory saves all previously tested splitting rules to prevent double checking.
Preliminary results are promising and show that our heuristic approach obtains good quality solutions in short runtimes.

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Stochastic Scheduled Service Network Design with Flexible Schedules

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We consider a consolidation carrier that seeks to design a physical network for transporting shipments, as well as a schedule for shipment and vehicle dispatches on that network, with explicit recognition of shipment volume uncertainty. The literature on this class of problem, i.e. the Stochastic Scheduled Network Design Problem (SSNDP), typically presumes that the carrier determines both the network and the schedule before having complete visibility of shipment volumes. This assumption is valid as transportation modes require scheduled use of infrastructure owned by a third party, e.g. airplanes having scheduled arrivals and departures at airports. However, modes such as trucking are more flexible and allow not committing to a schedule. In these modes, the carrier only needs to commit to the physical network before knowing shipment volumes. That commitment enables, amongst other things, the sales and marketing team to communicate capacity levels and service expectations to customers. On the other hand, the commitment to a schedule can be delayed until after shipment volumes are revealed. At that point, the carrier can schedule the network to achieve the lowest costs. Formally, we consider a consolidation carrier operating a fixed set of terminals to transport a fixed set of shipments from their origins to their destinations. Each shipment has a delivery window that dictates an available time at its origin terminal and a due time at its destination terminal. While shipment volumes are not known with certainty, fitted distributions are available for the volume of each shipment. Regarding the decision-making process, before knowing shipment volumes with certainty the carrier commits to a sufficient level of capacity, measured in number of vehicles, for transporting shipments from their origins to their destinations. These commitments are based on a point estimate of shipment volumes and an aggregation of time. Given these commitments and complete information regarding shipment volumes, the carrier then commits to an operational plan that includes when vehicles and shipments dispatch from terminals. The carrier must execute the capacity committed to, regardless of the volumes observed, but may execute additional capacity when necessary, at a cost premium. We model the Stochastic Scheduled Service Network Design with Flexible Schedules (SSSNDFS) as a two-stage stochastic program. We present a Benders decomposition-based approach that accommodates discrete variables in both stages, and we assess how the carrier benefits from not having to commit to a pre-defined schedule.

*Speaker

Machine Learning to Speed Up Solution Methods for the Joint Order Batching and Picker Routing Problem

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The Order Batching Problem (OBP) is the problem of grouping multiple customer orders into distinct batches while complying with the capacity restriction of a picking cart. The Single Picker Routing Problem (SPRP) aims to find a minimum cost tour, visiting all picking positions within a picking order. The Joint Order Batching and Picker Routing Problem (JOBPRP) integrates both decisions and is NP-hard in the strong sense (see Gademann and Velde, 2005).

We introduce machine learning techniques of regression to estimate the cost of optimal SPRP solutions. We use the estimates within the Adaptive Large Neighborhood Search and Tabu Search (ALNS/TS) introduced by Žulj et al. (2018) to solve the JOBPRP. To this end, we adapt the ALNS/TS to consider estimates instead of exact solution costs, and we propose a combined use of both to find the best quality-runtime tradeoff. We evaluate the speedup potential of this technique for different variants of the JOBPRP, e.g., with scattered storage or with multiple end depots.

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Order picking under dynamic order arrivals: an integrated scheduling approach

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To remain competitive in the current e-commerce environment, warehouses are expected to handle customer orders as efficiently and quickly as possible. This study focuses on operational decisions in manual picker-to-parts order picking systems, as these systems are still used most often in practice. In such a system, several interrelated decisions have to be addressed, including order batching (which orders to combine in a single picking tour), picker routing (the visiting sequence of locations in a picking tour), and batch scheduling (assigning batches to order pickers and sequencing the batches for every picker). Previous research on order picking in a static context has shown that integrating these decisions leads to better results than addressing each of them individually and sequentially. The underlying integrated optimization problem can be considered a variant of the multi-trip vehicle routing problem with time windows, in which multiple locations should be visited per customer.
In this study, we extend the research on integrated decision-making to a dynamic warehousing context by focusing on the online, integrated batching, routing and scheduling problem in which new orders still arrive during the picking process. We propose an online solution algorithm to deal with these dynamic order arrivals and we demonstrate the need to anticipate on future order arrivals to keep customer service levels high. The proposed algorithm is based on the large neighborhood search framework, combined with a traditional local search procedure.
First, our algorithm is shown to outperform a current state-of-the-art solution algorithm in a static problem context. Next, we analyze the algorithm under different dynamic settings by performing large-scale numerical experiments using an experimental design based on real-life data. The effect of several real-life characteristics is demonstrated by using an ANOVA, leading to several managerial insights that may help companies to operate efficiently without jeopardizing customer satisfaction.

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Multimodal commuter ride sharing with flexible transfer points and return trip planning

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In suburban areas, commuters frequently use cars to get to work. Even those who commute by public transport often need a car to reach, e.g., the nearest train station. The occupancy rate of these cars is normally close to one. This inefficient use of vehicles, which can lead to traffic congestion and overcrowded parking facilities near popular transfer points, could be mitigated via ride sharing.

In a ride sharing system, drivers who are willing to take on passengers can announce their planned trips in advance. Similarly, prospective passengers can enter their desired itinerary and be matched to drivers with compatible schedules and routes. The system can then find suitable meeting locations and optimize the resulting joint routes, including the places where participants (potentially) change from cars to public transport. In exchange for providing transportation to their passengers, drivers may be rewarded with monetary incentives or guaranteed parking spots at their desired destinations or transfer points.

We describe an algorithm based on an integer linear programming formulation for matching passengers to drivers and planning their joint routes. Given a set of itineraries for drivers and passengers, each with potentially multiple paths (via different transfer points) to their final destination, we match passengers to drivers according to schedule compatibility and proximity along these paths, find concrete travel routes for each user and determine pick-up and drop-off locations accordingly.
To ensure high user satisfaction, the morning and evening commutes of each user are planned together. This means that any passenger who is matched to a driver in the morning must be guaranteed a ride back home in the evening - though potentially with a different driver than in the morning.

We evaluate our algorithm on a set of benchmark instances derived from data provided by a ride sharing company operating in the metropolitan area of Vienna and compare it to their currently implemented dynamic first-come-first-served approach. We specifically focus our analysis on the achievable matching rate and the quality of the resulting routes from the matched users' perspective (regarding, e.g., the necessary deviations from their planned schedules and routes).

*Speaker

Optimization approaches for the Mixed Fleet Vehicle Routing Problem with Congestion Charge Zones

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Transportation sector is responsible for a great part of the Greenhouse Gas emissions, significantly contributing to climatic changes. For this reason, transportation companies are currently incentivizing the use of electric vehicles (EVs) that can guarantee a substantial reduction of air and noise pollution. Moreover, a company can also take advantage of a free access to the congestion charge zone (CCZ), usually the city center, where an internal combustion engine vehicle (ICEV) must pay a toll to enter. However, EVs' purchasing costs are higher with respect to ICEVs and, due to their limited driving range, they need to be recharged along the route; hence, it will be more convenient for a company to use a mixed fleet which better exploits the advantages of both types of vehicles.
In this work, we introduce the Mixed Fleet Vehicle Routing Problem with CCZ (MFVRP-CCZ) with the aim of routing a fleet of both EVs and ICEVs, in order to serve a set of geographically distributed customers at the minimum total operational cost. In particular, each vehicle departs from a central depot,, serves a subset of customers respecting their pre-specified time windows, and returns to the depot before the end of its shift. The total operational cost includes the fuel and energy costs associated with the distance traveled as well as the tolls paid by the ICEVs that enter the CCZ.
For this new VRP, we propose an arc-based Mixed Integer Linear Programming (MILP) formulation which allows multiple visits to recharging stations without the need of creating clones of them. Moreover, to solve large size instances we develop an Adaptive Large Neighborhood Search (ALNS) method. The ALNS exploits some existing mechanisms from the literature, along with problem-specific adaptations, and also some other mechanisms tailored for this problem like removal and insertion operators associated with the CCZ. We also introduce a set of benchmark instances based on a well-known dataset from the literature, where we consider circular CCZs with different sizes to include different numbers of customers. We perform a sensitivity analysis on the number of EVs in the solution and investigate how the cost profile changes with the different EV-ICEV mix configurations. The numerical experiments on small-size instances show that ALNS is able to obtain the optimal solution in most of the instances within shorter CPU times. The experiments on large-size instances provide managerial insights about the fleet configuration and routing decisions.

*Speaker

The warehouse reshuffling problem with swap moves

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In the warehouse reshuffling problem, the current assignment of pallets to storage locations in a warehouse has to be transformed into a given target assignment as fast as possible. So far, in the literature, as stacker crane movements for reshuffling, mainly relocate moves have been considered where a pallet is always relocated to an empty storage location. On the contrary, swap moves where the pallet of a storage location is swapped with that currently loaded on the stacker crane, were hardly considered. In this talk, we analyze and evaluate properties of the NP-hard warehouse reshuffling problem with swap moves, both theoretical and practical. At first, we examine differences to the problem variant with relocate moves. Moreover, we introduce a transformation to the traveling salesman problem. Finally, we present computational results of some heuristics for randomly generated data based on a real-world setting from a company. A comparison between swap and relocate moves shows several advantages of swap moves.

*Speaker

A two-stage heuristic for the park and loop problem for postal deliveries

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Postal routing activities are crucial for our industry partner Deutsche Post DHL Group (DPDHL), the world's largest postal company, that delivers 57 million letters every day. DPDHL executes the postal delivery tours using two different means of transportation: a vehicle is combined with the postman walking to do the final delivery. This can be modeled as a park and loop problem (PLP), in which a postman with a vehicle departs from a main depot to serve the demand of a set of households, which are reachable only by walking (without the vehicle). There is a set of given parking spots, where the postman can park the vehicle, get off, and load his bag with letters to serve a group of households. Because the bag has a limited capacity, the postman can walk one or multiple subtours, all starting and ending at the same parking spot. We refer to the tour traveled by the postman using a vehicle as first-level tour and to the walking subtours as second-level tours. The aim is to choose a set of parking spots and their visiting sequence and to determine the household visiting sequence from each selected parking spot in such a way that each household is visited exactly once. The objective is to minimize the total travel time of all tours. The described PLP exactly corresponds to the single truck and trailer routing problem with satellite depots (STTRPSD).
The best-performing heuristic method for the STTRPSD addresses instances with up to 200 customers and 20 satellites (Accorsi and Vigo, 2020), but it is specifically designed for symmetric instances. Considering that for real-world postal delivery problems, a postman travels a street network and has to satisfy the demand of hundreds of households and hundreds of parking spots are available, the lack of methods designed for such large-scale asymmetric instances represents a significant gap in the literature.
We propose a two-stage heuristic to address this problem. The first stage consists of exploring the space of satellite configurations by opening and closing satellites. The second stage consists of a routing phase, in which a multi-depot vehicle routing problem (considering the configuration resulting from the previous stage) is solved using a granular metaheuristic framework. Sets of different operators define a satellite configuration neighborhood and a route neighborhood, respectively. Results on real-world instances provided by DPDHL show the effectiveness and efficiency of our method to solve realistically sized instances.

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Set Partitioning Heuristics for Vehicle Routing Problems

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Most variants of the Vehicle Routing Problem present solutions with a simple structure: their solutions consist in a partition of the customer set into multiple independent routes (i.e., routes without inter-route constraints, aside for the partitioning one). For instance, this is the case for the Capacitated VRP (CVRP), the VRP with Time Windows (VRPTW), VRP with Pickup and Deliveries (VRPPD), and many others.
This structure enables the application of algorithms proper to other well studied problems, as the Set Covering (SCP) and the Set Partitioning (SPP) problems, which take advantage of the techniques developed in the past decades, available inside commercial solvers like CPLEX or Gurobi.
Nowadays, state of the art VRP heuristics are able to produce a large number of good-quality solutions from which many hundred thousands of different routes can be extracted, thus generating very-large scale SCP/SPP instances. In our work we focused complementing Helsgaun's LKH-3 algorithm for VRPs and the state-of-the-art CVRP heuristic by Accorsi and Vigo with a SPP heuristic phase able to somewhat merge together the solutions found up to that moment. Our technique is generic and, for any compatible VRP variant, can be easily applied to local search methods capable to produce a sufficient number of feasible routes.
We present the evolution of our technique during the last two years of work, starting from the first straightforward implementation using CPLEX with simple route selection, which has been replaced by a more sophisticated pricing procedure. We also implemented another, more sophisticated version, inspired to the Caprara, Fischetti and Toth SCP heuristic algorithm.
Finally we discuss the strengths and weaknesses of this type of techniques, what we have learned and how we have used it during DIMACS 12th Implementation Challenge on VRPs.

*Speaker

A heuristic guided by machine learning for the multi-compartment vehicle routing problem with stochastic customer demands

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The multi-compartment vehicle routing problem with stochastic customer demands (MCVRP-SD) consists of designing a set of routes that satisfies the uncertain demands of a set of customers for products which must be transported in independent compartments due to incompatibility constraints. Applications of this problem can be found in selective waste collection, groceries deliveries to supermarkets, different-coloured of glass collection and retail store deliveries. In order to handle uncertainties in customer demands, one common approach is to consider a distribution that fits the historical data for each customer and design a set of a-priori routes, where vehicles visit customers in a pre-defined fashion until a route failure occurs. A route failure happens when the capacity of a vehicle is not sufficient to fully collect the product quantities from the next customer and leads to additional costs. In this study, we use a heuristic approach that is guided by Machine Learning (ML) to solve the MCVRP-SD. The ML model is integrated into our solution approach for the demand estimation using a custom loss function. The custom loss function helps the ML model to overestimate the customers' demands by a given threshold and thus guiding the heuristic towards better solutions by reducing the likelihood of having route failures. We combine datasets previously proposed for the MCVRP with real-world customer demands for different products in a retail store. We then compare our approach to commonly used methods.

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Sustainable Supply Chain Transportation Modelling – Application to Norwegian Salmon

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Food supply chains encompass multiple stakeholders and simultaneously produce multiple products that require various transportation modes and logistics networks before reaching to retailers. Transportation costs and related carbon emissions along a supply chain, however, can be high, prompting a search for efficient management solutions. The current research work proposes a mathematical model in the form of a mixed-integer linear programming model, drawing on evidence from transportation network of Norwegian salmon supply chain. The model addresses environmental aspects from various transportation modes by aiming to minimize the fuel cost component and considers carbon emissions related restrictions.
The mathematical model for the salmon supply chain is developed considering the restrictions associated with carbon emissions and wastage/residuals to address sustainability aspects. Constraints related to supply, processing capacity, storage capacity, demand, carbon emissions, inventory balancing, transportation capacity, and modes of transportation between different facilities are incorporated. Primary data collection pertaining to the input parameters of the mathematical model, are supplied by industry stakeholders.

Various problem instances are tested on the proposed mathematical formulation to highlight the robustness of the mathematical model. Moreover, a real-world case study of a Norwegian salmon exporter is presented to emphasize the applicability of the proposed model. The research work discusses the impact of different supply chain arrangements regarding their overall cost, including fuel cost, and carbon emissions to understand the need for holistic optimization of Norwegian salmon supply chains. Sensitivity analysis regarding demand variability allows the proposed mathematical model to restructure the Norwegian salmon supply chain network to meet fluctuating retail demand. Transportation scenario analysis emphasizes the importance of shifting from road to maritime transportation for certain routes to achieve financial and environmental gains.
The model can aid supply chain managers to make decisions regarding the amount of inventory to be kept in different time periods and in selecting transport routes (e.g. whether maritime routes can be adopted in place of road/rail transportation, to address environmental concerns related to fuel consumption and carbon emissions). The model is valuable for policy makers in terms of understanding the costs and emissions associated with different configurations of food supply chains, as well as the effects of particular policy interventions and market developments (e.g., variation in demand, fuel costs, emission and waste constraints).

*Speaker

A Heuristic Algorithm for the Undirected Capacitated General Routing Problem with Profits

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In this work the Undirected Capacitated General Routing Problem with Profits is investigated. The class of problems with profits has become very popular in the last decades due to their capability a variety of real cases. The problem is defined on an undirected graph where customers are represented by sets of vertices and edges, with a non-negative demand and a given profit associated to each of them. We consider a fleet of homogeneous capacitated vehicles located at the depot to service the customers. The aim is to maximize the difference between the total collected profit and the traveling cost. A feasible solution is represented by a subset of customers that are selected according to their net profit, that is the difference between the profit and the additional traveling cost to serve them. Considering that the problem is NP-hard, a heuristic algorithm based on a local search technique is proposed for finding a solution. First, a set of feasible routes servicing a subset of customers is iteratively built by considering both the distance from the depot and the collected profit. Second, we use tailored moves embedded into a local search scheme to improve the initial solution. An in-depth analysis is conducted in order to investigate the effectiveness of each move. Preliminary computational results are presented.

*Speaker

Methods for solving very large-scale CVRPs in the context of waste collection

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Successfully solving capacitated vehicle routing problems with traditional methods is limited by computational resources. Typical examples for large-scale CVRPs occur in waste collection, where every household in e.g. a city has to be visited. While universities have access to supercomputers, parties outside the research community who attempt to solve waste collection problems often do not. These parties include e.g. municipalities, waste collection companies, and consulting companies. In this work we attempt to provide a solution method to solve a CVRP for Vienna which consists of over 274,000 nodes and requires actual, asymmetrical distances. With a problem of this size, we can neither use a complete distance matrix, nor use traditional solution methods. Instead, we propose to simplify large-scale CVRPs using a combination of decomposition, clustering of nodes, combining nodes to arcs, and elimination of long arcs. In this talk, we compare our proposed method to state-of-the-art large-scale literature with respect to solution quality and computational time.

*Speaker

Planning sustainable routes: Economic, environmental and welfare concerns

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This study introduces a problem called the Sustainable Vehicle Routing Problem in which the sustainability notion is considered in terms of economic, environmental and social impacts. Inspired by real-world problems that large cargo companies face for their delivery decisions, we present a new facet to the classical vehicle routing problem by considering the welfare of all three stakeholders of the problem: an environmentally conscious company, the drivers, and the indistinguishable customers, as our setting assumes that all customers belong to the same delivery class. Thus, the proposed problem consists of three objective functions. The first one is to minimize the total fuel consumption and emission to represent the companies' main economic and environmental concerns. The second one is to maximize the total welfare of the drivers through a function that encourages equitable payment across drivers while encouraging low total driver cost and the third one is to maximize the total welfare of the customers through a function that encourages fairness in terms of delivery times. The last two objectives are measured using slots for tour lengths and delivery times. We implement an efficient solution approach based on the ϵ-constraint scalarization to find the nondominated solutions of our triobjective optimization problem and present computational analysis that provide insights on the trade-off between the objectives. Our experiments demonstrate the potential of the suggested framework under the customer anonymity assumption to help decision makers make effective plans that all parties involved would give consent to.

*Speaker

Collaborative Transportation for Attended Home Deliveries

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Service providers for Attended Home Deliveries (AHD) face low profit margins, high customer expectations with respect to delivery time windows, and social and political pressure to operate with minimum emissions. AHD services are characterized by dynamic customer acceptance and narrow customer-specific delivery time windows. Their internal potential for optimization of delivery operations is limited and has been studied widely. Collaborative transportation planning is an opportunity to further maximize profit and minimize emissions by request reallocation of multiple collaborating carriers. This presentation focuses on the opportunities of request reallocation collaborations for AHD. We use an auction-based framework that allows participating carriers to buy and sell delivery requests without full disclosure of business information. We quantify the collaboration gain of such networks by solving the underlying routing and auction problems. The framework works as follows.
For a limited time horizon that ends before vehicles start their route, customers request a delivery from one of the carriers in the collaboration network. Upon request disclosure, the carrier offers a set of delivery time windows during which the customer's delivery can be executed feasibly based on the already accepted orders. This set of time windows is obtained by heuristically solving the Vehicle Routing Problem with Time Windows (VRPTW) using cheapest insertion. After cut-off, no more requests are accepted by any carrier and the route plans are optimized with an improvement algorithm. Afterwards, a two-sided combinatorial auction takes place. For this auction, every carrier submits a specified number of the accepted requests to a shared auction pool. The carriers' choice of submitted requests is based on spatial and temporal information. A central auctioneer will generate a limited number of attractive request bundles from that pool using a Genetic Algorithm. All participating carriers will then solve a VRPTW for each offered bundle to compute the corresponding bid price. By truthfully unveiling the delivery cost for each bundle in the pool to the auctioneer, the carriers enable the auctioneer to find a new, more efficient allocation of requests to collaborating carriers by solving a Set Partitioning Problem.
Using realistic instances based on the city of Vienna, we show that network-wide profit increases by around 19%. Moreover, we discuss how carriers can leverage the opportunities of the auction during dynamic customer acceptance by strategically accepting requests that they cannot fulfill themselves but hope to sell in the subsequent auction.

*Speaker

Planning car-sharing recharging and relocation activities under uncertainty: a stochastic programming approach

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This paper considers the Stochastic Electric Car-Sharing Relocation Problem (SECReP), which is an important planning problem arising in car-sharing systems with electric cars. The SECReP deals with how to optimally route employees to move cars in need of recharging to charging stations and to relocate cars to better meet uncertain demand in car-sharing system. When traveling between car-moves, it is assumed that the employees use folding bikes or public transport. The SECReP is formulated as a bi-objective two-stage stochastic mixed-integer programming (MIP) model. The model takes as input an initial distribution of cars and employees, as well as a probability distribution of rentals and returns, and returns a vehicle relocation plan for the following planning horizon. The vehicle relocation plan specifies which cars should be moved to where and which employees should perform the different car-moves in what order. The proposed MIP model includes two, lexicographically ordered, objective functions: 1) maximizing the number of cars in need of charging that are moved to charging stations, and then 2) maximize the operational profit. In the first stage of the stochastic programming model, which is defined by a given number of employee tasks or car-moves, all customer demand is assumed known. In the second stage, several possible demand scenarios are considered to generate solutions that perform better concerning the uncertain future demand. In order to solve real-sized instances of the SECReP, we propose a novel Adaptive Large Neighborhood Search (ALNS) heuristic adapted to the bi-objective two-stage stochastic programming model. The ALNS heuristic is tested on a number of realistic test instances generated based on data from a Norwegian car-sharing company. The computational tests show that the ALNS heuristic finds high-quality solutions within a reasonable amount of time and that the stochastic program provides an expected profit increase of approximately 18% compared to its deterministic counterpart.

*Speaker

Subset Row Inequalities and Unreachable Customers

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Subset Row Inequalities (SRIs) were introduced to strengthen the linear relaxation of set-packing formulations that arise as master programs in branch-price-and-cut algorithms for vehicle routing and crew scheduling. In these applications, the subproblem is often a shortest path problem with resource constraints (SPPRC). The standard approach for solving SPPRCs is a dynamic-programming labeling algorithm. SRIs strengthen the linear relaxation of the master program but do not come for free. They require the introduction of additional attributes (=resources), one for each active SRI, which have to be added to the subproblem to ensure a valid dominance between labels. The dominating label may be worse with respect to some SRI-related resources. In this case, it must however overcompensate this defect by having a reduced cost that is better than that of the dominated label by at least the dual price of the respective SRIs. Note that dominance is crucial for the effectiveness of branch-price-and-cut algorithms, since the dominance comparisons often consume more than 90 percent of the total computation time. The new contribution presented in this talk is to exploit that the customers defining an SRI may become unreachable. For the vehicle routing problem with time windows (VRPTW), criteria for unreachable customers are, e.g., accumulated demand and time. For the electric VRPTW, also the battery capacity can be considered. If all customers of an SRI are unreachable, the attribute of this SRI is irrelevant. We can therefore use the best attribute value depending on whether a label is potentially dominating another label or the label is potentially dominated. For ensuring a fast dominance check, we store both attribute values and use them in either case. Extensive computational studies compare standard branch-price-and-cut algorithms for VRPTW and electric VRPTW with versions that just differ in the consideration of unreachable customers for SRIs. Preliminary computational results show that this simple modification in the labeling algorithm can lead to a reasonable speedup.

*Speaker

Bike Repositioning Problem: Integration of a Private Vehicle and Public Transport

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In bike-sharing systems, there are a number of bicycle stations, which are located throughout the city, and users can rent the bicycles automatically, use them, and return them at any of the stations. Each bicycle station has a defined level of inventory, and the number of bikes varies throughout the day. Lack of bicycles in stations leads to dissatisfaction among customers. To address this issue, there are vehicles assigned to move bicycles from stations that have more bicycles than needed to stations that face shortages. However, using vehicles to balance the bicycles around the city is expensive, and it interferes with the bike-sharing operation's mission as a green transportation service. Our proposal integrates the use of a single-vehicle and public transport to do the repositioning operations. This paper presents MILP formulations as well as computational experience.

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Optimal transport of empties in automotive RTI-networks

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Digitalisation and the growing efforts to reduce emissions result in new opportunities and challenges for transport optimization in the automotive sector. Beside vehicle distribution, material logistics has a high share of logistics costs and offers a great leverage for avoiding carbon dioxide (CO2). A central task of material logistics is the provision of suppliers with empties, e.g. reusable transport items (RTI), in which they can pack and send their precursors or intermediates and which can be brought directly to the production line of the automobile manufacturer. The transport optimization of this part of the non-value-adding logistics process is particularly interesting from a scientific point of view, since various process requirements - such as the integrated optimization of filled and empty RTIs, the need to obtain transit lead times, and the endeavour to create a transparent and stable process of the RTI allocation - have to be taken into account. Thereby the main challenge is the high number of participants and the resulting large size of the underlying RTI-network. On the other hand, an optimization is highly relevant from a business perspective, since shortfalls in RTI at suppliers lead to the goods being packed in disposable cardboard boxes, which must be avoided for reasons of cost, process and waste prevention.

Changes in the distribution of empties have far-reaching effects, in particular on the process flow, supply reliability, and the costs and emissions incurred. Therefore, in close cooperation with a well-known automobile manufacturer, we develop various types of transport networks and examine those with regard to the effects mentioned. In the presentation, transport of empties is modelled as mixed integer program considering multiple commodities and periods, transit times, fixed charges and inventory management. Next, three network approaches and their advantages and disadvantages are presented. Due to the large size and high complexity of the problem, exact algorithms reaches their limits. Thus, for different network approaches tailored heuristics are developed, e.g. a consolidated costs greedy and a three-phase construction method, decomposing the problem for the usage of intermodal transport. Finally, we show preliminary results for a large test set of realistic instances and give an outlook on further research.

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Bundle Generation for Last-Mile Delivery with Occasional Drivers

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We present the vehicle routing problem (VRP) with occasional drivers (OD) and order bundles (OB). The problem VRP-OD-OB is an extension of the VRP-OD, where instead of assigning one customer per driver, drivers are assigned bundles of customers. The overall objective is to decide (i) which bundles should be assigned to which OD and (ii) which customers should be served by the fleet
of company-owned vehicles. Since the number of feasible bundles grows exponentially with the size of the problem, only a subset of bundles can be offered for bidding. To deal with the bundle-to-driver assignment, a bidding system is exploited, in which a company offers a set of bundles and the drivers raise their bids. These bids depend on features such as the drivers' destination, flexibility in deviating from the shortest path, and willingness to offer service. To generate valuable bundles of customers, we propose two strategies: (i) an innovative approach based on the creation of corridors, and (ii) a traditional approach based on clustering. We compare the performances of the two bundling approaches in different problem settings: (i) when ODs' final destinations are clustered, (ii) when the availability of ODs is not known in advance but is revealed at fixed time intervals along the working day, and (iii) when distances are computed on a real road network. We can show that the innovative corridor-based approach strongly outperforms the clustering-based approach in all these cases. Given a set of bundles and a corresponding set of bids, we make use of valid inequalities to solve the VRP-OD-OB. To address larger instances, we design an efficient large neighborhood search-based matheuristic. The results of an extensive computational study show that this method provides near optimal solutions within very short run times. An analysis of the impact of drivers' flexibility and willingness levels on the percentage of customers assigned to ODs is presented. Moreover, the case in which ODs dynamically appear at regular time intervals is investigated. Also in this dynamic setting, considerable total cost reductions are shown. Finally, we derive several important managerial insights, which cover the impact of drivers' characteristics on the ratios of customers served by ODs is analyzed. Also, we observe and discuss that it is not necessary to provide a high number of bundles to achieve good quality solutions. Companies should rather focus on generating fewer but more attractive bundles.

*Speaker

An exact method for the two-stage multi-period vehicle routing problem with depot location

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Motivated by a logistics company in Ecuador, we introduce a routing problem with sellers and vehicles, a planning horizon, and variable starting point for the sellers. We have a set of customers, each of which needs to be visited by a seller on one of the days of the planning horizon and then by a vehicle on the following day. The goal is to cluster the customers by day and seller, then by truck, and decide the routes so that the total travelled distance is minimised. We provide mathematical formulations to model this problem. Then we present some new valid inequalities that are a generalisation of the classical comb inequalities and a separation procedure that integrates them into a branch-and-cut method. Finally, some computational results illustrate the performance of this methodology.

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A heuristic solution framework for field service planning

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The field service planning problem seeks to plan daily tours for service technicians, i.e., skilled workers who install technical equipment and fulfil maintenance tasks. Tasks have time windows indicating when a client is available and may require certain skills that must be possessed by the assigned technicians. Furthermore, tasks may require multiple technicians for example due to their difficulty (e.g., handling) or because the necessary skills cannot be fulfilled by a single employee.
While some of these tasks are scheduled several weeks in advance, others arise in the short term. These are, for example, emergency maintenance tasks in case of failures, or follow-up appointments if a task cannot be completed as planned due to time constraints. As these short-term tasks constitute a significant proportion of the overall workload, it is possible that there are more tasks than could be reasonably completed. In this case, it is necessary to select tasks that can be completed while delaying others. To this end, tasks can be associated with priorities, e.g., based on the criticality of a failure or the contractual agreements with a customer.

In this talk, we propose a heuristic solution method developed together with PTV Group for planning operative tours for several technicians. We model the problem as a team orienteering problem with time windows and dynamic team building and introduce an adaptive large neighbourhood search procedure to determine solutions within reasonable time. Results based on benchmark instances and a real-world case study demonstrate the applicability of the approach.

*Speaker

Adaptive repositioning heatmaps for crowdsourced ride-sharing platforms

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Ride-sharing users spontaneously submit trip requests online, are picked up a short time afterward, are driven to their destination while possibly sharing part of their ride with other users. Sometimes, it may not be possible to provide a sufficient level of service because no vehicle is currently available in the vicinity of the user. Poor service leads to loss of revenue and user dissatisfaction. Thus, platform providers aim to balance the vehicles in the city to meet current and potential future demand. Ensuring such distribution is particularly challenging in the case of a crowdsourced fleet, as drivers are not centrally controlled but are free to decide where to reposition when idle. Thus, providers look for ways to ensure a balanced vehicle distribution that benefits both users and drivers.
We propose an intuitive means to improve idle ride-sharing vehicles' repositioning: Adaptive repositioning heatmaps. These heatmaps indicate expected revenue opportunities, i.e., the number of missing drivers in an area to satisfy the demand in the near future. Based on the heatmaps, drivers make decentralized yet better-informed repositioning decisions. Creating reliable heatmaps is challenging as showing heatmaps changes the repositioning of drivers in the system, which in turn may lead again to too many or too few drivers in certain areas. To address this issue, we propose an adaptive learning algorithm for designing our heatmaps. We simulate the system and generate heatmaps based on previously learned revenue opportunities in every iteration. We then update the expected revenue opportunities based on the simulation's outcome and use the updated values in the next iteration. Eventually, the expected opportunities and, therefore, the heatmap design policy converges.
We test our heatmap design in a comprehensive case study on New York ride-sharing data. We show that carefully designed heatmaps significantly improve service availability and platform revenue. Furthermore, providing heatmaps to drivers increases the average earning per driver and reduces the volatility in earnings among the drivers. We also show that heatmaps lead to a better and more balanced distribution of service availability in the city, another important factor for long-term user retention.

*Speaker

Electric Vehicle Routing Problem with Flexible Deliveries

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With an ever-growing interest in e-commerce, parcel delivery is taking new shapes by offering a variety of options to the customers such as an option for selecting multiple delivery locations. From another perspective, this increase in demand requires a new fleet of vehicles that should be added to the current capacities of parcel delivery companies. To meet the greenhouse emission requirements imposed by governments, these companies should adapt their infrastructure to use electric vehicles (EVs) more than before. To provide a solution to these concerns, we define the Electric Vehicle Routing Problem with Flexible Deliveries (EVRP-FD), for the first time. In the EVRP-FD, a fleet of capacitated fully charged EVs dispatch from the depot at the beginning of the planning horizon where the depot is equipped with charging facilities. Each customer is associated with multiple delivery locations with non-overlapping time windows and the demand of each customer should be satisfied in one of their locations within its specified time windows. We investigate the case where EVs can return multiple times to the depot for a full or partial recharge en-route. The solution to EVRP-FD finds the number of utilized EVs and their routes that might include returns to the depot for recharging while minimizing the travel costs associated with the utilization of the EVs. We first develop a mathematical model for the EVRP-FD and then propose a hybrid Variable Neighborhood Granular Tabu Search algorithm to solve this problem. We verify the performance of our algorithm on instances from the literature and generate new benchmark instances for the EVRP-FD. Finally, we present a detailed sensitivity analysis and a case study in Nottingham, the UK to provide further insights.

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Reinforcement Learning for Fleet and Demand Control in Restaurant Meal Delivery

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The demand for same-day pickup and delivery (e.g., restaurant meal delivery) has grown rapidly in recent years. Service providers must scale efficiently with increasing demand to stay ahead in a competitive market. Important steps towards efficient operational planning are anticipatory assignment of orders to couriers and, if possible, a sensible choice of pickup location. We propose a deep dueling Q-network with attention mechanism to learn both, the future value of assigning an order to a specific driver and the future value of choosing a specific pickup location. We test our method for a restaurant meal delivery problem based on data from a meal delivery platform located in Iowa city. Further, we derive a realistic customer behavior model on the basis of a large-scale data set of customer choices on a Slovenian meal delivery platform. This enables us to consider endogenous customer choices, i.e., customer behavior can be dynamically influenced to a moderate extent by altering the position or promotion of restaurants on the platform's website. We show that our reinforcement learning policy strongly improves upon a myopic policy commonly used in practice and quantify the value of fleet and demand control for all stakeholders.

*Speaker

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Two new exact algorithms for the single picker routing problem with scattered storage and the joint order batching and picker routing problem

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The basic single picker routing problem (SPRP) assumes that a set of picking positions in the warehouse is given. The task is to find a minimum length picking tour that starts and ends at the given I/O point and traverses all positions (at least once). For a standard rectangular single-block warehouse, the dynamic-programming approach of Ratliff and Rosenthal (1983) can be applied. We present solution approaches for two practically relevant problem extensions that both exploit the same idea: over an extended dynamic-programming state space, the SPRP with options of selecting picking positions are shortest-path problems with additional constraints. The first problem extension occurs when one or several SKUs are pickable from more than one picking position. In this case, the warehouse is operated as a scattered storage warehouse a.k.a. mixed shelves warehouse. Recent works stress that scattered storage is predominant in modern e-commerce warehouses of companies like Amazon or Zalando. The only know solution approaches for the NP-hard SPRP with scattered storage are MIP-based. We present a new IP formulation for the SPRP with scattered storage that can be generalized to different warehouse layouts and the multi-IO point case. The second problem extension is the joint order batching and picker routing problem (JOBPRP). For the JOBPRP, we present a branch-price-and-cut algorithm in which the subproblem is a profitable SPPR with additional coupling constraints. This is the first fully fledged branch-price-and-cut algorithm that optimally partitions orders and at the same time optimally solves the SPRP for each partition.

*Speaker

Multi-trip vehicle routing with delivery options: An application to the parcel industry

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To tackle the last mile of parcel delivery more efficiently, service providers offer more and more modes of delivery as alternatives to the traditional and often cost-intensive home delivery service. Parcel lockers and pick-up stations may be utilized to reduce the number of stops and avoid costly detours. To design smart delivery networks, service providers must evaluate different business models. In this context, a multi-trip vehicle routing problem with delivery options and location-dependent costs arises. We present a corresponding model and solve the problem heuristically using adaptive large neighborhood search. We apply both well-known techniques from the literature adapted to this context as well as new approaches explicitly developed for dealing with great problem sizes. Examining large, real-life instances from a major German parcel service, we determine the potentials and benefits of different delivery options. In particular, we show that delivery costs can be mitigated by consolidating orders in pick-up stations and how pricing can be applied to steer customer demand towards profitable, eco-friendly products.

*Speaker

Optimization of a Dial-A-Ride service with rail-road vehicles

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In this work, we investigate an original Dial-A-Ride service dedicated to sparse areas. The service relies on vehicles capable of switching between the road and an existing vacant railway network. It induces railway scheduling constraints that we must integrate in the solution algorithm. We develop solution methods based on the ALNS framework.
In sparse areas, trains are oversized for the service they bring to the clients and circulate with a low frequency. This mismatch between demand and offer causes clients to rely on personal vehicles and transport operators to lower investments in these areas. To reinvigorate the use of abandon railway tracks and bring more sustainable mobility, SNCF (the French railway operator) develops on-demand service transportation based on small rail-road vehicles.

The faced problem can be modelled as a Dial-A-Ride problem with additional ordering and scheduling constraints on railway sections, where we aim at, firstly, maximizing the number of served clients, and, secondly, minimizing the total travel time. The system organises itself around a single railway line dedicated to this system. The line possesses two terminus and some intermediate stations. Vehicles can join and leave the railway only at a station. Furthermore, the railway line is a single track, meaning that vehicle cannot circulate in opposite direction at the same time on the same portion. They must use stations to cross each other.

Two approximations of this problem are first addressed. The first one forbids the use of railway network to get a lower bound. The second one relaxes the constraints on the railway network, by pre-computing the fastest path between all pairs of pickup and delivery points. Both approximations result in a classical DARP that we solved heuristically with an ALNS framework.

Two series of experiments are conducted. The first one is on benchmark DARP instances to validate the ALNS implementation. The second one is on randomly generated instances organised around an abandoned railway track based on a region of interests for SNCF and bring us insight on the railway use in an on-demand service.
The next step is to fully integrate the railway constraints in our routing problem. If several methods can be imagined, we are currently exploring one based on a set-covering approach. The ALNS algorithm will generate routes for the two approximations. Then, routes will be chosen by a set-covering model including the railway scheduling constraints. Results on this method will be presented.

*Speaker

The dial-a-ride problem with stochastic interrelated trips

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In this paper, we introduce a stochastic variant of the dial-a-ride problem with interrelated trips. Interrelated trips are transportation requests, where users ask for simultaneous arrival at meeting locations, where round trips involve a stay time at some destination locations (e.g., doctor appointment), or the like. In this problem variant, the users' stay times are assumed to be stochastic. User lateness is especially challenging in such interrelated transportation schedules, because delays can likely propagate through the tours of other vehicles.
We look at smart ways of how to make these systems more reliable and attractive. In our approach, we carefully consider how to compute the service- and arrival-time distributions of the vehicles at each customer location. We employ a chance constraint to construct more reliable schedules and embed it in an Adaptive Variable Neighborhood Search metaheuristic.
Our computational experiments investigate the trade-off between operational costs and service reliability as well as the impact of different service policies for handling delayed users (e.g., wait or go at meeting requests) on the punctuality at succeeding locations.

*Speaker

The Dial-a-Ride Problem with Transfers and Walking

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The Dial-a-Ride Problem (DARP) consists of defining routes and schedules for a fleet of vehicles serving multiple transportation requests within a service area. In this work, we define and study a new variant of the DARP which considers both transfers and walking, namely, the DARP with Transfers and Walking (DARPTW). In particular, passengers are allowed to transfer multiple times and their itineraries may include several walking segments. The goal of the DARPTW is to minimize a bi-objective function consisting of the total distance covered by the vehicles and the total excess time of the passengers, while considering limitations on the number of transfers performed by each user and the total distance walked.
Introducing transfers and walking presents several opportunities. Multiple transfers may allow balancing the vehicle loads and reducing the service area covered by each vehicle, by decomposing itineraries to separate service segments that would be served by different vehicles. Walking may assist in reducing unnecessary vehicle detours to extreme regions of the service area. Additionally, walking may facilitate significant shortcuts that cannot be fulfilled by the vehicles due to travel directions imposed by the road network. Nevertheless, these opportunities generate a challenging problem to solve. Specifically, the DARPTW generalizes the DARP and therefore is also NP-Hard.

We devise an efficient algorithm for the scheduling sub-problem, which minimizes the total travel time of the passengers. The algorithm determines the feasibility of given routing plans and applies fast heuristics to construct good schedules. We implement the algorithm within a Large Neighborhood Search framework in search for promising solutions of the DARPTW. Numerical experiments are conducted using real-world data obtained from Bubble-Dan in Tel Aviv. Preliminary results over thousands of scheduling sub-problem instances demonstrate that our heuristic algorithm finds the optimal schedule in more than 90% of the cases and that the entire framework produces high quality solutions.

*Speaker

Efficient Move Evaluations for a Vehicle Routing and Truck Driver Scheduling Problem with Multiple Time Windows

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The Vehicle Routing and Truck Driver Scheduling Problem combines the VRP (Vehicle Routing Problem) with the problem of scheduling truck drivers such that the provisions on driver breaks are respected. In our talk, we consider provisions that are applicable in the EU and in the US for a planning horizon of one day. There is a constraint on the maximum accumulated driving time without break, the maximum total driving time, and the maximum route duration. Furthermore, we allow multiple time windows per customer.
We show how to evaluate moves efficiently by precomputing auxiliary data for partial routes. Evaluating a move means to check feasibility and to compute the impact on the objective function value when a customer is appended to a route or two routes are concatenated. This evaluation procedure can be plugged into many frameworks for solving the VRP, and it is already integrated into the vehicle routing services of PTV xServer and PTV Developer.

*Speaker

An evaluation of several heuristic routing policies for the Single Picker Routing Problem with Scattered Storage

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The process of collecting items of a customer's order from different storage locations in a warehouse accounts for the lion's share of the operating costs of the warehouse. Hence, optimizing the picker's route is an important instrument to reduce costs. We examine the single picker routing problem (SPRP) with scattered storage (or mixed shelves) in a one-block warehouse. While in classic storage each stock-keeping unit is assigned to one picking position in the warehouse, in scattered storage a stock-keeping unit is distributed to several picking positions throughout the warehouse.
Based on an extension of the state space of Ratliff and Rosenthal's dynamic program, we propose a network flow model consisting of a shortest path problem with additional covering constraints. In addition to exact routing, the generic approach can be employed to the established routing heuristics traversal, return, largest-gap, midpoint, and composite by mild adaptions in the state space.
Extensive experiments highlight a cost comparison of the different heuristics among each other for scattered storage warehouses. In addition, we investigate whether the observations on the cost difference between heuristic routing tours for different location assignments can be transferred from classical SPRP to SPRP with scattered storage.

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Potential of Mobile Parcel Lockers with Individual Customer Preferences

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The ongoing growth for last-mile deliveries leads to a significant increase in transportation volumes. New technologies are continuously being investigated to provide these deliveries efficiently and satisfactorily. A common practice is attended home deliveries and the use of parcel lockers. Fixed parcel lockers already operate today and are usually permanently installed at key locations in cities. Mobile parcel lockers have recently been investigated; these lockers are movable and can be parked in one place for a specific time. Then, customers can pick up their delivery at any time within the given time slot. This service is supposed to become efficient through autonomously operating vehicles.
Besides the general demand, customers' expectations of the delivery process constantly increase. The most obvious manifestations of individual customer preferences are reliable time windows and a restricted willingness to walk to the corresponding parcel locker. Some customers are unwilling to walk very far, whereas others prefer a larger pick-up time window to make their daily schedules more flexible. So far, little research has been done in search of the effects and potentials when we inquire about each customer's individual preferences and integrate them into the planning process.
We adapt and apply an existing LP model and evaluate all delivery options – fixed parcel lockers, mobile parcel lockers, and attended home deliveries – within one framework. We use a fixed fleet of parcel lockers or vehicles to maximize the number of customers served. We respect the individual customer preferences about walking distances and time window requirements. We evaluate the different options and possible combinations regarding the structure and quality of the obtained solutions. In the experiments, we analyze the effects of structural demand differences (clustered and randomly distributed customers) and the ratio and characteristics of individual customer preferences. First preliminary results show the potential to increase customer acceptance by up to 20% through the use of mobile parcel lockers, while considering individual customer preferences.

*Speaker

A two-phase hybrid algorithm for the periodic rural postman problem with irregular services

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We deal with the periodic rural postman problem with irregular services (PRPP-IS) in which some links of a mixed graph must be traversed a given number of times. In particular, they must be serviced in some subsets of days (or periods) of a specified time horizon. The aim is to define a set of minimum-cost tours, one for each day of the time horizon, that satisfy the service requirements. For the PRPP-IS, we propose a two-phase algorithm by combining heuristics and mathematical programming. In the first phase, two different heuristics are used to construct feasible solutions: a multi-start constructive heuristic and a multi-start random assignement first and feasibility pump routing second heuristic. From these solutions some fragments (i.e., parts of tours associated with the various days) are extracted. The second phase determines a solution for the PRPP-IS by combining the fragments through an integer linear program. We show the effectiveness of this solution approach through an extensive experimental phase on benchmark instances.

*Speaker

Territory Design for Multi-Period Vehicle Routing Problem with Time Windows

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This study introduces the Territory Design for Multi-Period Vehicle Routing Problem with Time Windows (TD-MPVRPTW), motivated by a real-world application at a food company's distribution center. This problem deals with the design of contiguous and compact territories for delivery of orders from a depot to a set of customers, with time windows, over a multi-period planning horizon. Customers and their demands vary over time. The problem is modeled as a mixed-integer linear program (MILP) and solved by a proposed heuristic. The heuristic solutions are compared with the proposed MILP solutions on a set of small artificial instances and with the food company's solutions on a set of real-world instances. Computational results show that the proposed algorithm can yield high-quality solutions within moderate running times. A methodology is proposed in which the territories computed by the proposed heuristic on the historic demand of one month are used for the operational routing during the following month, in which the demand is known only one day in advance. An evaluation shows that the territories obtained with our methodology would have led to levels of service significantly better than the ones that were experienced by the company, using a significantly lower number of vehicles to execute the deliveries.

*Speaker

Rich vehicle routing problem with three-dimensional loading constraints: a real-world application

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We present a complex real-world vehicle routing problem with three-dimensional loading constraints. Among others, key features in the vehicle routing part include multiple time windows, forced and optional splitting, clustered pickup and delivery, and a limited heterogeneous vehicle pool as well as vertical stability, horizontal rotation, and LIFO constraints in the container loading subproblem.

We propose an iterated local search metaheuristic with variable neighborhood descent. The loading subproblem is solved with an extreme-point based heuristic. According to the pack-first route-second approach, the loading length of orders is over-estimated in order to quickly identify feasible routes, which allows to bypass more expensive calls to the loading heuristic. The vehicle to route assignment is modeled as a minimum-weight maximum bipartite matching problem and solved by transforming it into a min-cost max-flow problem.

The algorithm is tested on real-world instances from our industry partner in the corrugated package industry. We show that the proposed algorithm is well suited to support planners in their operational tasks.

*Speaker

Multi-objective traveling repairman problem with profits

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This work presents an innovative multi-objective optimization problem appearing in an appliance repair company that would like to model their services. Specifically, we will name the problem as Multi-objective Traveling Repairman Problem with Profits (Mo-TRPP). The problem can be formally described as follows: Let G=(V,A) be a complete graph, where is the node set and is the arc set. Node 0 represents the depot and is considered the set of customers. Each arc has an associated finite cost that can be measured as a length or as a time, and each customer has associated a profit . This problem seeks to serve a subsect of customers, to optimize four different objectives:
Objective 1. Minimize the total cost (usually the total distance or total duration of the route);

Objective 2. Minimize the latency (that is the time that must wait the last customer to be served);

Objective 3. Maximize the profit; and finally,

Objective 4. Maximize the number of customers served.

Note that even if the Mo-TRPP models the problem proposed by the appliance repair company, there are other real-world situations that fits into the proposed model such as humanitarian logistics problems (for instance, populations affected by water).
Of course, these four objectives are in conflict and our task is to provide the company a set of efficient solutions. Therefore, to address the considered problem a Scatter Search algorithm is proposed. The algorithm is able to obtain a good approximation of the Pareto Front and the well-known NSGA-II is implemented to check the quality of the obtained set of efficient solutions.

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Locker boxes location under uncertainty in customers' demand and capacity availability

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In the last years, the delivery to locker boxes has become very popular in last-mile delivery, as a valid alternative to home delivery, which allows avoiding missed deliveries and reducing operational costs for the transportation companies. Locker boxes are composed by several lockers, each one of which can host the parcels related to a single customer at a time. The company perform the delivery to a locker box compatible with the customer (located in the nearby of her house, office, etc...) where the customer can pick it up when it is most convenient for her. This delivery system allows companies to strongly reduce their transportation cost since many customers can be served at the same facility. Moreover, it allows to completely eliminate the problem of missed deliveries, which has been shown to be a very relevant issue. Locker boxes should be located in sites accessible 24/7, or with long opening time windows, such as train stations, supermarkets and refueling stations. The decision of where to locate such facilities is a crucial issue, since it can have a strong impact on the number of customers willing to choose this delivery option, and on the percentage of them that can be actually served by it. This decision must be made considering uncertainty on demand (which may vary day by day) and on lockers availability. In fact, a locker could be temporarily unavailable because it is damaged or because the previous customer did not pick her parcel up yet. We define this problem as a facility location problem with uncertainty in customers' demand and capacity availability. The goal is to maximize the number of customers served over a set of demand and capacity scenarios, opening a fixed number of facilities. We provide a mathematical formulation and an efficient and effective matheuristic based on the idea of achieving consensus among scenarios. We compare this matheuristic with the Variable Neighborhood Search and the Iterated Local Search in order to state its performance. Results show a clear dominance of the consensus based matheuristic. We present a realistic case study related to the city of Turin in the north west of Italy.

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A Decomposition Approach to Last Mile Delivery Using Public Transportation Systems

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The aim of this study is to explore the potential of using public transportation systems for freight delivery, where we intend to utilize the spare capacities of the public transportation vehicles like buses, trams, trains, etc., particularly during off-peak hours, to transport packages within the city, instead of dedicated delivery vehicles. The study contributes towards the growing body of literature on innovative strategies for performing sustainable last-mile deliveries. We study an operational level problem, called the Three-Tier Delivery Problem on Public Transportation, where packages are first transported from the Consolidation and Distribution Center (CDC) to nearby public vehicle stations by the delivery vehicles, and from where they are transported into the city by the public vehicles. Then the last leg of the delivery is performed to deliver the packages to their respective customers using green vehicles or eco-friendly systems. We propose mixed-integer linear programming formulations to study the transport of packages from the CDC to the customers, use decomposition approaches to solve them, and provide numerical experiments to demonstrate the efficiency and effectiveness of the system. Our results show that this system has the potential to drastically reduce the length of trips performed by dedicated delivery vehicles, thereby reducing the negative social and environmental issues caused by existing last-mile delivery systems.

*Speaker

Truck-and-drone routing problems in Last Mile Logistics: exact and heuristic approaches

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In the last years, the integration of new distribution technologies in the delivery systems, specifically drones, has been investigated by several companies to reduce the costs of the Last Mile Logistics. The most promising delivery system, in terms of emissions and completion time reduction, consists of a truck and a drone operating in tandem for the parcel delivery to the customers. In a nutshell, this system generally performs as follows: the truck and the drone must depart and return to a single depot, either in tandem or independently; each customer must be served once by either the truck or the drone; the truck has an infinite capacity and acts as a mobile depot for the drone, replenishing its batteries and providing the parcels to be delivered. These truck-and-drone delivery systems have led to the definition of new and complex decision and optimization problems also known as truck-and-drone coordination problems. In this context, several contributions appeared in the last years providing different solution methods for these kinds of problems. However, these methods are generally designed to tackle very specific variants of the problem, so preventing their usage except for a significant rethinking of the method with no effectiveness guarantee. In this work, we present a twofold methodological contribution. On one side, we present an extended Mixed Integer Linear Programming formulation for truck-and-drone coordination problems, strengthened by several additional valid inequalities, and integrated in an exact branch-and-cut-and-price algorithm. On the other side, we propose a heuristic approach to deal with larger instances. Both contributions are based on a new representation of a truck-and-drone problem solution. This representation allows us to easily address different truck-and-drone problems but nevertheless leads to competitive results. We perform extensive computational experiments on literature instances for different truck-and-drone variants demonstrating the flexibility and performance of the proposed approaches in terms of solution quality and computation time. Then, the results of this computational study are analyzed to determine features characterizing good/optimal solutions and to derive several managerial insights. Finally, we present a preliminary study, based on this analysis, aimed at evaluating the benefits that can be obtained using a combination of data science techniques and combinatorial optimization methods for these kinds of problems.

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Profitable tours for field sales forces – Combining sales analytics and tour planning

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Field sales forces play an important role in direct marketing, especially for companies offering complex products, services, or solutions in the business-to-business context. Sales representatives are not only responsible for increasing sales in the short run, but they also maintain long-term relationships with their customers and try to understand their (future) needs.
A key task for sales representatives is to select the most promising customers to visit within the next few days for introducing the current campaign or new products. For predicting or, rather, approximating the customer profitability there exists a broad range of scoring methods strongly varying in the level of aggregation and the content of information. In contrast to direct marketing campaigns by mail or phone calls, in the case of sales representatives working in the field, the final customer selection is strongly intertwined with tour planning decisions.
To this end, we formalize the profitable salesperson tour problem: For each category of scoring methods, we introduce a model variant of the multi-period team orienteering problem resulting in different profitability approximations. For our computational study on real-world instances from the retail industry, we propose an adaptive large neighborhood search approach that adapts successful strategies for solving orienteering problems from literature. We systematically examine the impact of the level of information provided by a scoring method, as well as the sensitivity of the proposed models concerning prediction errors. Based on these results, we show that the level of detail that should be considered when planning profitable tours for sales representatives strongly depends on the data availability and, hence, on the quality of the prediction or approximation.

*Speaker

The Mixed Fleet Green Vehicle Routing Problem with Green Zones

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Public administrations all over Europe have started introducing environmental zones in city centers to limit noise and air pollution generated by industries in densely populated areas. As part of this, different types of green zones have been proposed across Europe. For road freight transport, the introduction of green zones poses a new operational challenge where certain vehicles are either not allowed to enter a zone or must pay compensation for GHG emissions inside the zone. Especially for companies operating a heterogeneous fleet of internal combustion engine vehicles and alternative fuel vehicles in areas with green zones, optimal utilization of the fleet becomes vital.

In this work, we introduce a new VRP variant called the Mixed Fleet Green Vehicle Routing Problem with Green Zones (MFGVRP-GZ) that aims to serve all customers at a minimum travelled distance, such that no green zone restrictions are violated. Through computational studies, we (i) investigate to what extent different green zones restrictions can help limit the environmental footprint of distribution operations and (ii) test the performance of different formulations to solve the problem.

Keywords: Green Zones; Fleet Utilization; Green Logistics; Vehicle Routing

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Scheduling procedures for electric autonomous shuttles on a fixed circuit

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Shared mobility services involving electric autonomous shuttles have increasingly been implemented in recent years. Due to technological and legal restrictions, these services are typically offered on fixed circuits and operated according to fixed schedules. In this talk, we analyse whether a service variant with a fixed circuit, but flexible stopping patterns and schedules leads to cost reductions and service level improvements. The problem is defined as the Electric Dial-a-Ride Problem on a Fixed Circuit (eDARP-FC). It is assumed that a fleet of capacitated electric shuttles operates on a given circuit, consisting of a recharging depot and a sequence of stations where passengers can be picked up and dropped off. The shuttles may perform multiple laps between which they may need to recharge. The goal of the problem is to determine the vehicles' stopping sequences and schedules, including recharging plans, in order to minimize a weighted sum of the total excess passenger ride time and the total number of laps. The eDARP-FC is NP-hard and can be formulated as a non-standard lap-based MILP. In order to develop a metaheuristic solution approach for this problem, an efficient algorithm to solve the scheduling sub-problem needs to be designed first. For a given sequence of passenger pickup and drop-off nodes, this sub-problem consists of finding the feasible schedule and recharging plan that minimizes the passengers' excess ride times. An exact dynamic programming algorithm is devised for this purpose, as well as several heuristics. They are then applied as sub-routines within a Large Neighborhood Search (LNS) metaheuristic framework. Experiments on instances derived from a real-life system demonstrate that the flexible service results in a 26%-74% decrease in the excess passenger ride time for the same fleet size and operational costs. In addition, managerial insights will be presented regarding the impact of various problem parameters, including the battery capacity, vehicle fleet size and time-window width. Finally, we discuss how the proposed scheduling procedures can be extended to fit a more general eDARP context without a fixed-circuit setting and with multiple recharging depots.

*Speaker

Vehicle routing at work: a real-world implementation and case studies

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Vehicle routing problem (VRP) and its variants are commonly and widely used in many areas of logistics and supply-chain industry to optimize the whole business process and providing significant savings in terms of development time and costs.
Optit-logistics is a decision support tool designed for advanced transportation planning, its optimization core is based on fully customizable algorithms for VRP.

The model can be enriched with several different features and constraints relevant for specific applications, such as: homogeneous and heterogeneous fleets, multiple-depots and intermediate facilities, hard and soft multiple time windows, pickup & delivery, decision-making cross-docking, split-deliveries and many others.

The algorithmic framework behind the Optit-logistics solver is the well-known Ruin and Recreate approach (Schrimpf et al. 2000).

This general-purpose solver was used in several real-world applications ranging from pickup & delivery for retail distribution, to home delivery, closed-loops full-truckload daily transportation and on-demand waste collection. To guarantee the robustness and to validate the reliability of the implemented algorithms, an extensive experimentation phase was carried out taking into account a large data set of VRP benchmark instances, selected with the aim of covering the best-known variants of the VRP in literature.

In this session, we focus on a recently addressed new variant of the VRP, for which we introduce a mathematical formulation and the adopted solution strategy. In addition, we discuss an extensive analysis of real-world instances of the problem.

The problem under consideration contains considerable complexities that cannot be trivially modeled and which, to the best of our knowledge, their combination was not previously treated in the existing literature. The problem belongs to the general family of Pickup and Delivery VRPs (PD-VRP). Furthermore, we have heterogeneous fleet, multiple-depots and multiple-time-windows. Finally, orders can be split over different trips, and at the same time the algorithm should be able to decide if each order can be shipped in "direct-mode" from pickup point to the delivery point or alternatively in "cross-docked-mode" appropriately selecting the so-called transit-point where the order is consolidated with others for the last-mile delivery. The overall solution approach is based on two phases. In a first one a min-cost-flow over the distribution network is solved to define the distribution strategy, while in a second step the detailed routing is determined through the above-described solver. Such, combined approach is extensively validated on real-world instances and proved able to determine very good results compared to the previously implemented solutions.

*Speaker

An exact algorithm for a stochastic bi-objective TSP with multiple drones with application in post-disaster rapid damage assessment

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Nowadays, drones are attracting increasing attention in the context of logistic applications. We address the case of rapid post-disaster damage assessment (RDA), which is critical in disaster relief for humanitarian organizations to plan an effective and efficient response. A prior investigation in the affected areas helps humanitarian organizations to be more prepared financially and operationally. RDA starts immediately after a disaster and is usually completed within a few days. On the one hand, the assessment should be performed as fast as possible due to the limited assessment horizon. On the other hand, since visiting all the affected nodes within a limited time may not be possible, a larger explored area of the affected region provides more accurate data for further relief operations. To this end, we consider a case when a truck and drones collaborate to improve the assessment operations exploiting the benefits of using both drone and truck in a sudden-onset disaster setting. This study proposes a scenario-based two-stage bi-objective variant of the traveling salesman problem with multiple drones (TSP-MD). We consider a heterogeneous set of drones that differ in some characteristics, such as flight speed and battery capacity. Multiple drones can be launched simultaneously; however, the drone performs an assessment for exactly one affected node and returns to the truck, i.e., the truck must wait until all drones return. The first objective aims at maximizing the number of assessed affected nodes given their priority scores. Whereas the goal of the second objective is to minimize the total sum of truck travel time and waiting time for drones to return after assessment, i.e., total assessment completion time. In this paper, we consider the travel time of trucks as an uncertain parameter, as the state of the transportation network depends on the crisis intensity, which is uncertain. In addition, due to uncertain wind conditions, the operating time of the drones is also treated as an uncertain parameter in our problem. We analyze the performance of the model for different risk attitudes, i.e., expected value and worst-case. To solve the proposed model efficiently, we develop a branch-and-Benders-cut scheme. In the end, we conduct numerical studies on a set of test instances to evaluate the performance of the proposed approach.

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Consistent nurse-patient assignment for home healthcare services with nurse absences

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Home healthcare services provide medical assistance to patients who are unable to leave their residences on their own. Each nurse sequentially visits his or her assigned patients in a day. Consistent nurse-patient assignments make the medical assistance more comfortable and efficient because nurses increase understanding of patients' needs by regular interaction with them. Thus, home healthcare services likely assign a nurse to the same patient for a longer time. However, nurses have a relatively high sickness absence rate, partially because of the stressful job and contagious risks. If a nurse is sick, the service of the corresponding patients must be compensated by the other nurses. Eventually, these absences make it necessary to reassign the available nurses to other patients. The goal of this research is to determine a consistent nurse-patient assignment that mitigates the number of reassignments in the case of nurse absences. To this end, we propose a two-stage stochastic program, in which scenarios depict the absence of nurses in representative days. In the first stage, the patients are assigned to nurses. In the second stage, the reassignment of nurses, as well as the routing for patient visits, is determined based on potential absences on a specific day. To address real world-sized instances, we introduce a column-generation based matheuristic that carefully fixes routing decisions to reach solutions of high quality. We show the efficacy of the solution approach in an extensive computational study.

*Speaker

Mathematical Optimization Methods for a Horse Manure Collection Model

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Methane production can be obtained from horse manure as a source of electric energy. The Horse Manure Collection Problem (HMCP) is related to Vehicle Routing Problem where a logistical system is designed to collect horse manure in a timely manner before too much of its methane has evaporated into the atmosphere and deliver it to a suitable biogas plant. We present optimization methods of transporting horse manure to biogas plants. Since the HMCP is a mixed-integer nonlinear program and hard to solve, we also present a developed piecewise-linearization of a univariate function using the Convex Combination (CC) models and Increamental models.

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Time-dependent routing with speed optimization: a case from offshore supply logistics

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We consider a real problem arising in the offshore oil and gas industry, in which offshore installations have a set of delivery and pickup orders to be serviced with a given fleet of vessels departing from an onshore depot at a given day. The decisions to be made are the route and sailing speeds along this route for each of the vessels such that sailing costs are minimized. The sailing costs consists of fuel costs for the vessels and depends on the sailing speeds. Furthermore, the fuel consumption functions and the feasible speed ranges for the vessels are also largely affected by the weather conditions, which may vary over time. Therefore, we also take as input to the problem the weather forecast for the planning horizon, corresponding to the duration of the vessel routes (i.e., 2 – 3 days). This results in a *Time-Dependent Vessel Routing Problem with Speed Optimization* (TDVRP-SO).
We develop a mixed integer programming (MIP) model defined over a time-space network for the TDVRP-SO. To solve real-life instances of the problem, we propose an Adaptive Large Neighborhood Search (ALNS) heuristic, extended with a local search. We also add to the ALNS heuristic a set partitioning model that selects useful combinations of vessel routes from previous ALNS-iterations. In order to calculate the costs of a given solution, the heuristic includes solving the sub-problem of determining the optimal sailing speeds along each vessel route.
Experiments on test instances generated based on realistic data from the Norwegian continental shelf show that the ALNS heuristic is able to find optimal solutions in short computational times to all instances that could be solved to optimality by the MIP solver. The experiments also show that including speed optimization results in significant reductions in both costs and environmental emissions compared to the more common approach of applying a fixed vessel speeds. Furthermore, our results highlight the importance of considering the correct weather conditions when planning the vessel routes, as, otherwise, the solutions will substantially underestimate the true cost of conducting the planned voyages under actual weather conditions. Ignoring weather conditions in the planning might even result not being able to service some orders due to weather-dependent delays in the actual execution of the schedule.

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A matheuristic approach for efficiently routing a fleet of electric vehicles under a realistic energy consumption model

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The European Commission is currently promoting the use of Electric Vehicles (EVs), disincentivizing that of the Internal Combustion Engine Vehicles (ICEVs), especially in road transportation responsible of producing about 70% of the total harmful emissions in the transportation sector. EVs can enter the Limited Traffic Zones, guaranteeing also here door-to-door transportation/distributive services, and have maintenance and kilometer costs by far less than those of ICEVs. However, the EVs driving range remains a bottleneck, especially if they are used in distributive logistics, since they may require recharging also more than once during a trip. In addition, since the Recharging Stations (RSs) are not yet widespread on the territory, the routes of EVs must be properly planned in advance, including possible stops at RSs, to prevent running out of battery. Such an issue leads to the Electric Vehicle Routing Problem with Time Windows, E-VRPTW (Schneider et al., 2014), which is currently attracting the attention of many operations research specialists. E-VRPTW aims at routing a fleet of EVs, to serve all customers within their time windows, allowing possible recharges en-route, with the objective of minimizing the total traveled distance. Each route must start from a common depot and return to it within a maximum time. This work aims at addressing E-VRPTW considering a realistic Energy Consumption Rate, i.e., EVRPTW-ECR. In EVRPTW-ECR, the energy consumption depends on both the vehicle load and speed, the latter considered a decision variable that can vary between a minimum and a maximum value. We propose a Mixed Integer Linear Program (MILP) formulation of EVRPTW-ECR in which an RS can be used more than once in the same route or solution without creating dummy copies of it (cloneless formulation). Moreover, for efficiently addressing also large-sized instances of the problem, we design a matheuristic approach, based on a randomized version of the Kernel Search (Angelelli et al, 2010). The effectiveness of the proposed matheuristic is shown considering a benchmark set of instances, with up to 100 customers, and a sensitivity analysis on both the initial solution and the time limit given to the restricted MILPs highlights its robustness.

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The Commodity constrained Split Delivery Vehicle Routing Problem with Temperature requirements

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In refrigerated transport, products (or commodities) are transported under different temperature requirements. Trucks are typically equipped with cooling/heating units and sensors to ensure the desired temperature for the cargo. Apart from pursuing minimal distribution costs and respecting the side constraints common to most distribution logistics settings, logistics service providers must set the desired temperature inside the cargo space (so-called "target temperature") following the temperature requirements of the consolidated products. The allocation of cargo to the trucks, the design of the distribution routes and the choice of target temperature for each truck is a challenging problem for practitioners that has not been examined in the academic literature.
We define the Commodity constrained Split Delivery Vehicle Routing Problem with Temperature requirements (C-SDVRP-T) as an extension and generalization of the well-known Commodity constrained Split Delivery Vehicle Routing Problem (C-SDVRP). The C-SDVRP consists of defining a distribution plan to serve a set of geographically dispersed customers, each requesting a certain quantity of different commodities. Each customer can be visited multiple times and can receive different commodities in each visit. In the C-SDVRP-T, however, each commodity must also be transported under specific temperature conditions. A set of commodities is considered compatible, if a target temperature exists that satisfies the temperature requirements of all the commodities in the set. Given a homogeneous capacitated fleet of vehicle, the aim is to determine the routes and the target temperature of each vehicle such that each customer is served minimizing routing and temperature regulation costs while respecting temperature requirements and capacity.
To solve the C-SDVRP-T, we propose an exact approach based on decomposition techniques. Furthermore, we study the impact of optimal and integrated target temperature and routing decisions on emissions and costs based on real-life data from an international LSP specialized in refrigerated transport.

*Speaker

Two-Commodity Opposite Direction Network Flows for Vehicle Routing Problems

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This study revises two-commodity network flow solution approach for a wide range of Vehicle Routing Problems with identical vehicles. The equally sized flows of two commodities considered in this paper are organized in the opposite directions along the collection of tours assigned to vehicles. The resulting mathematical programming models are demonstrated to have several interesting properties new to the literature: (i) the linear programming relaxations of such models are strictly stronger than that of the existing one- or two-commodity flow counterparts in the assymmetric case and that (ii) a general, asymmetric VRP problem instance, even with presence of Time Windows constraints, can be formulated using n(n + 1)/2 binary variables (where n is the number of customers involved in the definition of VRP problem), which is the number of required binary variables for the standard and symmetric VRP only. The compact mathematical formulations of the VRP problem can be further improved using valid inequalities to improve the quality of their linear programming relaxations. Rounded Capacity Cuts is one of the most important family of valid inequalities known to date, whose separation has been recently proved to be NP-hard. This study proposes an exact, simple and efficient procedure for separation of Rounded Capacity Cuts through mixed integer programming. The proposed two-commodity flow mathematical programming VRP formulations are further evaluated in a computational study, together with other known compact problem formulations. The computational study demonstrates that a wide range of problem instances from the literature can be handled using a simple solution methodology that only employs a mixed integer programming solver.

*Speaker

An exact algorithm for the Multi-Commodity two-echelon Distribution Problem

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We consider a problem where multiple commodities are collected from the suppliers, sent to the distribution centres for consolidation purposes and delivered to the customers to fulfil their requests. We name it Multi-Commodity two-echelon Distribution Problem (MC2DP).
The collection operations are performed by an unlimited fleet of homogeneous capacitated vehicles with direct trips from the suppliers to the distribution centres.
Conversely, each distribution centre owns an unlimited fleet of homogeneous capacitated vehicles performing routes to deliver the commodities to the customers.
All vehicles can transport any set of commodities as long as their capacity is not exceeded.
In addition, as in the Commodity constrained Split Delivery Vehicle Routing Problem (C-SDVRP), customers can be visited multiple times.
However, the request for a given commodity has to be delivered in a single visit.
The aim of the MC2DP is to minimize the overall transportation cost.
We propose an extended formulation for the MC2DP based on the set covering problem. We develop a branch-price-and-cut algorithm to solve it. The pricing problem is modelled as an Elementary Shortest Path Problem with Resource Constraints (ESPPRC). Our algorithm incorporates several classical and advanced speed-up techniques: the ng-path relaxation, the bidirectional labelling search, the automatic dual pricing smoothing stabilization, a multi-phase strong branching procedure and three heuristic approaches to solve the ESPPRC. Two of these are graph reduction heuristics arising from the literature. The third one is a novel two-phase heuristic. Specifically, the first phase computes customer sequences by solving the ESPPRC on a modified graph, where customers are delivered with their least requested commodity. This phase provides a lower bound on the value of the pricing problem. The second phase retrieves the routes to be inserted in the master problem by solving the ESPPRC again on acyclic graphs, one for each sequence of customer computed in the first phase. In addition, before the branching phase, we look for violated valid inequalities. We consider the capacity constraints and two new families of valid inequalities based respectively on the set covering polytope and on the number partitioning problem polytope.
Our approach yield promising preliminary results on a set of small instances of the MC2DP.

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The Disaster-Recovery Graphical Traveling Salesman Problem

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In many routing problems, the characteristics of the network in which the problem is solved (the network structure and the associated costs or travel times) are usually fixed or, at least, not controlled by the planner. However, in some situations the connections between nodes may be improved by paying a certain price to reduce travel times or even opening new connections. This could be the case of, for example, the delivery of aid in case of natural disasters, after which roads may be damaged or even cut off. In such a situation, a set of limited resources could be employed to improve the network with the goal of finding a route visiting a set of vertices (populations to be reached by the aid) in the shortest possible time.
In this work we introduce the Disaster-Recovery Graphical Traveling Salesman Problem (DR-GTSP). Let $G=(V,E)$ be an undirected graph. Each edge e in E can be upgraded to level $k=1,\dots,K$. There is a set of K non-increasing costs associated with each edge representing the cost of traversing it if the edge is upgraded to level k, and a set of K non-decreasing values corresponding to the price that has to be paid to upgrade the edge to level k. Considering that the total amount paid to upgrade the edges cannot exceed a certain total budget P, the DR-GTSP consists of finding the optimal route traversing all the vertices in V and the optimal upgrade level for each edge so that the total cost of the route is minimized.
Here we propose a formulation for the DR-GTSP, several valid inequalities that strengthen this formulation, and a branch-and-cut algorithm. This exact procedure has been tested on a set of randomly generated instances.

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Comparing branch-and-cut with branch-cut-and-price for 10,000 CVRP instances

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The introduction of column generation into the classical branch-and-cut (BC) scheme has produced state-of-the-art exact algorithms (a.k.a. branch-cut-and-price (BCP)) for the capacitated vehicle routing problem (CVRP) and related problems. However, a pure BC algorithm may be more efficient than BCP for some particular classes of instances. To investigate that, we compare BC with BCP for a diverse and large benchmark with 10,000 instances of 100 customers, which was recently proposed for testing machine learning heuristics. To our knowledge, this is the first time these algorithms were stressed in such a large and diverse benchmark, which includes the so-called ultra-long route instances. The ultra-long route instances are particularly important because they were neglected by most of the existing benchmarks and represent many real-life applications. For example, in the Amazon Last Mile Routing challenge organized in 2021, the provided training dataset had thousands of historical very long routes from multiple delivery stations in North America. At the conference, we will present a detailed analysis of the computational experiments performed, including those ones with customized parameterization of both algorithms for some particularly difficult instance groups. Finally, we believe the optimal solutions found can be very useful for the community for many purposes, especially for the development and assessment of innovative approaches combining machine learning and operations research techniques.

*Speaker

Revenue Maximizing Tariff Zone Planning in Public Transportation

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Public transportation companies are under pressure to reduce operational costs and increase the number of passengers and revenue. The design of the tariff system has been proven valuable to impact revenues in public transportation. There exist different tariff systems in public transportation. The most widely accepted public transportation tariff system is the counting zones tariff system. The literature on combining zoning and fare problems is scarce. We contribute to this literature by a new approach yielding a counting zones tariff system that maximizes the revenue. We propose an optimization approach to partition the service area into zones and find a price per zone (counting zone tariff) that maximizes expected revenue. It is assumed that (i) the price per zone takes denumerable values, (ii) the number of public transport trips depends on the price (system), and (iii) public transport passengers always choose the time-shortest path. Our new model formulation is (1) flexible to adjust to any objective function; (2) not limited to a predefined number of tariff zones; we impose contiguity of the tariff zones using the properties of primal and dual graphs, (3) coming with a new set of constraints that ensures contiguity and forces tariff zones to a desired spatial pattern (rings or stripes) without altering the model structure; (4) able to optimally solve instances of up to 120 districts (stops) within a reasonable time using off-the-shelf solvers.

*Speaker

Impact of Warehouse Capacities on Transportation Planning. When is integrated planning necessary?

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When the distribution of ordered items from a warehouse to customers is scheduled, the transportation planning is generally done first and this serves as input for the planning of warehouse operations. However, when the deliveries to customers have time window restrictions and the availability of (order picking and staging) capacities at the warehouse is limited, the sequential approach of transportation-first-warehousing-second can lead to substantial inefficiency. Moreover, the routes can also be infeasible for warehouse managers to implement with limited picking capacities. This paper studies the routing decisions of vehicles to customer locations with hard time windows while considering warehouse processes, namely order picker scheduling and order staging to understand which warehouse and network conditions require an integrated approach to planning. We propose a mathematical model for the integrated problem and develop a metaheuristic. Furthermore, we develop exact algorithms to provide bounds and benchmarks for the integrated solutions. Computational experiments distinguish amongst a variety of warehouse and delivery network characteristics to generate managerial insights. The experiments are based on empirical data from one of the largest grocery retailers in The Netherlands. The results show that different warehouse and network characteristics have varying levels of impact on the value of the integrated solution approach. Retailers with limited staging space stand to reduce as much as 4.6% of the logistics cost on average through the adoption of the integrated planning approach. Furthermore, among the delivery network characteristics, small drop sizes and wide time windows are ideal for the adoption of an integrated planning approach. However, for retailers with high staging capacity and low drop sizes, the conventional planning approach is already close to optimal and the adoption of an integrated approach cannot be justified.

*Speaker

Service network design for next-day mail delivery

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We model and solve a long-haul postal distribution problem motivated by the next-day delivery of our industry partner Deutsche Post DHL Group in Germany. This problem belongs to the class of service network design problems and considers different aspects distinct to the mail delivery at Deutsche Post DHL Group. Origin-destination shipments of letter boxes are produced at sorting centers and must be delivered within a given planning horizon to other sorting centers acting as destinations. Letter boxes are loaded into roll containers with limited capacity, and roll containers are in turn loaded into vehicles each having a capacity dependent on its type. During the delivery of shipments, some sorting centers serve as hubs allowing to consolidate different shipments according to structural resorting restrictions on incoming and outgoing roll containers. A particular aspect of our problem is the availability of letter boxes of origin-destination shipments over time due to strict latest arrival times and capacitated processing periods at destination sorting centers. As letters are sorted in origin sorting centers by destination, letter boxes containing these letters become gradually available over time to allow for a timely delivery to their destinations. The objective is then to find a distribution plan that delivers as many letter boxes of the origin-destination shipments as possible while minimizing the total transportation cost of used vehicles.

We model our service network design problem on a time-expanded network with an exponential number of arcs. To solve this problem, we present a heuristic based on slope-scaling and evaluate its performance on a set of instances inspired by the postal network of Deutsche Post DHL Group.

*Speaker

Adaptive large neighborhood search for a rich vehicle routing problem with private fleet and common carrier

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Our work is based on real-life problems of a company that wants to minimize the cost for a heterogeneous fleet of vehicles based on the current load and minimal price of vehicles. A pickup and delivery problem is considered to handle various logistics types. Requests' external costs are specified to allow transportation by a common carrier if it is more advantageous than transportation by the private fleet. Other constraints include weights and volumes of requests, multiple time windows, maximal route duration, or multiple depots. Two stages of adaptive large neighborhood search are proposed and optimized. While the first stage does not involve the minimal price of vehicles, the second stage takes the best solution of the first one and considers the full problem definition.
We have first evaluated the solver on Li&Lim benchmarks where our results are comparable to the best results. We have also extended these instances by three different types of vehicles based on real-life problems. It allows us to demonstrate the behavior of our solver on a broad set of problems with the heterogeneous fleet. Finally, our solver was run on 12 instances provided by the company and compared with their solution computed using Google OR-Tools. In most cases, significant cost improvement was achieved (5–14%), the solution was computed much faster, and the memory usage was better in order of magnitude. The company used the solver for various case studies, and its deployment is in progress.

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Optimization of container transportation in port hinterland with trucks - Approaches to cooperation

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In recent years, containerized transportation has become increasingly important. According to the UNCTAD review, the annual growth rate for goods transported in containers amounted to 1.1 % in 2019. This leads to challenges for container handling in ports and hinterland transportation. At the same time, the advancing digitalization of ports and the ever-increasing amount of available data lead to new opportunities for data-based optimization.
Logistics in the hinterland of ports account for up to 80% of the total cost of the maritime logistics chain. Therefore, optimizing hinterland logistics offers large potential for using infrastructure resources more efficiently, for reducing emissions and costs, and for providing high quality hinterland services to increase competitiveness.

Cooperation is one promising approach here. Based on a literature review and expert interviews, the relevant approaches, such as compensation mechanisms, which are required for a balanced and long-term cooperation between trucking companies, are identified.

A mathematical model for the operative optimization of container transportation in port hinterland with trucks, considering cooperation, is presented. It is discussed how costs in hinterland container logistics with trucks can be reduced by using horizontal cooperation, i.e. by sharing and/or exchanging customer orders, and how stable and long-term-oriented cooperation can be established. A setting is considered in which each trucking company has its own customer orders, some of which it is willing to share or pass on to others, but only at a certain price or compensation. Hence, each order is specified by a value indicating how much another truck company has to pay if it wants to perform this order as well as by its origin, its destination, time windows and the preferred empty container depot. To enable and promote stable and long-term cooperation, fairness is important; therefore, different fairness constraint groups are modelled and implemented. Moreover, different constellations of so-called "trust groups", i.e. groups within which an exchange of orders may take place, are studied.
The analysis shows that different degrees of cooperation, i.e. different sizes of trust groups and different intensity of order exchange, as well as different fairness constraints have a strong and varying impact on the efficiency of the system, e.g. in terms of cost and emission reduction as well as with respect to the distribution of orders and profits. The relation between these aspects and the influence on different objectives as efficiency and sustainability is studied and results are presented. Finally, further research needs are identified.

*Speaker

Dynamic pickup and delivery with auction-based collaboration

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In this work, we consider the problem setting of a less-than-truckload carrier in an urban environment. Throughout the day, the carrier receives stochastic customer requests consisting of a pickup location, delivery location, volume, and revenue. Each request must be answered dynamically by either accepting or rejecting it immediately. On the next day, the accepted requests are fulfilled in routes that are performed by a set of vehicles, each with limited load capacity and route duration. After the request acceptance phase and before the requests must be served, the carrier has the possibility to exchange requests with other carriers in a combinatorial auction. Each carrier selects a set of requests to submit to the auction pool, based on which an auctioneer generates bundles of requests. After carriers place bids on each bundle denoting their price for serving the included requests, the auctioneer allocates the bundles to carriers such that the total cost is minimized. The auction profits are shared equally among all participating carriers. This type of horizontal collaboration promises efficiency gains for carriers and is considered as a means for more sustainable transportation systems without requiring carriers to reveal sensitive information. We model the carrier's sequential optimization problem of maximizing its profit as a Markov decision process that depicts all phases and their specific decisions, i.e., request acceptance, request selection for the auction, bidding, and routing, in an integrated way. Heuristic approaches are used for inserting requests into vehicle routes, solving a dynamic version of the vehicle routing problem with pickups and deliveries. We develop policies for strategically accepting or rejecting requests while recognizing the outsourcing and acquisition options provided by the auction. A computational study is conducted to assess the profitability of entering collaborations and to compare different acceptance and routing policies. Results show that carriers in this dynamic setting can achieve considerable collaboration gains that are impacted by their request acceptance decisions.

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Using unmanned aerial vehicles in last-mile deliveries

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Delivering packages in urban areas is becoming increasingly difficult. Not only high traffic congestion and strict parking regulations pose major challenges for carriers. They also have to deal with restrictions imposed by urban development and environmental policies. One possibility to deal with these challenges is to integrate alternative transportation modes, like unmanned aerial vehicles (so-called drones) into classical freight flows. Compared to regular trucks, drones are not tied to the street network, can operate faster, and are more environmental-friendly than trucks. On the other hand, their loading capacity and flying range are much more limited than those of the trucks. To combine the advantages of both trucks and drones we consider a Vehicle Routing Problem, where each truck is equipped with a drone. The idea is that each truck does not only deliver parcels to customers, it also serves as a hub for its drone. On a truck's route, the drone can be released (several times) from the truck to serve a customer and meet the truck again before its flying range is reached. The overall goal is to minimize the total routing costs that consist of the routing costs of trucks and drones. To solve the problem, we present a branch-and-price algorithm. The resulting pricing problem is a shortest-path problem with resource constraints that is solved with a labeling algorithm on an auxiliary network. We present computational results on CVRP benchmark instances.

*Speaker

A branch-and-cut algorithm for the dial-a-ride problem with ride and waiting time minimization and time windows

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In recent years, several ridesharing providers launched in large cities. In contrast to the standard dial-a-ride problem, these providers focus on the general public. As they are amongst others in competition with taxis and private cars, it is important for them to ensure short travel times for the customers. In this talk, we consider the resulting dial-a-ride problem with ride and waiting time minimization, which minimizes the relative detours of all customers in relation to the earliest point in time the customer can be picked up. Furthermore, we assume time windows for every customer request. We present a branch-and-cut algorithm with several techniques to improve the search. Moreover, we analyse our techniques in a computational study.

*Speaker

The Multi-Purpose K-Drones General Routing Problem

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In this talk, we present the Multi-Purpose K-Drones General Routing Problem (MP K-DGRP). On this optimization problem, a fleet of multi-purpose drones, aerial vehicles that can both make deliveries and some imaging as well, have to jointly map a set of continuous areas and visit a set of nodes. The continuous areas that have to be mapped can correspond to flooded areas or regions with a disease outbreak or infrastructures to be inspected, while the delivery, e.g. of healthcare items, has to be performed on a set of nodes. The continuous areas to be imaged can be modeled as a set of lines so that each area is completely serviced if all the lines covering it are traversed. Thus, given a set of nodes and a set of lines, the problem is to design drone routes of shortest total length traversing the lines and visiting the nodes, while not exceeding the range limit (flight distance) and capacity (loading) of the drones. Unlike ground vehicles in classical routing problems, drones can enter a line through any of its points, service only a part of that line and then exit through another of its points. The possibility of flying directly between any two points of the network offered by drones can lead to improved services and reduced costs, but it also increases the difficulty of the problem. To deal with this problem, the lines are discretized, allowing drones to enter and exit each line only at a finite set of points, thus obtaining an instance of the K-vehicles General Routing Problem (K-GRP). We present in this talk an integer programming formulation for the K-GRP and propose a matheuristic algorithm and a branch-and-cut procedure for its solution. Some computational experiments are shown to summarize the performance of both algorithms on a set of instances generated for this work.

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A Hybrid Variable Neighborhood Search Algorithm for the Multiple Roaming Salesman Problem

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In this paper, we study multiple Roaming Salesman Problem (m-RSP), a new variant of the recently introduced Roaming Salesman Problem, the goal of which is to determine daily tours for traveling salesmen who collect time-dependent rewards from various cities during a planning horizon. m-RSP is a generalization of the traditional traveling salesman problem and has a wide range of real-world applications including multi-period vehicle routing, touristic trip planning, election logistics, nurse routing, and marketing campaigns. We propose a MILP model to tackle the m-RSP that includes relevant real-life assumptions, some of which are widely used in the business context. Rewards are increased linearly in time as we get closer to the end of the planning horizon rather than the other way around. The objective function consists of maximizing collected rewards, including rewards corresponding to first and repeat meetings, and minimizing traveling costs. To tackle large-size instances, we develop a new hyper-heuristic algorithm that consists of a Skewed Granular Tabu Search which is embedded in a Variable Neighborhood Search algorithm. The proposed method is experimentally validated on 50 real-life instances with actual travel times and distances. The computational results indicate that our method can produce near-optimal solutions effectively.

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Multi-stage Stochastic Programming Methods for Adaptive Disaster Relief Logistics Planning

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We consider a logistics planning problem of prepositioning relief items in preparation for an impending hurricane landfall. This problem is modeled as a multiperiod network flow problem where the objective is to minimize the logistics cost of operating the network and the penalty for unsatisfied demand. We assume that the demand for relief items can be derived from the hurricane's predicted intensity and landfall location, which evolves according to a Markov chain. We consider this problem in two different settings, depending on whether the time of landfall is assumed to be deterministic (and known a priori) or random. For the former case, we introduce a fully adaptive multi-stage stochastic programming (MSP) model that allows the decision-maker to adjust the prepositioning decisions, sequentially over multiple stages, as the hurricane's characteristics become clearer. For the latter case, we extend the MSP model with a random number of stages, introduced by Guigues (2021), to the case where the underlying stochastic process is assumed to be stage-wise dependent. Our numerical results provide key insights into the value of MSP, in disaster relief logistics planning, compared to other approximation policies such as the static and rolling-horizon two-stage stochastic programming approaches.

*Speaker

Dynamic Fleet Size and Order Assignment Problem

Natasja Sluijk * [1], Alexandre Florio [1], Joris Kinable [1], Tom Van Woensel [1]

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We study a canonical version of a real-world problem faced by a logistics service provider (LSP). The LSP has its own fleet and the option to rent additional vehicles if the demand of its customers exceeds the capacity of its fleet. Each day, the LSP receives new transportation orders and has to assign them a delivery date within the orders' indicated delivery horizon. The demand is stochastic and revealed over time, which implies that the uncertainty regarding the total demand for a delivery day decreases as we approach the delivery day. After the new orders have been assigned, the LSP revises its capacity planning for each day in the planning horizon and decides on the number of (additional) vehicles to rent. The rental price of the vehicles is not fixed and increases as the time till deployment decreases. Typically, renting a vehicle well in advance is cheaper than renting a vehicle last-minute. Therefore, when deciding on the assignment of orders to delivery days, as well as the timing and number of (additional) vehicles to rent, one has to trade-off the increasing rental costs and decreasing demand uncertainty. We refer to the resulting online optimization problem as the *dynamic fleet size and order assignment problem* (DFSOAP).
We formalize the problem and formulate a sequential stochastic optimization model for DFSOAP. The problem is defined over an infinite horizon with discrete time steps (periods) and a finite planning horizon. Each day, new incoming orders have to be assigned and additional vehicles may have to be rented to ensure that all orders can be satisfied. The objective is to minimize the expected total discounted reward, which is the sum of the rental and routing costs.
We propose two algorithms (policies) that, given a state, return a decision for DFSOAP. The first policy is a myopic approach that only takes known information into account, whereas the second policy anticipates future demand. In the first policy, we cluster orders that are promising to be served together, while taking space, time and capacity dimensions into account, and assign them to delivery days. Given the assignment, we revise our fleet size decisions. The second, more advanced, policy is obtained with a roll-out algorithm on the myopic policy. Preliminary computational experiments on a set of instances show that the second policy outperforms the myopic policy.

*Speaker

Rich transport capacity matching problem for a digital LTL freight marketplace

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Our rich transport capacity matching problem stems from a research project with a German logistics company. Our goal is to build a digital freight marketplace for the highly fragmented less-than-a-truckload (LTL) sector where demand and supply for transport capacity meet virtually. A matching algorithm based on complex mathematical optimization is at the core. With that matching algorithm, we aim to significantly optimize the utilization of cargo space and thus diminish existing economic and ecological inefficiencies, such as national empty road journeys that accounted for more than 20% of the vehicle kilometers traveled in 2018 in Germany (see Eurostat, 2018).

Our research relates to the field of rich vehicle routing problems (VRP) with real-world characteristics. We assume the transportation requests each to be a pair of pickup and delivery for which multiple time window restrictions exist. A finite amount of heterogeneous trucks starting at different locations is available within the time frame to fulfill the transportations requests. A decision has to be made which transportation requests are fulfilled and, if so, by which truck (i.e., our rich transport capacity matching problem). Unlike the vast majority of VRP literature, we focus not only on physical vehicle constraints (e.g., load restrictions) or customer requirements (e.g., time windows). For the digital freight marketplace to become a success, the matching algorithm also takes the European EC 561/2006 hours-of-service regulations for truck drivers into consideration – the regulations contribute significantly to the combinatorial complexity of the transport capacity matching problem.

Building on an extensive review of the VRP literature and related (meta-)heuristics, we develop a heuristic to solve the rich transport capacity matching problem. Our primary goal is to maximize the number of matches, i.e., the number of fulfilled transport requests. We nest an iterative procedure with resource extension functions in the heuristic to ensure our algorithm complies, among other restrictions, with the European EC 561/2006 hours-of-service regulations for truck drivers. Eventually, we test the heuristic in a deterministic setting on real instances from carriers and customers in the network of the logistics company.

Overall, our research will advance the existing VRP-research and paves the way for future research, for instance, on stochastic settings with incomplete information. It also offers practitioners great opportunities: minimization of empty journeys also translating into an improved ecological footprint, realization of network and scaling effects and optimization of productivity in the route planning and execution process, e.g., through automation and standardization.

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Modeling Driver Preferences in a Bicycle Courier Service based on a Multigraph

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Courier services have a long tradition in logistics, primarily in the delivery of valuable documents or medicines. In cities and on short-trips, bicycle couriers have major advantages as they are less affected by traffic volume and congestion, they do not block small streets while serving, and they can serve customers in car-free zones more easily.

Since many courier service companies engage driver as freelancers in a gig economy, they have to incorporate driver satisfaction into routing objectives to hold drivers in their company. Satisfaction can be supported by considering the individual preferences of each driver while assigning orders. This is, for example, an adequate workload corresponding to the individual physical conditions, or a time schedule considering preferred working times. Additionally, the drivers may have different safety and comfort requirements with respect to the road network. For example, some drivers prefer bicycle streets and side streets and their dissatisfaction increases significantly when they are forced to use main streets with or without separated bicycle lanes. Other drivers would also use separated bicycle lanes and their satisfaction only decreases significantly if they have to drive on main streets without separated bicycle lanes.

In this paper, we present a routing model that includes individual driver preferences. As the basic problem formulation for a courier service, we define a static pickup and delivery problem that is based on a multigraph. Considerations about fairness and satisfaction from the drivers' perspective are then included in the model. For example, different edges between two nodes in the multigraph correspond to real-world routes with different levels of driver-friendliness. Based on this, we introduce a function that represents a driver's regret about having to travel an efficient route rather than the more comfortable route suggested by their individual preferences. However, by reintroduction efficiency, we avoid idiosyncratic driver tours. We present a computational study in which we provide insights about the difference and the trade-off between efficient and driver-friendly routing in courier services.

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Stochastic and Dynamic Pickup-and-Delivery with Time-Dependent Travel Times and Crowdshipping

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We study a pickup-and-delivery problem in which customers stochastically request orders over the course of a day from a choice of vendors on an e-platform. Based on the specifications of the customers' requests, a dispatcher dynamically schedules the service on a combination of dedicated vehicles and crowdshippers who experience time-dependent travel times. We model the problem as a Markov decision process (MDP) over finite, discrete-time horizon and obtain policies (solutions) using a parametrizable cost function approximation (CFA) that accounts for the limited availability of the crowdshippers. We benchmark this approximate dynamic programming (ADP) method with a myopic approach based on adaptive large neighborhood search (ALNS). To reflect the impact of marketing promotions on the e-platform, our data sets consider two types of correlations between customer orders: (1) varying densities of a single customer placing near-simultaneous orders from multiple vendors, and (2) varying densities of neighboring customers placing near-simultaneous orders from a single vendor.

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A granular local search for the demand-scenario-based district cutting problem for postal deliveries

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Cost-efficient routing of postmen is of major importance for companies like our industry partner Deutsche Post DHL Group (DPDHL). Currently, DPDHL pursues the strategy of clustering street segments of a city into districts and determining a tour within each district, all starting at the depot. The objective is to minimize the total travel time required by the postmen for completing their tours. Because the number of letters varies on different days of the week and different seasons, we have different demand scenarios, characterized by the number of districts to form. DPDHL already solved the problem based only on the most likely demand scenario, the so-called standard demand scenario. The resulting problem is called the standard demand district cutting problem (SDDCP).

Before starting the tour, each postman has to pick up the letters at the depot. The letters are already sorted on so-called preparation tables with respect to the SDDCP solution and the order cannot be changed on a daily basis. Motivated by the need of optimizing the use of postmen and of keeping the postmen workload balanced, we study the problem of modifying the district composition and the associated tours for demand scenarios different from the standard one, which require either a smaller or a larger number of postmen, i.e., districts. We refer to this problem as the demand-scenario-based district cutting problem (DSBCP). The objective is to minimize the total travel time. Because the letters at the depot are sorted according to the SDDCP solution, additional constraints arise.

Similarities of the DSBCP to problems in the literature can only be found to a limited extent. Moreover, standard solvers cannot even find a feasible solution to realistically sized instances in reasonable runtimes, so using heuristics is the only viable alternative. We propose an iterated local search to address the DSBCP and derive a preprocessing technique and sparsification methods which allow us to discard the evaluation of unpromising solutions.

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Optimal Service Time Windows

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With aging populations and millennials seeking work-life balance, home-service companies are experiencing increasing demand. These services include appliance installation and repair, furniture delivery and setup, parcel delivery, utilities such as cable, home health assistance, and various on-demand services (e.g., Handy), among others. In provding these services, the customer's preference for convenience conflicts with their desire for reliable service. Because customers must usually take off work to be present for such services, they desire an accurate estimate of when the service will take place. However, the challenge facing companies in communicating the exact time of service is that this time is unknown. The practice of quoting large time windows (e.g., four hours) has led to customer dissatisfaction. From the perspective of a firm providing on-location services, we address the problem of determining service time windows that must be communicated to customers at the time of request. We set service time windows under incomplete information on arrival times to customers. We show how to minimize expected time window width subject to a constraint on service level. Under mild assumptions, our main result characterizes the optimal policy, identifying structure that reduces a high-dimensional stochastic non-linear optimization problem to a root-finding problem in one dimension. We use these results to inspire a practice-ready heuristic for the more general case. Relative to the industry standard of communicating uniform time windows to all customers, and to other policies applied in practice, our method of quoting customer-specific time windows yields a substantial increase in customer convenience without sacrificing reliability of service. Our results show that (i) time windows should be tailored to individual customers, (ii) time window sizes should be proportional to the service level, (iii) two time windows for one customer are helpful in some cases, (iv) larger time windows should be assigned to earlier requests and smaller time windows to later requests, and (v) larger time windows should be assigned to customers further from the depot of operation and smaller time windows to closer customers.

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Covering Salesman Problem with Varying Coverage: Application in Carbon Storage Monitoring

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Carbon Capture and Storage (CCS) is an important greenhouse gas mitigating technology in which CO2 is captured from emission points, transported, and injected underground for permanent storage. Although leakage of injected CO2 is considered unlikely, in order to comply with regulatory requirements, monitoring of storage sites is essential. To reduce the associated costs, the monitoring program must be designed with optimal use of the equipment.
Here we use the solution of a Covering Salesman Problem (CSP) with varying coverage to optimize the routing of an Autonomous Underwater Vehicle among a subset of pre-defined locations, henceforth called nodes, with the purpose of detecting a seep of CO2 through the seafloor from an unknown location.

We assume that by staying in a node, we obtain information on the surrounding area, i.e., cover an area, and that this area expands with the duration of stay of the AUV in each node, up to some pre-defined maximum coverage.

The objective is to maximize scaled weighted coverage of nodes taking away the cost of such operation. The cost is assumed to be comprised of the cost of moving among nodes and the cost of staying and measuring in the chosen nodes for the specified duration.

The mathematical model accounts for the flow conservation and keeping track of time, as well as varying coverage and the limit to it, whether or not a specific node is covered, and the battery capacity of the vehicle.

The model is implemented in AMPL using Gurobi solver. It was observed that only in a limited number of instances in small sizes can this problem be solved using the solver. Thus, we designed a heuristic to tackle the problem.

The Adaptive Heuristic starts with the initial solution, and at each iteration, a new solution is obtained by choosing a heuristic based on the associated weights, which are updated at the end of each segment based on their performance and applying it to the current solution. The obtained solution is evaluated and the best and current solutions are updated accordingly and the loop continues until the stop criteria are met. Moreover, an escape routine is implemented so as to prevent the algorithm from being stuck in a local optimum.
The proposed heuristic is much faster at solving the problem, while maintaining a good level of proximity to the optimal solution given by the solver in small-size instances.

*Speaker

Joint Order Batching and Picker Routing Problem including congestion

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Warehouse management at the operational level is mainly focused on the efficient execution of the picking process. Picking activities consist in collecting all the products of a given set of customer orders. In this presentation, we consider a rectangular warehouse composed by a set of parallel cross and vertical aisles. A sub-aisle is a piece of a vertical aisle delimited by the intersection with two consecutive cross aisles. Products are stored in racks located in the sub-aisles. Pickers walk around the warehouse pushing a capacitated trolley to collect the products. Order picking tasks represent the majority of the total operational cost, and managers have to take two main decisions: (1) assign and group the orders to be collected by the available pickers, and (2) define the exact route to be followed by each picker to pick the items of its assigned orders. Several pickers are simultaneously moving around the warehouse to collect the products. Several pickers must likely compete to use the space, producing an undesirable effect named congestion. This occurs when two or more pickers are located in the same space simultaneously, producing a delay in the nominal travel times. This delay is directly related to the number of pickers located in the same zone. In a real scenario with human pickers, it is impossible to exactly coordinate them, so we propose to divide the planning horizon into time intervals, and then define a situation of congestion when several pickers are using the same sub-aisle during the same time interval.

We propose a Mixed Integer Linear Program formulation that considers the integrated batching and picker routing decisions and minimizes the total completion time (travel, picking, and delay). We propose an approximation using a piecewise linear function to quantify the delay. A time delay is imposed each time several pickers are in a situation of congestion. Since we need to decide the arrival of the pickers at each picking location, we developed a transformation of the warehouse graph.
The model allows obtaining optimal solutions in small instances. To achieve optimal solutions on larger instances, we develop two-step solution procedure in which the first step solves the batching and picker routing without considering congestion, and then the second step solves the scheduling problem minimizing congestion. Computational results will be presented and the relevance of the model will be discussed.

*Speaker

Fair and profitable VRP for e-commerce logistics

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During last few years, e-commerce sector experienced a significant growth, especially due to the effect of COVID-19 pandemic. This unexpected event forced local lockdowns in most countries worldwide and, consequently, fostered the spread of online shopping. A novel but fundamental component of e-commerce is the social sustainability, which is gaining importance within both governments and customers. For instance, in 2015 United Nations defined 17 Sustainable Development Goals, some of which are strongly related to social sustainability themes. The objective of this research is to develop and implement an original mathematical model for the Vehicle Routing Problem (VRP) to optimize not only the economic aspect of e-commerce produces distribution, but also the social one in terms of drivers' energy expenditure for delivery activities. Considering this latter, the term to minimize is the maximum percentage of energy spent by each driver compared to his or her availability. In fact, human energy capacity depends on the physical characteristics of a person (e.g., age and gender). Thus, the loads assigned for delivery should be proportional to each driver's characteristics. Firstly, a mathematical model for a Capacitated VRP is defined. Then, since the problem is NP-hard, a Simulated Annealing metaheuristic algorithm is proposed to offer a very good solution in an acceptable time. The metaheuristic is tested and validated with a realistic case study that simulates an e-commerce platform for food produces delivery. The importance of the economic and social aspects is varied using two weights to find the best tradeoff between these two aspects. After 11 different scenarios, the obtained results suggest that just by assigning a little relevance to the social sustainability aspect (weight of 10%), e-commerce platforms could improve their performance in this aspect by 21% with a small worsening in their economic aspect of just 4%. So, such platforms could become in the future highly socially sustainable through the adoption of the proposed model just accepting a small increase in their costs. Moreover, the KPIs computed report that the min-max approach adopted for the social sustainability simultaneously minimize the drivers' energy expenditure and balance the delivery loads among all of them.

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An Exact Approach for a Rich Vehicle Routing Problem with a Zone-Based Tariff Scheme

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While most retailers, relying on third-party logistics providers, must cope with zone-based tariff schemes, the available literature on vehicle routing problems (VRP) focuses on distance-based cost structures. However, zone-based schemes show a non-additive cost structure, and as such only complete tours can be priced. Therefore, most of the prevailing solution approaches cannot be used for this problem. Our work addresses this issue and considers a VRP with a zone-based tariff scheme from a German retailer with more than 300 stores. We formulate the real-world problem as a multi-depot, open vehicle routing problem with a heterogeneous fleet and an outsourcing option (MD-HF-OVRP-PC). Due to the requirements given for the distribution, we further consider an order consolidation policy and truck driver time restrictions. We propose a two-phase set partitioning algorithm working on a complete set of feasible tours to solve the MD-HF-OVRP-PC. The set of tours is computed using a tree structure with efficient pruning strategies. In numerical experiments, we show that the newly developed set partitioning algorithm is efficient for highly constrained problems with a zone-based cost structure. In a case study, we highlight the savings potential of our solution approach compared to the retailer's status quo. In further sensitivity analyses, we discuss the implications of a zone-based tariff compared to standard cost schemes and show under which conditions the different cost schemes are beneficial.

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The Online Ride-Hailing Problem with Fairness

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Ride-hailing is a prevalent transportation service that facilitates mobility in urban areas. A ride-hailing service system encompasses several research problems, among them is the operational assignment of on-demand ride requests to vehicles in real-time. The literature suggests various approaches to address similar systems, mainly optimizing the system efficiency, but recent studies pointed out that these systems are likely to cause geographical unfairness among passengers. Such unfairness may imply, for example, that requests whose origin or destination are far from centralized locations, may suffer from excessive service rejections.
In this work, we suggest an assignment mechanism that aims to overcome this phenomenon. We formulate the Online Ride-hailing Problem with Fairness that aims to maximize both efficiency and fairness in the system, while achieving an adequate balance between them. We find good assignment solutions from a considerable number of mixed-integer linear programming (MILP) formulations that are solved off-line, but are applicable to the online setting. The, we use these solutions as the training data for a K-nearest Neighbors-inspired classifier. Offline, we create a reference set that stores multiple system states and their corresponding decisions, as determined by the MILPs. In real-time, when a new request arrives to the system, we consider the system state, compute its distance from all relevant system states in the reference set, and find the nearest states. Lastly, to determine the current decision, we use a voting function to combine the nearest states, considering the states' distances from the current state, and their corresponding decisions.
We performed experiments to evaluate the performance of our dynamic policy. With a simulation study, we examine the performance of our new approach relative to commonly used dispatching rules, as well as some more sophisticated rules, using synthetic random data that represent a real city layout and movement. Our results demonstrate that a good system performance is achieved using this approach.

*Speaker

Dynamic Time Window Assignment for Next-Day Service Routing

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We consider a problem where customers dynamically request next-day home service, e.g., repair or installment. Different to attended home delivery, customers cannot select a time window (TW). Instead, the service provider assigns a next-day TW to each new requesting customer, if the customer can feasibly be added to the next day service without violating the TWs of the existing customers. Else, the customer service is postponed to another day (which is outside of the scope of this work). For fast service and efficient operations, the provider aims on serving many customers the next-day. Thus, TWs have to be assigned that allow flexible reactions to future requests. For such anticipatory assignments, we propose a scenario algorithm that samples a set of future request scenarios, solves the corresponding team orienteering problems (TOPs) with TWs, and uses the solutions to evaluate current TW-assignment decisions. One challenge is to set the TWs of the sampled customers in the scenarios. Setting them randomly leads to underestimation of the potential future services. Relaxing the TW-constraints leads to overly optimistic evaluations. Therefore, we create a compromise of both, assigning each sampled customer a carefully selected subset of TWs where service can take place. For real-time solutions of the TOP with multiple TWs, we propose to approximate the optimal solution values by solving the linear relaxation of a set packing reformulation via column generation. To check feasibility of the individual TW-decisions, we use a flow-based formulation with a branch-and-cut algorithm. We test our algorithm on artificial and Iowa City data. The results show that our method increases customer services significantly. We further show that our TW-compromise in the scenarios is crucial for successful decision making.

*Speaker

Matheuristics for a multi-day electric bus assignment and overnight recharge scheduling problem

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To limit greenhouse gas emissions in the public transportation sector, transit authorities are constantly increasing the proportion of electric buses (EBs) in their fleets. Due to space and budget constraints, more often than not, the number of chargers that can be installed at the depots is inferior to the number of EBs in the fleet. Moreover, even if there is a 1-to-1 match between EBs and available chargers, it is virtually impossible to use all the chargers at the same time due to maximum power grid constraints. Thus, it is necessary to develop methods in order to recharge the buses in an efficient and acute way, taking into account these charging infrastructure capacity constraints. In this study, we consider a multi-day electric bus assignment and overnight recharge scheduling problem which can be defined as follows. A set of vehicle blocks is defined over several days. Each block represents a one-day long fixed sequence of bus trips starting and ending at the same depot. A set of identical buses and a set of chargers are available to a depot. The problem consists in assigning a bus to each vehicle block and to schedule the bus overnight recharging operations at the depot, such that i) the buses always have sufficient energy to complete their vehicle blocks and ii) the depot charging capacity is never exceeded every night. The objectives are twofold: minimizing the total charging costs and minimizing the long-run damages on the battery. Indeed, the battery represents a substantial part of the purchase cost of an EB and its lifetime is strongly impacted by decisions such as: the state of charge level during storage and the battery storage conditions, among others. We first model this problem as a mixed integer linear program (MILP) that can be solved with a commercial MILP solver. Then, to yield faster computational times, we develop two multi-stage matheuristics based on the MILP. To show the interest of considering a multiple-day horizon, we introduce two other matheuristics that mimic current industrial practices and solve the problem sequentially, one day at a time. To evaluate all these algorithms, we used a set of 264 instances generated using data provided by Giro, an IT company that commercializes optimization software for public transit.

*Speaker

Branch-Price-and-Cut for Order Batching Problems

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In this talk, we present the first full-fledged branch-price-and-cut (BPC) approach for the order batching problem (OBP) in warehousing. Given a set of customer orders, each comprising a list of items to be picked, the OBP consists of grouping all orders into batches such that the total distance traveled to pick all items is minimized while respecting the pickers capacity and assigning each order to exactly one batch. We consider a rectangular warehouse with parallel aisles of equal length and width. The storage locations of the items and the routing strategy used by the pickers to traverse the warehouse are assumed to be fixed a priori. The routing strategies considered are return, traversal, midpoint, largest gap, combined as well as exact routing. Starting from a set partitioning formulation of the OBP, the column-generation pricing subproblem is modeled as a shortest path problem with resource constraints on a linear digraph and is solved with a dynamic-programming labeling algorithm where bounding is used as an acceleration technique. Strong valid inequalities are used to strengthen the formulation and dedicated separation heuristics are derived. Ryan and Foster branching is applied to finally ensure integer solutions. Computational tests indicate that the proposed BPC leads to a significant speedup compared to the state of the art.

*Speaker

Split Delivery Vehicle Routing Problem with Shipment Preparation Capacity

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When it comes to the last mile of finished vehicle delivery, making efficient use of the available truck resources is a challenging task. These resources, called autotransporters, are dedicated solely to carrying cars, so that an incomplete load cannot be supplemented with other cargo. In addition, the cars are generally visible during transport and manufacturers usually do not want to see their models being combined with those of other brands. Transportation contracts in this area therefore typically foresee a terminal dwell time of several days to allow cars destined for a specific delivery region to be collected until they form an efficient truckload. Apart from the load consolidation aspect, a car may need to spend a certain time on the terminal to undergo mandatory checks or receive customization before it is ready for shipment. Cars destined for a specific dealer location can be delivered as part loads by two or even more trucks on the same day, but also on different days as long as this does not violate the delivery promise. This study focuses on the integrated operational planning problem of selecting and preparing cars for delivery and building efficient trips. Both the preparation facility and the available truck fleet may exhibit constraint capacity.

*Speaker

Online Order Dispatching and Vacant Vehicles Rebalancing for the First-mile Ride-sharing Problems using autonomous vehicles

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The first-mile ride-sharing problem (FMRSP), which refers to the design of ride-sharing transport services for passengers to reach their nearby transit station, has attracted growing attention recently.

In our problem setting, we have a set of customers, a set of vehicles and one station, which is the destination of all the customers. The problem consists of dispatching and rebalancing the available fleet simultaneously. Order dispatching decisions assign customers to vehicles in order for them to reach the station within their desired arrival time. Rebalancing decisions assign vehicles to selected locations in order to prepare for future customer requests. We propose an online optimization process, which means that we divide the operating hours into small planning periods and re-optimize dispatching and rebalancing decisions for each planning period in light of updated information, such as customers requests and vehicles positions. We formulate the re-optimization problem for each planning period using a Mixed-Integer Linear Programming model. The model ensures that customers that had already been accepted during a previous re-optimization, but have not yet been picked up, will be assigned to a vehicle. On the other hand, the model may reject new customer requests incurring a corresponding penalty. Finally, the model optimizes the dispatch of empty vehicles to rebalancing centers. We assess different methods to generate rebalancing locations based on historical data as well as different ways of rewarding rebalancing activities. The efficiency of the model and the result of different rebalancing strategies are evaluated in simulation process. Extensive numerical experiments are conducted to analyze the efficiency of the model as well as compare different methods for obtaining rebalancing points and rewarding rebalancing activities.

In conclusion, in this talk we discuss a new MILP model to optimize the order dispatching and vacant vehicle rebalancing process in a first-mile ride-sharing problem. The model, and different rebalancing strategies are extensively tested in a simulation experiment based on real world data.

*Speaker

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The bi-objective traveling salesman problem with time windows under travel time uncertainty

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We address the traveling salesman problems with time windows under travel time uncertainty. We consider the knapsack-constrained robust model studied by Bartolini et al. (2020) and investigate its bi-objective extension in which one objective is the sum of the tour cost, and the other encodes a robust measure of the tour's resilience against travel time uncertainty. We consider different resilience measures, maximizing each of them often conflicts with the minimization of the cost. Inspired by the concept of Pareto robust efficiency (Iancu and Trichakis, 2014), we propose to solve the resulting bi-objective problem in such a way that the robust feasibility is required only with respect to a smaller value of the uncertainty budget, but the resilience measure is computed with respect to a larger value to rank the robust solutions with respect to their tolerance against delay. We develop a bi-objective algorithmic framework based on the multi-directional local search of Tricoire (2012) and the balanced box method of Boland et al. (2015). It enables the implementation of problem-specific algorithms for solving different single-objective problems. The resulting algorithm is able to approximate the Pareto front for each investigated bi-objective problem. We conduct extensive numerical experiments to assess the performance of the robust solutions in the obtained Pareto front against travel time uncertainty. The assessment is carried out via Monte Carlo simulation and is illustrated by estimating the tradeoff between cost and service quality (i.e., likelihood and magnitude of time window violations). Moreover, we present a comparative analysis with similar tradeoff curves obtained by solving the original knapsack-constrained model of Bartolini et al. (2020) for different parameterizations of the uncertainty budget.

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*Speaker

Two-dimensional vehicle loading and dispatching problem with incompatibility constraints in freight logistics

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This study introduces a multi-period, two-dimensional vehicle loading and dispatching problem, called Two-Dimensional Vehicle Loading and Dispatching Problem with Incompatibility Constraints (VLDP). The problem originates from a long-haul FTL transportation problem of a freight transportation company and considers a single lane of the provider between a given origin-destination pair. A set of customer orders are to be transported from the origin to the destination by a heterogeneous fleet of vehicles within a planning horizon and can be consolidated in the vehicles for more efficient use of vehicle capacity. The aim is to prepare a single-origin single-destination multi-period transportation plan of loading required orders to vehicles at the origin and dispatching the vehicles to deliver the orders to the destination within their due dates. The vehicle fleet is formed of owned and outsourced vehicles with each vehicle having a fixed transportation cost per trip, where outsourced ones have higher costs. There are constraints regarding the due dates of the orders, pairwise incompatibility of orders packed in the same vehicle, incompatibility of orders and vehicles, as well as area and weight capacity of the vehicles. An order can be delivered earlier than its due date, incurring an earliness penalty due to storage requirements at the destination. The objective is to minimize the total vehicle usage and earliness penalty costs. A Mixed-Integer Linear Programming model is developed and an Adaptive Large Neighbourhood Search algorithm is proposed for the problem. Computational experiments on instances derived from real-world data show the effectiveness of the proposed heuristic.

*Speaker

Inventory Routing Problem with Multiple TimeWindows and Time-based Cost Structure

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In this study, we propose a mathematical model and a math-heuristic algorithm to solve an Inventory Routing Problem (IRP) with multiple time windows and time-based cost structure. The main purpose is to manage forward and revers flows of two different products called full and empty Returnable Transport Items (RTI). A heterogeneous fleet is supposed to transport products through a many to many distribution network where the vehicles differ by their characteristics. It is supposed that each vehicle can visit each node only during multiple predefined time windows. Assuming production and consumption rates and the amount of initial inventory, the predefined minimum and maximum stock level for both products should be satisfied. Additionally, the total number of visits for each node is limited to a given number during the planning horizon. It is supposed that in different period of times (shifts) during planning horizon, both economical and environmental costs of transportation are varied for different type of vehicles. In addition, driver wage cost per unit of time may vary in different shifts. We have assumed other operational costs as fixed and variable loading/unloading costs at each node. Formulating problem as a mixed-integer linear model, generating small to large-sized instances, and using a conventional solver (Gurobi), it has been observed that only the small size of the problem can be solved within a reasonable time limit. Therefore, we develop a math-heuristic algorithm which includes an Adaptive Heuristic for fixing the routing variables and a mixed integer programming formulation for determining the value of the rest of the variables. To initiate the algorithm with a feasible solution, two main sets of constraints in the model are relaxed and the corresponding penalties for the violated constraints are added to the objective function. Moreover, with respect to the other constraints, a sub model of the penalized model is solved accordingly. In the first part of the algorithm, several heuristics are designed to decrease penalty function. Once the algorithm reaches to the original feasible solution space, the other heuristics are applied for finding the best solution of the original problem. The performance and effectiveness of the algorithm is assessed through several small and large-sized problems. 160 different instances in 32 different sizes have been solved. The results show that the quality and running time of the proposed math-heuristic algorithm provide us with promising results compared to the solutions reported by Gurobi in 6000 seconds.

*Speaker

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