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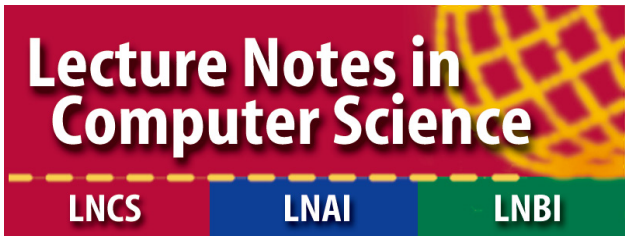
BOOK OF ABSTRACTS

Organizing Institutions



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Collaborative Freight Transport

Monday, Sept. 28, 13:30-15:00

1 **Waterborne Hinterland Transports for Floating Port Terminals**

2 **Towards a Unifying Framework for Self-Organization in Transport Logistics**

3 **Decentralized Combinatorial Auctions for Dynamic and Large-Scale Collaborative Vehicle Routing**

Monday, Sept. 28, 13:30-15:00; Session: Collaborative Freight Transport

Waterborne Hinterland Transports for Floating Port Terminals

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Abstract. Port terminals on floating modular platforms are a conceivable solution for the problem of limited space and water depths restrictions of ports in estuary regions. A design of a dedicated Transport&Logistic hub has been developed in the scope of the Horizon 2020 project Space@Sea. This paper addresses dedicated options of waterborne hinterland transports and discusses opportunities for bypassing onshore terminals by means of river-sea or sea-going inland vessels. A tailored simulation method for ship operations utilises a specific cost model and is applied to derived demand scenarios. Cargo flow statistics of an onshore port have been projected onto the hub to identify relevant waterborne transports to the hinterland. Three different vessel types are implemented, whereas inland vessels are considered with two different sizes. A comparison of round trip durations and transport costs per transported container between a floating terminal and a relevant hinterland port pointed out, that a non-stop connection with sea-going inland vessels is the economically favourable solution. A feeder vessel is the faster solution in coastal waters but it can not compensate the time saved by omitted terminal visits on a direct hinterland connection.

Keywords: Port Terminal at Sea, Waterborne Hinterland Transport, Strategic Simulation Model

Monday, Sept. 28, 13:30-15:00; Session: Collaborative Freight Transport

Towards a Unifying Framework for Self-Organization in Transport Logistics

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Abstract. This presentation gives voice to the call of both researchers and practitioners to establish a common ground and typology for self-organization in transport logistics. The presentation focuses specifically on vehicle automation and how delegation of control – or autonomy – to these vehicles, may result in various forms of self-organizing logistics. This is motivated by the lack of clear vision amongst researchers and practitioners on what automation and autonomy bring from a logistics point-of-view and how it is related to self-organization in the transport logistics domain. Contrary to established literature, typologies and classifications, the focus is not on a single-vehicle perspective, but rather a holistic perspective is taken on how automated vehicles impact logistics processes and how they may affect the hierarchy of control, and specifically how decentralization plays a role towards self-organizing systems. Since there is some ambiguity around the notions of automation and autonomy, both in literature and practice, and in particular around the question of how they may lead to a self-organizing logistic system, this presentation touches upon these notions first. Based on this discussion a clear distinction is made between manually organized logistics and self-organizing logistics. A visionary approach to the latter category is then presented.

Key in this approach is the interplay between the degree of autonomy of logistic systems and their degree of cooperativeness. On these two pillars, a unifying framework is presented, distinguishing four fundamental categories of self-organizing logistics. To illustrate the working of the framework in practice, we present four real-life case studies, one per each category. The case studies are positioned as-is, and concrete directions for (more) self-organization are presented for each case. Moreover,

possible additional dimensions of the framework, e.g., control hierarchy, system intelligence, connectivity, and predictability are discussed.
The usefulness of the framework established is two-fold: (i) it provides a common ground for researchers to position their work and to identify potential future directions for research and (ii) it serves as a practical and understandable starting point for practitioners on investigating how self-organization may affect their business and where their limited resources should be focused upon.

Keywords: Self-Organization, Logistics, Transport, Autonomous Vehicles, Framework

Monday, Sept. 28, 13:30-15:00; Session: Collaborative Freight Transport

Decentralized Combinatorial Auctions for Dynamic and Large-Scale Collaborative Vehicle Routing

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Abstract. While collaborative vehicle routing has a significant potential to reduce transportation costs and emissions, current approaches are limited in terms of applicability, unrealistic assumptions, and low scalability. Centralized planning generally assumes full information and full control, which is often unacceptable for individual carriers. Combinatorial auctions with one central auctioneer overcome this problem and provide good results, but are limited to small static problems. Multi-agent approaches have been proposed for large dynamic problems, but do not directly take the advantages of bundling into account. We propose an approach where participants can individually outsource orders, while a platform can suggest bundles of the offered requests to improve solutions. We consider bundles of size 2 and 3 and show that travel costs can be decreased with 1.7% compared to the scenario with only single order auctions. Moreover, experiments on data from a Dutch transportation platform company show that large-scale collaboration through a platform results in system-wide savings of up to 79% for 1000 carriers.

Keywords: Collaborative Vehicle Routing, Collaborative Transportation, Platform-Based Transportation, Combinatorial Auctions, Multi-Agent System, Bundling, Logistics, Dynamic Pickup-and -Delivery Problem

Maritime Case Studies

Monday, Sept. 28, 13:30-15:00

1 **Evaluating Port Development Strategies for a Modal Shift: a Norwegian Case Study**

2 **Analyzing the Impact of the Northern Sea Route on Tramp Ship Routing with Uncertain Cargo Availability**

3 **Ferry Service Network Design for the Kiel Fjord**

Monday, Sept. 28, 13:30-15:00; Session: Maritime Case Studies

Evaluating Port Development Strategies for a Modal Shift: a Norwegian Case Study

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Abstract. We study the design of a multi-modal distribution network for the transportation of incoming containers from a container terminal to nearby customer regions. The motivation for the study has been the relocation of the existing cargo terminal in the Port of Bergen, which is expected to increase the road transportation need in the region. To mitigate the consequences of increased driving distances, maritime solutions have been suggested as replacements for truck transportation, but as no such concepts currently exist, more knowledge and insight is needed. Therefore, in this paper we propose a Mixed-Integer Programming (MIP) model for optimizing and evaluating strategies for a modal shift in the final stage of the supply chain, i.e. the short distance final distribution from the main terminal to the customer regions. We use it on the case study for the Port of Bergen to analyze whether it is possible to come up with solutions where a significant share of the distribution is done by small electric (and possibly autonomous) container ships, instead of trucks. The analyses indicate that a multi-modal distribution network can be a cost-effective option for this particular case.

Keywords: Maritime Transportation, Modal Shift, Mixed-Integer Programming

Monday, Sept. 28, 13:30-15:00; Session: Maritime Case Studies

Analyzing the Impact of the Northern Sea Route on Tramp Ship Routing with Uncertain Cargo Availability

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Abstract. The opening of the Northern Sea Route (NSR) provides an alternative in connecting Asia and Europe. We evaluate the impact of the NSR on tramp shipping through a two-stage stochastic programming model featuring tramp ship routing and scheduling with uncertain cargo availability. Decisions regarding deterministic cargoes with known availability are made in the first stage and decisions regarding spot cargoes and detailed routing and scheduling plans are made in the second stage when the available spot cargoes are revealed. We solve the problem by Sample Average Approximation. The case study shows that the introduction of the NSR leads to an increase in gross margin. It allows picking up more cargoes or picking up cargoes with higher revenues. The advantages of the NSR are more obvious when the bunker price increases. The effect of the NSR on tramp ship routing decisions depends on the region. The effect is most significant for transportation between Northern Asia and Northern Europe, while less interesting to Southern Asia. In general, the NSR is more favored than the Suez Canal Route for both transporting cargoes and repositioning vessels.

Keywords: Tramp Ship Routing and Scheduling Problem, Northern Sea Route, Uncertain cargo Availability

Monday, Sept. 28, 13:30-15:00; Session: Maritime Case Studies

Ferry Service Network Design for the Kiel Fjord

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Abstract. This paper considers a ferry service network design problem using autonomous ferries for the practical case of the Kiel fjord. Among others, the city of Kiel, Germany, currently runs a number of initiatives for developing an autonomous ferry system to open up new mobility opportunities. The city is divided by the Kiel fjord into an eastern and a western part and the current infrastructure is mainly built to accommodate car transportation on roads around the fjord. We provide a new optimization model for the generation of schedules for an autonomous ferry service, including route design and determination of departure frequencies. The model captures practically relevant aspects of minimum required departure frequencies between specific port pairs and understandable ferry schedules, whilst maximizing customer service quality (i.e., excess transit times and departure frequencies).
We provide a two-step optimization approach where candidate combinations of routes and departure frequencies are heuristically generated a priori and fed into an integer programming model. Experiments on real-world data provide managerial insights with regards to ferry fleet size, port network design and ferry schedules.

Keywords: Network Design Problem, Autonomous Ships, Kiel Fjord

Public Transport

Monday, Sept. 28, 13:30-15:00

1 **Developing Robust Electric Bus Systems through Simultaneous Optimization of Charging Infrastructure and Vehicle Schedules**

2 **Improving the Performance of a Traffic System by Fair Rerouting of Travelers**

3 **Robustness and Disturbances in Public Transport**

Monday, Sept. 28, 13:30-15:00; Session: Public Transport

Developing Robust Electric Bus Systems through Simultaneous Optimization of Charging Infrastructure and Vehicle Schedules

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Abstract. Electric buses (e-buses) are regarded as a beacon of hope for emission-free public transport. In order to implement a transition from traditional fuel-based or hybrid bus systems towards electric bus systems, key issues to be considered are the setup of (i) a new transportation system in terms of electric fleet and charging stations, and (ii) new vehicle schedules due to the limited range of e-buses and their additional charging times. While the first issue refers to a long-term planning problem with the main goal of minimizing investment costs into e-buses and charging infrastructure, the latter addresses an operational planning problem under a plethora of scheduling constraints. Albeit vehicle scheduling is, in practice, performed after infrastructure planning and implementation, in the opposite direction, strategic planning results need to anticipate scheduling requirements in order to enable cost-efficient schedule operations. These logical interdependencies call for the development and solution of a single planning model that optimizes both the charging infrastructure and vehicle schedules at the same time ("simultaneous optimization"). The solution of such a model can be used to investigate another key planning requirement in terms of identifying a charging infrastructure that remains feasible and sufficiently low-cost when environmental factors vary ("robustness").
Planning models considering both simultaneity and robustness have not been addressed in the OR literature to the best of our knowledge. We contribute to this research gap by suggesting a new realistic linear optimization model based on empirical data.

Accounting for the computational complexity of solving large-scale instances, we develop and implement a Variable Neighborhood Search (VNS) metaheuristic. Drawing on several real-world instances and empirical data, we computationally apply VNS on various problem instances of different sizes with different topological characteristics.
We interpret computational results not only in terms of achieved investment costs into e-buses and charging infrastructure but we also adopt a complementary, bi-objective perspective by approximating Pareto fronts of the dimensions "number of e-buses" and "number of charging stations". Our computational experiments also focus on the analysis of solution robustness against changes of three environmental factors: (i) the ratio between investment costs per e-bus and those per charging station, (ii) temporal variations, such as weekday vs. weekend, and (iii) increasing levels of electrification of a transportation system. Robustness concerning the latter factor is of particular importance as transitions towards electric bus systems are expected to occur as a multi-step migration rather than as a "big bang" switch. Thus, our approach can be used to identify persistent structures in an organically growing electric transportation system, and it supports the derivation of instructions for a gradual expansion of the e-bus fleet and the charging infrastructure.

Keywords: Electric Bus System, Charging Infrastructure, Vehicle Scheduling, Simultaneous Optimization, Variable Neighborhood Search

Monday, Sept. 28, 13:30-15:00; Session: Public Transport

Improving the Performance of a Traffic System by Fair Rerouting of Travelers

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Abstract. Traffic authorities implement management measures to route drivers towards socially-desired paths. The main goal of such measures is to steer the network from the inefficient but fair user equilibrium to the system optimum: the traffic state that minimizes total travel time (Wardrop, 1952). Here, the behavioral response to route advice is often not accounted for, since some drivers are advised to take a significant detour for the system's benefit. Hence, these drivers may not comply with such advice, and the optimal state will not be achieved. However, empirical evidence shows that (some) users are receptive to advice that proposes reasonable routes that benefit the system (van Essen et al., 2020).

In this study, we propose a social routing service that steers the traffic network towards an efficient but also fair, and, therefore, attainable and over time maintainable traffic state. This social routing system anticipates user responses: only a portion of the demand is assumed to receive and follow the advice, and the realized travel time difference among travelers is explicitly limited.

Although empirical research shows that social routing has great potential in real life, there are theoretical challenges to be addressed before implementation. It is not yet known which paths to propose to which type of travelers, and how to efficiently calculate these paths. In this paper, we show that the theoretical challenges can be addressed by formulating and analyzing a bilevel optimization problem. This program calculates the best possible paths to be proposed to receptive travelers (those that use and comply with advice) and limits travel time differences in the resulting state.

A critical issue in solving the bilevel problem is that the lower-level optimal solution is non-unique. We use techniques from variational analysis to show that the directional derivative of the lower-level link flow nonetheless exists. This generalized derivative can be efficiently found as a solution of a quadratic optimization problem but requires a suitable route flow solution as parameter. We provide an auxiliary linear program that finds this path flow solution efficiently.
We use the directional derivative in a descent algorithm to solve the bilevel program. Numerical experiments show that a real-world implementation of the social routing service has the potential to substantially improve efficiency and preserve fairness at the same time. If only 25% of all travelers take a very small detour (less than 0.6 minutes, where a system optimum requires 3.2 minutes), 27% of the maximum-possible savings are achieved.

Keywords: Traffic, Social Routing, System Optimum, Network Efficiency, Anticipatory Traffic Control

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Monday, Sept. 28, 13:30-15:00; Session: Public Transport

Robustness and Disturbances in Public Transport

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Abstract. Network-based systems are at the core of our every-day life. Whether it is electronic networking, electricity grids, or transportation, we expect the networks to function properly and give us a feeling of safety and security. However, there may be disturbances. In this presentation, we consider disturbances in the context of public transportation. Public transport in our sense refers to rail, bus, ferry and alike, whenever we are moving people especially in public mass transit and rail.
To classify and cope with disturbances, we find many words in the literature that often are more or less loosely coupled, including robustness, resilience, vulnerability, disruption mitigation, or delay management, just to mention a few. We survey related literature and put them into perspective. As a major insight, we show that different strands of literature exist that may benefit from becoming better connected and intertwined. When focusing, we are mostly interested in disturbances in public transport as well as related issues of robustness. Though, robustness (or even slightly modified concepts) is just one of the specific means available to cope with disturbances. Some of the concepts seen in the real world are reflected by means of academic frameworks. They are used to analyze situations (e.g. bus bunching, where we observe two or more buses of the same line following close to each other without that being planned deliberately) while others are used to describe frameworks for solving problems (e.g. bus bridging, where buses are used to replace broken connections in other systems like metro or (light) rail). This needs some differentiation. That is, we aim to put these different versions of disturbance, robustness, etc. into perspective and provide a survey of respective literature. Moreover, we propose some modeling attempts from

literature to explain possible consideration of integrated problem settings as well as an enhancement by means of incorporating robustness. While our choice of problem settings and references is selectively subjective, it may shed some light on important issues to be explored further in future research. The base consists of some 250+ papers that have been surveyed and classified under the umbrella of prevention, reaction, and anticipation.

Proactive approaches. Examples include building an evacuation plan, extension of capacity (this can be devoted towards network design), adding buffer times to encounter primary delays and propagated delays, maintenance, and repair.

Reactive approaches. Examples include bus bridging, delay management, short turning.

Anticipation. Examples include the provision of spare capacity or building reserve shifts.

We note that problem settings in most papers are related to planning for the public transport service provider and not necessarily for the customer. Changing views could also include the planning of the customer. Moreover, in the advent of integrated problem settings, robustness can play a major role.

Keywords: Public Transport, Resilience, Disturbances, Robustness, Delay Management, Digital Transformation, Bus Bridging, Bus Bunching

Plenary Talk I:

Automating Transportation and Logistics in the Digital Age: Past, Present and Future Challenges

Prof. Warren Powell

Abstract. Amazon and Uber have shown the way to the digital era in transportation and logistics in the post-2000 era, exploiting the power of the internet and the explosive growth in the use of smart phones. Less visible is the growth of major freight companies such as UPS, DHL, FedEx, along with major shipping companies such as Maersk and domestic postal services. Today, there is an explosion of services that require fast delivery of products and services with 2-day, same-day and real-time response. Today, we are looking at the possibility of fully-digital transportation operations, where people primarily monitor systems while computers perform all the "thinking" tasks previously performed by people. We have become accustomed to using statistical models and machine learning to perform inference and prediction. The next phase will be using computers to make decisions, especially those implemented in an operational setting. I will talk about the evolution of modern analytics in transportation and logistics, beginning with network models and heuristics in the 1970s and 1980's, and the emergence of powerful deterministic optimization solvers in the 1980's and 1990's. Throughout this period, transportation companies have had to deal with uncertainty, but only recently have we started to develop the type of general modeling frameworks long enjoyed by deterministic optimization. I will give the highlights of this framework, and then bring out the challenges that still remain in the path to full automation.

Inventory Routing

Monday, Sept. 28, 16:30-18:00

1 **Time-Dependent Travel-Time Constrained Inventory Routing Problem**

2 **Inventory Routing in a City Logistics Context: Review and Collaborative Model**

3 **Cyclical Inventory Routing with Unsplittable Pick-up and Deliveries**

Monday, Sept. 28, 16:30-18:00, Session: Inventory Routing

Time-Dependent Travel-Time Constrained Inventory Routing Problem

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Abstract. Inventory Routing Problem (IRP) is an integration of two operational problems: inventory management and routing. The Time-Dependent Travel-Time Constraint (TD-TC-IRP) is a new proposed variant of the IRP where the travelling time between two locations depend on the time of departure throughout the day and the length of a trip is time-constrained. In this paper, time-dependent travelling time functions from the literature are presented and discussed and a mathematical formulation for the TD-TC-IRP is proposed. Numerical experiments are conducted, to validate the mathematical formulation, on a new benchmark combining benchmarks from the IRP and time-dependent routing problems literature.

Keywords: Inventory Routing Problem, Time-Dependent Routing, Travel-Time Constrained Routing, Piece-wise Travelling Time Function

Inventory Routing in a City Logistics Context: Review and Collaborative Model

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Abstract. The concept of city logistics has been introduced as a result of the issues related to the transportation of goods in the urban area, like traffic congestion, CO2 emissions, noise pollution, parking difficulties, etc. City logistics has the aim to optimally plan, manage, and control the vehicle movements within a logistical network in an urban area considering integration and coordination among involved stakeholders (Neghabadi et al., 2019). Innovative solutions for city logistics have been introduced over the years. However, while there is a clear trend towards integrated decision making in the supply chain (Speranza, 2018), such integrated decisions have received less attention in a city logistics context.

Based on Lagorio et al. (2016), vehicle routing problem (VRP) solutions are the most frequently addressed topics in city logistics by researchers. However, only a few studies consider inventory aspects along with the routing decisions, although integrating these decisions can be highly beneficial (Speranza, 2018). The type of problem that integrates routing and inventory decisions is known as the Inventory Routing Problem (IRP). In VRP, the main decision to take is the set of routes to travel in a single time period. In IRP, three main decisions have to be taken: when and how much to deliver to each customer and the routes to travel at each time period. Therefore, the IRP adds some complexity due to the integration of inventory and routing elements into a multi-period decision process, but may lead to better overall decisions.

This study makes two main contributions. First, existing literature on IRP in the context of city logistics is reviewed and interesting research opportunities are identified. Second, first ideas on a new optimization model to address these opportunities are proposed.

The literature review shows that while the IRP has been studied extensively, little research exists on IRP in the city logistics context that pays attention to important aspects or characteristics that occur in urban transportation. Examples of such characteristics include access time windows, multiple vehicle trips per day, the use of heterogeneous vehicles, simultaneous pickups and deliveries, time-dependent travel times, and so on. Hence, one promising research direction is the study of IRP that includes more realistic features that appear in urban transportation. In addition, very few studies examine aspects of collaboration in IRP, while collaboration is considered a crucial element in city logistics, Lagorio et al. (2016). Soysal et al. (2018) is the only work that analyzes a collaboration aspect in IRP. However, their model is not specifically designed for city logistics context.
Based on these research opportunities, we propose an IRP model that focuses on a city logistics context and assumes a network of multiple suppliers and multiple customers. Besides using the concept of collaboration between suppliers and customers using the VMI system (as in IRP), we aim to also investigate the effects of collaboration among the suppliers. To this end, two versions of the multi-depot IRP model have been developed, one with and one without collaboration, to study the impact of collaborative mechanisms in the IRP in a city logistics context.

Keywords: Inventory Routing, City Logistics, Collaboration

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Cyclical Inventory Routing with Unsplittable Pick-up and Deliveries

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Abstract.
We address a milk run logistics problem in which goods must be transferred between facilities on a regular basis to support a company's production. The resulting optimization problem is a form of cyclical, multi-commodity inventory routing problem with pick-ups and deliveries. This problem becomes particularly challenging when either all available cargo of a particular commodity must be picked up or none of it, so as to simplify internal logistics procedures. We model the problem mathematically and introduce a two-phase heuristic to solve the problem. The first phase consists of an adaptive large neighborhood search (ALNS), and the second phase uses a relaxed version of the mathematical model to improve the routes for the vehicles. We present experimental results on a dataset based on real-world data from a company in Germany and show that our two-phase procedure can find high-quality solutions even to real-world sized problems in reasonable amounts of computation time.

Keywords: Cyclical Inventory Routing, Unsplittable Cargo, Adaptive Large Neighborhood Search, Vehicle Routing, Metaheuristic

Trains & Barges

Monday, Sept. 28, 16:30-18:00

1 **Pickup-and-Delivery Problem with Transshipment for Inland Waterway Transport**

2 **Ant Colony Optimization versus a Branch-and-Bound Approach for the Robust Train Marshalling Problem**

3 **Daily Distribution of Duties for Crew Scheduling with Attendance Rates: A Case Study**

Monday, Sept. 28, 16:30-18:00, Session: Trains & Barges

Pickup-and-Delivery Problem with Transshipment for Inland Waterway Transport

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Abstract. Inland waterway transport is becoming attractive due to its minimum environmental impact in comparison with other transportation modes. Fixed timetables and routes are adopted by most barge operators, avoiding the full utilization of the available resources. Therefore, a flexible model is adopted to reduce the transportation cost and environmental impacts. This paper regards the route optimization of barges as a pickup-and-delivery problem (PDP). A Mixed-Integer Programming (MIP) model is proposed to formulate the PDP with transshipment of barges, and an Adaptive Large Neighborhood Search (ALNS) is developed to solve the problem efficiently. The approach is evaluated based on a case study in the Rhine Alpine corridor and it is shown that ALNS is able to find good solutions in reasonable computation times. The results show that the cost is lower when there is more flexibility. Moreover, the cost comparison shows that transshipment terminals can reduce the cost for barge companies.

Keywords: Inland Waterway Transport, Pickup-and-Delivery Problem, Transshipment, Adaptive Large Neighborhood Search

Ant Colony Optimization versus a Branch-and-Bound Approach for the Robust Train Marshalling Problem

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Abstract. This presentation considers the problem of train marshalling, which consists of detaching the railcars of incoming trains and reassembling them to constitute outbound trains with optimal movements. A major assumption in our model is the uncertainty in the arrival order of incoming trains. 10 different random scenarios for the arrival time of each incoming train are considered. The other inputs of the problem are randomly generated as well. The generated instances include 10 to 100 incoming and outgoing trains consisting of altogether 100 to 1000 railcars. The number of receiving and departure tracks are equal and 0.2 of the number of trains; 0.4 × (the number of trains) of classification tracks are also available.

A robust optimization approach is proposed to provide solutions that remain appropriate regarding all the scenarios. A branch-and-bound (B&B) approach is applied to tackle the problem in the first step. This method is implemented in MATLAB. Since a major challenge in the solution process and an exponential increase in the execution time are observable as the problem size grows, an ant colony optimization (ACO) algorithm is modified and employed to obtain high-quality solutions for the large-scale instances in short times. The choice of this algorithm is due to the similarity of constructing solutions including orders of railcars and finding optimal paths in graphs. The main parameters of ACO like the number of ants, evaporation rate and etc. are set by the Response Surface Method (RSM). 10 replications of any problem size with different input values are solved by the B&B and ACO. Finally, the two solution approaches are compared by the Wilcoxon signed ranked test, which is a non-parametric statistical test. The criteria for our comparisons are the quality of solutions

and the required execution time to obtain them. Our examinations show that in the two smallest cases, the ACO solutions are near-optimal, however, for the larger cases, the ACO can obtain solutions having much better quality than those obtained by B&B after one hour. On the other hand, the execution time of ACO is very short in all the cases.

Keywords: Train Marshalling, Robust Optimisation, Ant Colony Optimisation, Branch-and-Bound

Monday, Sept. 28, 16:30-18:00, Session: Trains & Barges

Daily Distribution of Duties for Crew Scheduling with Attendance Rates: A Case Study

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Abstract. The railway crew scheduling problem with attendance rates is particularly relevant for the planning of conductors in German regional passenger transport. Its aim is to find a cost-minimal set of duties. In contrast to other crew scheduling problems, only a given percentage of trains has to be covered by personnel. As a result, existing solution approaches for this complex planning task often generate schedules in which the number of duties per day varies significantly. However, schedules with an uneven distribution are often not applicable in practice, as a proper assignment of duties to conductors becomes impossible. Therefore, we discuss several ways how an even distribution can be considered in a column generation solution method, namely post-processing and integrated approaches. In addition, the daily distribution is also examined for each depot, where a given number of conductors may be assigned to. In a case study the presented approaches are examined and compared for three real-world transportation networks. It is shown that without much additional computational effort and only a minor increase of cost schedules with evenly distributed duties can be achieved. Especially the depot-based integrated approaches show promising results. Hence, this study can contribute to an improved applicability in practice of automated railway crew scheduling.

Keywords: Railway Crew Scheduling, Column Generation, Case study

Cooperation in Transport

Monday, Sept. 28, 16:30-18:00

1 **Quantifying the Effect of Flexibility and Information Sharing in Transportation Planning**

2 **Introducing Cooperativeness for Agrobotics: an Agent-Based Approach**

3 **Smart Containers with Bidding Capacity: A Policy Gradient Algorithm for Semi-Cooperative Learning**

Monday, Sept. 28, 16:30-18:00, Session: Cooperation in Transport

Quantifying the Effect of Flexibility and Information Sharing in Transportation Planning

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Abstract. In this paper, we analyze the effect of information sharing between a wholesaler and a transport company in the Norwegian grocery supply chain. The planning process of each company is formulated as a set covering problem, where the input data of the transport company depends on the optimal solution of the wholesaler model. Information sharing is modeled through controlling which information from the wholesaler model is sent to the transport company model. We define three different cases of information sharing and introduce two types of flexibility, namely the abilities to deviate from the planned delivery date and selected routes. We use real-world data to calculate the effect of information sharing for the different cases. Our results indicate that the benefits from information sharing are limited if there is no flexibility in the system.

Keywords: Transportation Planning, Information Sharing, Flexibility

Monday, Sept. 28, 16:30-18:00, Session: Cooperation in Transport

Introducing Cooperativeness for Agrobotics: an Agent-Based Approach

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Abstract. The Dutch agriculture sector currently faces many challenges. Including the continuous increase in scale, climate change, deterioration of arable land due to soil compaction, a decrease in available manual labor, and changing governmental regulations. To tackle these challenges and to strive towards increased efficiency and productivity, the sector has embraced many automated and robotic systems. For example, in the field of livestock robotics, solutions like automated milking systems, automated feeding systems, and barn cleaning robots are widely used in practice. Moreover, in the field of crop production, automated steering and guiding systems, based on GPS, are improving the accuracy and efficiency of field operations and are reducing the overall driving time. Both fields may greatly benefit from these robotic solutions and particularly when combined with intelligent logistic planning and control.

This presentation focuses on the planning and control of two cases deploying mobile robots, which may greatly benefit from enhanced logistic control, namely: (i) manure cleaning robots in barns, and (ii) carrier robots providing in-field transportation during (bulk) crops harvesting, both of which are motivated by companies active in the sector. We argue that – from a logistics point-of-view – both cases can be addressed in a similar fashion. More specifically, the scheduling and routing of mobile robots can be addressed using the notion of Simultaneous Driving with Pickup and Delivery (SD/PD). Contrary to typical TSP or VRP problems, in SD/PD the actual operations occur while driving (e.g., harvesting crops or picking up manure) rather than at the pick-up or drop-off locations. This calls for a different approach, especially when considering capacitated vehicles, battery depletion, and task handovers among robots.

This presentation argues that the notion of SD/PD can be used to develop a generic approach for both cases. Additionally, cooperative fleets of robots are introduced, which are believed to outperform the currently used, non-cooperative, fleets. To control the logistics of these cooperative fleets, a generic Multi-Agent System (MAS) is presented and illustrated using the two cases. In order to assess the performance of the proposed MAS, and to quantify the impact of cooperativeness, an agent-based simulation model is presented.

Keywords: Multi-Agent Systems, Agrobotics, Smart Agro-Logistics

Smart Containers with Bidding Capacity: A Policy Gradient Algorithm for Semi-Cooperative Learning

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Abstract. Smart modular freight containers - as propagated in the Physical Internet paradigm - are equipped with sensors, data storage capability and intelligence that enable them to route themselves from origin to destination without manual intervention or central governance. In this self-organizing setting, containers may autonomously place bids on transport services in a spot market setting. However, for individual containers it might be difficult to learn good bidding policies due to limited observations. By sharing information and costs between one another, smart containers can jointly learn bidding policies, even though simultaneously competing for the same transport capacity. We replicate this behavior by learning stochastic bidding policies in a semi-cooperative multi-agent setting. To this end, we develop a reinforcement learning algorithm based on the policy gradient framework. Numerical experiments show that sharing solely bids and acceptance decisions leads to stable bidding policies. Real-time system information only marginally improves performance; individual job properties suffice to place appropriate bids. Furthermore, we find that carriers may have incentives not to share information with the smart containers. The experiments give rise to several directions for follow-up research, in particular the interaction between smart containers and transport services in self-organizing logistics.

Keywords: Self-Organizing Logistics, Smart Containers, Multi-Agent Reinforcement Learning, Bidding, Policy Gradient

Dynamic VRPs

Tuesday, Sept. 29, 10:30-12:00

1 **Dynamic Assignment Vehicle Routing Problem with Time Windows**

2 **The Multistage Stochastic Vehicle Routing Problem with Dynamic Occasional Drivers**

3 **Eco-Labeling in Dynamic Vehicle Routing as a Markov Decision Process**

Dynamic Assignment Vehicle Routing Problem with Time Windows

Kim Los[1], Frank Phillipson[1], Elisah Van Kempen[1], Hans Quak[1], Uilke Stelwagen[1]

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Abstract. Offering time windows to receivers of last-mile delivery is becoming a distinguishing factor. However, we see that in practice carriers have to create routes for their vehicles based on destination information, that is just being revealed when a parcel arrives in the depot. The parcel has to be assigned directly to a vehicle, making this a Dynamic Assignment Vehicle Routing Problem. Incorporating time windows is hard in this case. In this paper an approach is presented to solve this problem including Time Windows. A comparison is made with a real observation and with a solution method for the base problem.

Keywords: Home Delivery, Dynamic Vehicle Routing, Time Windows

The Multistage Stochastic Vehicle Routing Problem with Dynamic Occasional Drivers

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Abstract. Thwe widespread use of smart phones and cellular networks allows for new solutions to lower the costs of last-mile delivery to the customers. We consider a setting where a company not only uses its own fleet of vehicles to deliver products from their store, but can also make use of ordinary people who are already on the road. This may include people who visit the store and are willing to take a detour on their way home for a small compensation. The availability of these occasional drivers is naturally highly uncertain, and we assume that some stochastic information is known about them. This leads to a multistage stochastic vehicle routing problem, with dynamic appearance of vehicles. The contribution of this work is to present a formulation of the multistage stochastic programming problem, identifying what type of problem structures makes this model superior to that of a two-stage formulation, and when a two-stage formulation can be an adequate simplification.

Keywords: Stochastic Programming, Uncertainty, Crowdshipping, Mixed-Integer Programming

Eco-Labeling in Dynamic Vehicle Routing as a Markov Decision Process

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Abstract. Eco-labels can be used to indicate the environmental impact of transport orders. In particular, such labels state a maximal amount of greenhouse gas emissions to be emitted while transporting orders from their origins to their destinations. Using eco-labels in transportation problems requires an exact estimation of the actual emissions. However, in addition to environmentally oriented transportation problems that minimize or limit total emissions, the use of eco-labels raises also the issue of how to allocate emissions to orders. Several emission allocation methods are proposed in the literature, such as an egalitarian, distance-based, or payload-based allocation. This means that transportation problems with eco-labeling encompass two decisions: assigning orders to vehicles (routing) and distributing emissions to orders (allocation).

In this talk, we apply eco-labeling to a stochastic dynamic transportation problem. In particular, requests in the Dynamic Vehicle Routing Problem (DVRP) are enhanced by an indication of whether the customers want their orders to be shipped as "green" or "red". Here, an order is considered as "green" if the GHG-emissions allocated to the order are below a certain relative GHG-emission threshold (e.g., 20 gCO2e/ton-km) and an order is considered as "red" otherwise. Requests are stochastic in terms of the point in time in which they appear as well as in terms of their associated eco-label. We model the problem as a Markov Decision Process (MDP) and solve it with Value Function Approximation (VFA). For this, we use a VFA approach that makes use of characteristics specific to eco-labeling. The MDP model, solution approach, and preliminary computational results are presented and the implications of considering both decisions (routing and

emission allocation) embedded in eco-labeling transportation problems are demonstrated.

Keywords: Eco-Labeling, Emission-Oriented Transportation, Markov Decision Process

Yard Operations

Tuesday, Sept. 29, 10:30-12:00

1 **An Optimization Model for Defining Storage Strategies for Export Yards in Container Terminals: a Case Study**

2 **Extended Tree-Based Properties and Heuristics for the Preemptive Stacker Crane Problem**

3 **An Improved Branch-and-Bound Algorithm for the Blocks Relocation Problem to minimize Total Working Time under a Realistic Crane Trajectory Model**

An Optimization Model for Defining Storage Strategies for Export Yards in Container Terminals: a Case Study

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Abstract. In maritime container terminals, yards have a primary role in permitting the efficient management of import and export flows.
In this work, we focus on export containers and storage strategies to minimize the space used in the export yard. The main aim is to define the rules to use to allocate containers into the bay-locations of the yard for minimizing both the number of bay-locations used and the empty slots.
The storage rules are related to the configuration of classes of weight in terms of the number of classes to use and the weight limitations of each class. The idea is to use a 0-1 linear programming model to periodically modify the storage rules for defining the groups of containers that can be stored together. This model uses updated input data derived by periodical data analysis. A real case study related to an Italian terminal is reported and preliminary results are given.

Keywords: Export Containers, Storage Policies, Optimization Model, Yard Space Minimization

Extended Tree-Based Properties and Heuristics for the Preemptive Stacker Crane Problem

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Abstract. The Preemptive Stacker Crane Problem (PSCP) considers the cost-minimal routing of a single unit-capacity vehicle that needs to satisfy a given set of one-to-one pickup and delivery requests. Additionally, the vehicle is allowed to temporarily drop its current payload at arbitrary locations in the network and perform other requests while the payload is stored. A prominent real-world scenario is the road transportation of trailers provided by customers with towing vehicles of external transportation service providers. In such a scenario, preemption may reduce the total deadheading and thus increase the profitability of the transportation service providers.

Assuming that the costs between all pairs of locations satisfy the triangle inequality, Quilliot et al. (2010) have shown that a specific tree structure is sufficient to represent optimal solutions for the PSCP. Building on this tree structure, in this talk, we discuss further structural properties of optimal solutions, propose adaptations of well-known constructive heuristics, and compare them in a large computational study.

We show that preemption may improve non-preemptive solutions by at most 50% and that the introduction of additional locations for drops, so-called drop locations, may improve an already preemptive solution by at most 50% in case of asymmetric costs, by at most 33.3% in case of symmetric costs and not at all for costs resulting from locations on circles or lines. With respect to solution representations, we show that an optimal preemptive solution can be recovered from a permutation of the requests in polynomial time as to the overall number of locations. As such, the search space may be restricted to permutations of the requests,

given that the number of explicit drop locations is polynomially bounded in the number of requests.
Two constructive heuristics based on the Modified Karp-Steele Patching Heuristic (MKS) for the Asymmetric Traveling Salesman Problem and the Savings Heuristic for the Capacitated Vehicle Routing Problem are presented. Variants of both heuristics and variants of a randomized Monte-Carlo Insertion Heuristic (MCI) from the literature are compared on a large set of instances. The results show that the MCI heuristic works well on highly clustered instances, while the MKS and Savings Heuristic perform better on partially- and non-clustered instances. Overall, only a single MKS-based heuristic produces solutions that improve based on optimal non-preemptive solutions on average. A comparison of the best-known preemptive and non-preemptive solutions indicates that the savings enabled by preemption are large in a few instances but rather small in most instances. As such, the decision to apply preemption should be well-considered as the additional complexities may otherwise outweigh its benefits.

Keywords: Pickup-and-Delivery, Preemptive Stacker Crane Problem, Construction Heuristics, Reduced Solution Representations

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An Improved Branch-and-Bound Algorithm for the Blocks Relocation Problem to minimize Total Working Time under a Realistic Crane Trajectory Model

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Abstract. Container handling operation plays an important part in maritime container terminals. Its difficulties lie in that gantry cranes can access only topmost containers, and hence relocations of containers are required when retrieving a container below them. One of the problems for reducing such relocations is the block(s) relocation problem (BRP), which is also known as the container relocation problem (CRP). Its objective is to find the best crane operation sequence for retrieving all blocks (containers) from a single bay in a specified order. Most of the existing studies for the BRP are aimed at minimizing the total number of relocations. Some of them consider minimizing the total working time, taking into account crane motion (e.g. [1]). However, they are based on a simplified model of crane trajectories: The crane always hoists a block up to the topmost height when moving it horizontally. In practice, we only need to hoist it up to the height where no collisions occur with other blocks.

We have already proposed a branch-and-bound algorithm for the BRP for minimizing the total working time under this realistic crane trajectory model [2]. However, its applicability was limited: Due to difficulties in handling the crane working time, it can solve only smaller-sized instances to optimality than that for the ordinary BRP aiming at minimizing the total number of relocations.

In this study, we propose two improvements for this algorithm: One is the memorization technique that stores already visited nodes in the search tree to suppress the search from dominated nodes. The other is a new lower bound on the objective value. The

previous study computed the lower bound, assuming that each block is retrieved directly from its current position. The working time for relocations was computed separately using a known lower bound on the total number of relocations. In this study, we enumerate all possible combinations of a relocation operation and retrieval operation for each block that should be relocated at least once. Then, we adopt the minimum working time as a lower bound for this block. It enables us to consider relocation and retrieval at the same time in the lower bound computation.
We conducted computational experiments using benchmark instances in the literature. The crane specifications were also taken from the literature and are the same as those in [2]. It is shown that the proposed improvements make the algorithm eight times as fast as the original one [2] on average for instances with 25 blocks.

This work is partially supported by JSPS KAKENHI Grant Number JP18K04607.

Keywords: block relocation problem, working time, branch-and-bound algorithm

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Shared Mobility

Tuesday, Sept. 29, 10:30-12:00

1 **Formulations of a Carsharing Pricing and Relocation Problem**

2 **Dynamic Pricing for User-Based Rebalancing in Free-Floating Vehicle Sharing: A Real-World Case**

3 **Overcoming Mobility Poverty with Shared Autonomous Vehicles: A Learning-Based Optimization Approach for Rotterdam Zuid**

Formulations of a Carsharing Pricing and Relocation Problem

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Abstract. This article presents and compares two formulations for a pricing-based carsharing relocation problem. Given a target planning period, the problem consists of deciding simultaneously on the price of carsharing rides between different zones of the city and on performing the relocation of vehicles to better serve demand. Customers' responses to pricing decisions are captured by utility functions. Results illustrate that the more compact of the two formulations is superior in terms of ease of solution and scalability.

Keywords: Carsharing, Relocation, Pricing

Tuesday, Sept. 29, 10:30-12:00, Session: Shared Mobility

Dynamic Pricing for User-Based Rebalancing in Free-Floating Vehicle Sharing: A Real-World Case

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Abstract. Dynamic pricing can be used for better fleet distribution in free-floating vehicle sharing (FFVS), and thus increases utilization and revenue for the provider by reducing supply-demand asymmetry. Supply-demand asymmetry refers to the existence of an undersupply of vehicles at some locations at the same time as underutilization of vehicles at other locations. We propose to use dynamic pricing as an instrument to incentivize users to rebalance these vehicles from low-demand locations to high-demand locations. Despite significant research in rebalancing vehicle sharing, the literature so far lacks experimental results on dynamic pricing in free-floating vehicle sharing. We propose to use an algorithm that minimizes the differences in the idle time of vehicles. The algorithm is tested in a real-life experiment that was conducted in cooperation with an FFVS provider. The experiment shows that even slight differences in pricing and a simple algorithm can already influence user-behavior to counter supply-demand asymmetry. Improving the existing algorithm with more experimental research is advised to further uncover the potential of this strategy.

Keywords: Dynamic Pricing, User-Based Rebalancing, Free-Floating Vehicle Sharing, User-Based Operations, Living Lab, Price Sensitivity

Overcoming Mobility Poverty with Shared Autonomous Vehicles: A Learning-Based Optimization Approach for Rotterdam Zuid

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Abstract. Residents of cities' most disadvantaged areas face significant barriers to key life activities, such as employment, education, and healthcare, due to the lack of mobility options. Shared autonomous vehicles (SAVs) create an opportunity to overcome this problem. By learning user demand patterns, SAV providers can improve regional service levels by applying anticipatory relocation strategies that take into consideration when and where requests are more likely to appear. The nature of transportation demand, however, invariably creates learning biases towards servicing cities' most affluent and densely populated areas, where alternative mobility choices already abound. As a result, current disadvantaged regions may end up perpetually underserviced, therefore preventing all city residents from enjoying the benefits of autonomous mobility-on-demand (AMoD) systems equally.

In this study, we propose an anticipatory rebalancing policy based on an approximate dynamic programming (ADP) formulation that processes historical demand data to estimate value functions of future system states iteratively. We investigate to which extent manipulating cost settings, in terms of subsidies and penalties, can adjust the demand patterns naturally incorporated into value functions to improve service levels of disadvantaged areas. We show for a case study in the city of Rotterdam, the Netherlands, that the proposed method can harness these cost schemes to better cater to users departing from these disadvantaged areas, substantially outperforming myopic and reactive benchmark policies.

Keywords: Mobility Poverty, Shared Autonomous Vehicles, Approximate Dynamic Programming

Rich VRPs

Tuesday, Sept. 29, 13:00-14:30

1 **Vehicle Routing Problem with Reverse Cross-Docking: an Adaptive Large Neighborhood Search Algorithm**

2 **Solving a Bi-Objective Rich Vehicle Routing Problem with Customer Prioritization**

3 **Metaheuristic Approaches for the Fleet Size and Mix Vehicle Routing Problem with Time Windows and Step Cost Functions**

Tuesday, Sept. 29, 13:00-14:30, Session: Rich VRPs

Vehicle Routing Problem with Reverse Cross-Docking: an Adaptive Large Neighborhood Search Algorithm

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Abstract. Cross-docking is a logistics strategy that aims at less transportation costs and fast customer deliveries. Incorporating an efficient vehicle routing could increase the benefits of cross-docking. In this paper, the vehicle routing problem with reverse cross-docking (VRPRCD) is studied. Reverse logistics has attracted more attention due to its ability to gain more profit and maintain the competitiveness of a company. VRP-RCD includes a four-level supply chain network: suppliers, cross-dock, customers, and outlets, with the objective of minimizing vehicle operational and transportation costs. A two-phase heuristic that employs an adaptive large neighborhood search (ALNS) with various destroy and repair operators is proposed to solve benchmark instances. The simulated annealing framework is embedded to discover a vast search space during the search process. Experimental results show that our proposed ALNS obtains optimal solutions for 24 out of 30 problems of the first set of benchmark instances while getting better results for all instances in the second set of benchmark instances compared to optimization software.

Keywords: Vehicle Routing Problem, Cross-Docking, Reverse Logistics, Adaptive Large Neighborhood Search

Tuesday, Sept. 29, 13:00-14:30, Session: Rich VRPs

Solving a Bi-Objective Rich Vehicle Routing Problem with Customer Prioritization

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Abstract. This paper considers a rich vehicle routing problem in which a combination of transportation costs and customer-perceived waiting times should be minimized and a differentiation is made between priority and non-priority customers. We illustrate the problem using a case study of a wholesaler with its own last-mile delivery network where customers can have pickup and delivery demand and are served by a heterogeneous fleet of vehicles. We propose a bi-objective mathematical problem formulation, minimizing the combination of transportation costs and customer dissatisfaction. We model customer dissatisfaction using a non-linear function that approximates the perceived waiting time of the customers. To be able to solve realistically-sized problems in reasonable time, we propose a Simulated Annealing heuristic, Variable Neighborhood Search, and a combination of these. We perform various experiments considering different customer preferences (visit as soon as possible or at a specific time) and problem settings. For the combined objective, we see an average costs reduction for the dissatisfaction function approach compared to the standard time window approach of 48% over all experiments. Furthermore, we observe an average reduction in perceived waiting time of 48% and 20% for priority and non-priority customers, respectively.

Keywords: Vehicle Routing Problem, Customer Satisfaction, Simulated Annealing, Variable Neighborhood Search, Time Windows

Metaheuristic Approaches for the Fleet Size and Mix Vehicle Routing Problem with Time Windows and Step Cost Functions

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Abstract. The vehicle routing problem is a traditional combinatorial problem with practical relevance for a wide range of industries. In the literature, several attributes have been tackled by dedicated methods in order to better reflect real-life situations. This article addresses the fleet size and mix the vehicle routing problem with time windows in which companies hire a third-party logistics company. The shipping charges considered in this work are calculated using step cost functions, in which values are determined according to the type of vehicle and the total distance traveled, with fixed values for predefined distance ranges. The problem is solved with three different metaheuristic methods: Variable Neighborhood Search (VNS), Greedy Randomized Adaptive Search Procedure (GRASP) and a hybrid proposition that combines both. The methods are examined through a computational comparative analysis in 168 benchmark instances from the literature, small-sized instances with known optimal solution, and 3 instances based on a real problem from the civil construction industry. The numerical experiments show that the proposed methods are efficient and show strong performance in different scenarios.

Keywords: Vehicle Routing Problem, Step Cost Functions, Metaheuristics, Local Search, Third Party Logistics

Automated Transport

Tuesday, Sept. 29, 13:00-14:30

1 **Introducing Smart Yards: a New Concept in Smart Transport Logistics**

2 **Automated and Autonomous Driving in Freight Transport - Opportunities and Limitations**

3 **Platooning of Automated Ground Vehicles to Connect Port and Hinterland: A Multi-Objective Optimization Approach**

Introducing Smart Yards: a New Concept in Smart Transport Logistics

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Abstract. This presentation introduces a new concept in the field of smart transport logistics: smart yards. A smart yard is a buffer area to decouple long-haul operations from last-mile logistics and can be implemented at various logistics hubs, e.g., airports, seaports, or distribution centers. The presentation will briefly discuss the generic smart yard concept and conceptualizes this in a smart yard framework. We focused on complex mixed-traffic environments. Within these environments, roads are not private, but partly public, and traffic management is only partially controlled. This shift towards a more complex environment will have an impact on the development of connected and automated concepts, such as Automated Vehicles (AVs).

The smart yard concept can be divided into a physical smart yard and a digital smart yard. Both concepts will be briefly discussed in the presentation. Within the physical smart yard, a cargo decoupling point and AVs are implemented. In the digital smart yard, a seamlessly integrated network system is deployed, that utilizes technological applications such as IoT or 5G, to enable data sharing.

To get a grasp on the smart yard concept, a conceptual smart yard framework has been developed. In this framework, decisive factors are stated that are used as the input for a smart yard. A taxonomy, based on the decisive factors, characterizes a case. Based on these inputs, decisions on key elements (for example, the type of AV and control architecture) should be made. This framework provides directions for further research and addresses practical aspects.

To exemplify the smart yard concept, we present a use case, namely the Schiphol case. Based on the framework, we determine the taxonomy of the Schiphol use case and show the potential

concept and the potential impacts that a smart yard can have. The usefulness of the smart yard is researched from a logistical point of view, to show the impact and effectiveness on KPIs such as throughput time, waiting time, and utilization. This is substantiated with a simulation model, which will be the main focus of the presentation. The approach, the simulation model itself, and the detailed results of this simulation study will be discussed. Furthermore, we will discuss the conclusions about smart yards and the potential areas for further research drawn from this study.

Keywords: Smart Yards, Freight transportation, Smart Logistics

Automated and Autonomous Driving in Freight Transport - Opportunities and Limitations

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Abstract. The development of mobility has always had a considerable influence on economic, social and political structures. Without efficient transport systems, the industrial revolutions of the last centuries would not have been possible or only to a much lesser extent. With the advancing digitalization and the development of automated and autonomous vehicles, new framework conditions are emerging, which are leading to far-reaching changes in the transport sector. In this contribution, the discussions regarding the existing automated and autonomous vehicles in the field of the main freight transport modes as well as possible developments will be presented and considered in the light of future demand structures.

Keywords: Freight Transport, Automated and Autonomous Driving, Applications

Tuesday, Sept. 29, 13:00-14:30, Session: Automated Transport

Platooning of Automated Ground Vehicles to Connect Port and Hinterland: A Multi-Objective Optimization Approach

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Abstract. Automated ground vehicles (AGVs) are an essential part of container operations at many ports. Forming platoons-as conceptually established in trucking-may allow these vehicles to directly cater demand points such as dry ports in the hinterland. In this work, we aim to assess such AGV platoons in terms of operational efficiency and costs, considering the case of the Port of Rotterdam. We propose a multi-objective mixed-integer programming model that minimizes dwell and idle times, on the one hand, and the total cost of the system involving transportation, labor, and platoon formation costs, on the other hand. To achieve Pareto optimal solutions that capture the trade-offs between minimizing cost and time, we apply the augmented epsilon constraint method. The results indicate that all the containers are delivered by AGVs. This not only shortens the dwell time of the containers by decreasing loading/unloading processes and eliminating stacking but also brings considerable cost savings.

Keywords: Platooning, Automated Ground Vehicles, Container Terminals, Loading/ Unloading Operations, Emission Analysis

Mobility & Positioning

Tuesday, Sept. 29, 13:00-14:30

1 **Idle Vehicle Repositioning for Dynamic Ride-Sharing**

2 **Minimizing Movements in Location Problems with Mobile Recycling Units**

3 **Smart City: A Perspective of Emergency and Resilience at a Community Level in Shanghai**

Idle Vehicle Repositioning for Dynamic Ride-Sharing

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Abstract. In this work, we present a forecast-driven algorithm for idle vehicle repositioning, a problem arising in the context of dynamic ride-sharing applications. The objective is to intelligently reposition vehicles in order to maximize the service rate of future trip requests. Without repositioning, a service provider may often need to reject trip requests due to a lack of nearby vehicles.

The core part of our algorithm is a mixed-integer programming model that takes a demand forecast as an input and aims to maximize the coverage of forecasted demand by repositioning vehicles. As a secondary objective, we aim to minimize the travel times for repositioning movements. We assume that vehicles may cover demand near their current location as they may reach these trip requests within a specified maximum waiting time. Our model takes the current state of all vehicles into account and reflects the fact that vehicles may serve multiple trip requests at once. The model itself is embedded into a rolling horizon planning process that is triggered at regular intervals.

Our forecast-driven repositioning algorithm is part of a planning service for dynamic ride-sharing also encompassing other relevant tasks, such as a dispatching algorithm adapted from [1]. The planning service is coupled with a simulation that is fed by real-world taxi trip data and realistically simulates trip requests as well as vehicle events. This system enables us to assess the impact of repositioning within the larger setting of a dynamic ride-sharing application.

We evaluate our approach through extensive simulation studies on three real-world datasets from Hamburg, New York City and Manhattan with up to 20,000 trip requests per hour. We test our

forecast-driven approach with a perfect demand forecast as well as a simple naive forecast. As a benchmark, we compare our algorithm to a reactive strategy inspired by [2]. The computational results show that our algorithm is suitable for real-time usage even in large-scale scenarios. Compared to the reactive algorithm, the rejection rate of trip requests is reduced by an average of 2.5 percentage points and customer waiting times are improved by 13.2 %.

Keywords: Repositioning, Ride-Sharing, Dial-a-Ride-Problem, Mobility-as-a-Service, Vehicle Routing

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Tuesday, Sept. 29, 13:00-14:30, Session: Mobility & Positioning

Minimizing Movements in Location Problems with Mobile Recycling Units

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Abstract. This article addresses the twofold question of at which location and at what point in time waste is recycled. Immediate recycling is unnecessary since storage is available to a limited extent. One approach is to conduct large-scale recycling centrally at one location, but this would lead to high transport efforts for the waste. In this paper, a different, distributed approach is presented. Due to the miniaturization of production and recycling units and their being embedding in standard containers, it is possible to relocate them from site to site at short notice. We present a dynamic location problem for mobile recycling units (DLPMRU) to limit both the transport of waste and the movement of mobile recycling units. In addition to a mixed-integer programming (MIP) formulation, a bilevel decomposition algorithm is proposed, which, in an iterative process, determines the movement of recycling plants through several local search operations and a linear programming (LP) subproblem. Early computational tests show that our algorithm achieves competitive results, especially for large-sized problems.

Keywords: Mobile Facility, Location Problem, Distributed Recycling, Inventory Optimization, Waste Management

Smart City: A Perspective of Emergency and Resilience at a Community Level in Shanghai

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Abstract. Natural disasters, contagious diseases and political conflicts might become emergencies which, to some extent, trigger an abnormal form of traffic and logistics at the level of municipal cities as well as managerial control at the level of communities. In such context, neither the level-of-service nor the cost-benefit-analysis is considered as an appropriate approach for measuring governance performance of related cities and communities. At the level of a municipal city, Shanghai (China) takes action considering the fact that it is a well-connected Chinese city which comprises many transportation modes domestically and internationally. As mentioned in a report released at the early stage of the Coronavirus disease (COVID-19) outbreak in Wuhan City, there exists a mean 10-day delay between infection and detection; therefore, self-sustaining human-to-human transmission should not be ruled out [11]. China's health authorities and the government have been moving quickly [9]. Stopping the the disease from spreading further out of Wuhan City by banning infected people from leaving Wuhan became a top priority on 23 January, 2020. Ever since then, Shanghai is taking actions step by step to avoid secondary outbreaks of COVID-19 in the city after the primary outbreak in Wuhan City. One of the actions is to integrate manual measures together with advanced information technology applications for gaining control at the community level.

Keywords: Smart City, Logistics, Resilience, Urbanization, Mobility, Digitalization, Complex Networks

Inventory Routing 2

Tuesday, Sept. 29, 14:45-16:15

1 The Multi-Period Petrol Station Replenishment Problem: Formulation and Solution Methods

2 Distance Approximation for Dynamic Waste Collection Planning

3 Cash Distribution Model with Safety Constraints

Tuesday, Sept. 29, 14:45-16:15, Session: Inventory Routing 2

The Multi-Period Petrol Station Replenishment Problem: Formulation and Solution Methods

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Abstract. We present a "rich" Petrol Station Replenishment Problem (PSRP) with real-life characteristics that represents the complexities involved in actual operations. The planning is optimised over multiple days and, therefore, the new variant can be classified as the Multi-Period Petrol Station Replenishment Problem (MP-PSRP). A Mixed-Integer Linear Programming (MILP) formulation is developed and a decomposition heuristic is proposed as a solution algorithm, which is evaluated with a case study from a real-life petrol distributor in Denmark. To determine delivery quantities, the heuristic uses the newly introduced simultaneous dry run inventory policy. A procedure is applied to improve the initial solution. A commercial solver is able to find feasible solutions only for instances with up to 20 stations and 7 days for the MILP model where optimality is guaranteed for instances up to 10 stations and 5 days. The heuristic, on the other hand, provides feasible solutions for the full case study of 59 stations and 14 days, within a time limit of 2 hours.

Keywords: Petrol Station Replenishment, Inventory Routing, Simultaneous Dry Run Inventory Policy, Decomposition Heuristic

Tuesday, Sept. 29, 14:45-16:15, Session: Inventory Routing 2

Distance Approximation for Dynamic Waste Collection Planning

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Abstract. Approximating the solution value of transportation problems has become more relevant in recent years, as these approximations can help to decrease the computational effort required for solving those routing problems. In this paper, we apply several regression methods to predict the total distance of the traveling salesman problem (TSP) and vehicle routing problem (VRP). We show that distance can be estimated fairly accurate using simple regression models and only a limited number of features. We use features found in scientific literature and introduce a new class of spatial features. The model is validated on a dynamic waste collection case in the city of Amsterdam, the Netherlands. We introduce a cost function that combines the travel distance and service level, and show that our model can reduce distances up to 17%, while maintaining the same service level, compared to a well-known heuristic approximation. Furthermore, we show the benefits of using approximations for combining offline learning with online or frequent optimization.

Keywords: Distance Approximation, Vehicle Routing, Inventory Routing Problem, Waste Collection

Cash Distribution Model with Safety Constraints

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Abstract. This article studies the cash distribution problem for bank correspondents that are geographically dispersed, and the associated risk indicators, service times, and logistics costs. The proposed model is a variant of the Inventory routing problem (IRP) that considers risk-management strategies. The model considers a single cash center with unlimited capacity, from which cash deliveries are carried out by a single vehicle with limited capacity for cash distribution. The bank correspondents to which the cash deliveries are made handles a limited storage capacity. This paper considers the routing decisions of vehicles with hard time windows, and risk constraints focused on inducing unpredictability of routes in a cash supply chain. The proposed model is denoted as a risk constrained inventory routing problem with time Windows (RcIRPTW). A mathematical formulation based on mixed-integer programming is proposed, studying the impact of incident risks in the transport of cash, generating computational experiments on test instances where four types of variations of the IRP are evaluated with several random demand scenarios. The results show the importance of simultaneously optimizing inventory decisions considering routing and inventory costs along with the consideration of risk mitigation strategies. These risk constraints force changing the routes of the vehicle, reducing incident rates, and reducing route predictability for secure transportation and logistics.

Keywords: Cash Distribution, Inventory Routing, Time Windows, Branch Banking, Risk Management, Currency Supply Chain

Port Operations

Tuesday, Sept. 29, 14:45-16:15

1 **A Self-Adaptive Hybrid Search Technique for Solving the Quadratic Semi-Assignment Problem**

2 **New Formulation and Solution Algorithm for the Strategic Berth Template Problem**

3 **Stowage Planning with Optimal Ballast Water**

Tuesday, Sept. 29, 14:45-16:15, Session: Port Operations

A Self-Adaptive Hybrid Search Technique for Solving the Quadratic Semi-Assignment Problem

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Abstract. The problem discussed in this presentation is related to logistics and seeks the management of different interacting services towards minimizing the delay of consumers waiting for using some of those services. These interacting services can be vehicles serving people in different places via different routes intersecting with one another, or even different kinds of movable cranes with each type of crane serving different types of ships in different multiple-pier facilities.
Some problems related to managing these interacting services can be modeled by the quadratic semi-assignment problem (QSAP), which can be considered as optimal assigning of items to sets. Interestingly, there are various logistic applications for this setting, ranging from floor layout to schedule synchronization in public transit networks [1]. For instance, the berth allocation problem, which is about the allocation of berth spaces to vessels in container terminals, with the objective of minimizing total service time is also an example [2]. In our heuristic solution strategy, an adaptive improvement technique is embedded into a genetic algorithm. In effect, all efficacious parameters of the procedure are embedded in the employed genomes and evolve while the process of problem solving continues by the procedure. For this purpose, the presented procedure represents a genome in two parts; in the first part, the allocation of each set to each item is shown, and in the second part, a governing technique is embedded. Computational experiments show that the presented procedure successfully finds the optimal solution for randomly generated 20x5 instances in less than a millisecond. These instances are the largest instances for which we

could find optimal solutions within a reasonable time of several hours, for the purpose of comparison.

Keywords: Quadratic Semi-Assignment Problem, Schedule Synchronisation, Berth Allocation Problem, Public Transit Networks, Self-Adaptive, Hybrid Methods, Genetic Algorithm

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Tuesday, Sept. 29, 14:45-16:15, Session: Port Operations

New Formulation and Solution Algorithm for the Strategic Berth Template Problem

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Abstract. The Strategic Berth Template Problem (SBTP) [1] aims at deciding which calling ships should be accepted for berthing, and determines the most appropriate berth/time allocation for the accepted incoming traffic. Specifically, the aim of the SBTP is to develop a template for the accepted ships for a cyclic time horizon. In addition to the limited number of available berths, such a template must take into account that service to a ship may start in the next cycle to the one when it arrives at the port, or that, even if service starts in the same cycle when the ship arrives, its service may terminate in the next cycle. The objective is to minimize the sum of the waiting times of the accepted ships plus a penalty for each rejected call.

We develop a new mixed-integer linear programming (MILP) formulation for the SBTP, with binary decision variables that avoid linking explicitly served ships with the berths they are allocated to. Instead, we relate served ships with their immediate predecessor in the corresponding berths. This reduces the number of binary decision variables and, particularly, the high symmetry (multiple representations of the same solution) that appears when decision variables associate ships with berths. The new formulation is reinforced with the addition of another set of indicator decision variables for the starting service times for ships. Furthermore, we develop a biased random key genetic algorithm (BRKGA) for finding good quality solutions for larger instances. Alternative decoding strategies are presented and compared.

Numerical results from computational experiments with the formulation and the solution algorithm with benchmark instances from the literature are presented and analyzed. The results of the proposed MILP, which are compared with those of [1], show its good performance, particularly in terms of the quality of the lower

bounds that it produces. The results of the BRKGA are also promising as it produces good-quality solutions in small computing times.

Keywords: Strategic Berth Template Problem, Mixed-Integer Linear Programming, Formulation, Biased Random Key, Genetic Algorithm

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Tuesday, Sept. 29, 14:45-16:15, Session: Port Operations

Stowage Planning with Optimal Ballast Water

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Abstract. Stowage planning is at the essence of a maritime supply chain, especially for short sea Ro-Ro ships. This paper studies stowage optimisation of Ro-Ro ships with a focus on stability constraints and the applicability of models. The paper contributes to short sea Ro-Ro ship stowage in two ways. First, we propose an integrated approach of designing stowage models with the consideration of loading computers to generate an optimal stowage plan which meets stability requirements by means of the weight of cargoes instead of excess ballast water, i.e. excess fuel consumption. We present a mathematical formulation of the Ro-Ro Ship Stowage Problem with Ballast Water with a discretisation method. Computational tests based on empirical data indicate significant savings and potential of model application in the real world. Preliminary results show 57.69% ballast water reduction, equivalent to 6.7% fuel savings and CO2 reduction. Additional tests on instances with various cargo weight distribution and discretisation levels are conducted, and finally, improvements are suggested for further research considerations.

Keywords: Stowage Optimisation, Ballast Water, Maritime Transportation, Environmental Impact

Warehousing & E-Commerce

Tuesday, Sept. 29, 14:45-16:15

1 **Game-Theoretic Analysis of State Interventions to Reduce Customer Returns in E-Commerce**

2 **Increasing the Practical Applicability of Order Picking Operations by Integrating Classification, Labelling and Packaging Regulations**

3 **Online Integrated Order Batching, Picker Routing and Picker Scheduling in a Warehouse**

Tuesday, Sept. 29, 14:45-16:15, Session: Warehousing & E-Commerce

Game-Theoretic Analysis of State Interventions to Reduce Customer Returns in E-Commerce

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Abstract. The constantly growing online trade offers various opportunities for companies, but is also associated with the issue of an increasing number of customer returns. Since these are both economically and ecologically problematic, policymakers are currently discussing strategies to avoid these returns and the associated disposals. In a game-theoretic model, different options of state intervention in the supply chain are investigated and compared with each other, i.e., the prohibition of disposal, the remission of value added tax on donations and a state-imposed return fee. For the resulting complex optimization problem, a solution approach is first presented to determine the Stackelberg equilibrium of the game. A comprehensive numerical analysis shows that above all the remission of the value added tax on donations as well as a state-imposed return fee for customers can lead to promising results. Nevertheless, the analysis also reveals that even without intervention in the market, members of the supply chain always have a personal interest in avoiding returns and disposal whenever possible.

Keywords: Reverse Logistics, Customer Returns, State Interventions

Tuesday, Sept. 29, 14:45-16:15, Session: Warehousing & E-Commerce

Increasing the Practical Applicability of Order Picking Operations by Integrating Classification, Labelling and Packaging Regulations

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Abstract. Warehouses play a vital role in every supply chain. The focus of warehouses is often on organising efficient and flexible order-picking systems. However, warehouse managers indicate that planning order-picking operations becomes extra complicated as they have to comply to many legislations. Warehouses in Europe are subject to the classification, labelling and packaging (CLP) regulation. Accounting for this regulation is vital in order to limit the risk of chemical reactions in the warehouse; therefore, this regulation mainly affects storage decisions. The first objective of this study is to integrate the CLP regulation in storage assignment. An integer linear programming model is developed to formulate the CLP restricted problem. The second objective is to design an efficient order-picking system by simulating different storage, batching and routing policies for a real-life warehouse subject to the CLP regulation.

Keywords: Order Picking, Storage Assignment, Simulation, Practical Factors

Online Integrated Order Batching, Picker Routing and Picker Scheduling in a Warehouse

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Abstract. Order picking is one of the most important processes in warehouses. It consists of multiple planning problems: order batching, picker routing, and picker scheduling. These problems are highly interrelated and are ideally solved in an integrated way. Research looking at the integration of all three of these problems is scarce [1]. Van Gils et al. [1] studied the integrated batching, routing, and sequencing problem (IBRSP) under the assumption that all orders are known at the start of the planning horizon. Discussions with practitioners indicated that this assumption does not always hold in a real-life setting, as urgent orders can arrive and have to be inserted in the picking schedule. Online or dynamic order batching and picker routing is thus necessary to cope with new order arrivals. However, such a setting is not yet studied for the IBRSP.

In practice, warehouses have a limited staging area, which means that only orders of a limited number of trucks can be picked at the same time. This limitation is usually ignored in the existing literature. Because space will become gradually available when finished trucks leave the warehouse, the planning horizon can be identified as a rolling horizon. Although rolling horizons are used in other research areas, e.g. aircraft scheduling, we are not aware of its application in a warehousing setting.

To fill these gaps, we propose a model and solution algorithm for the online IBRSP that uses a rolling horizon. The algorithm consists of an iterated local search (ILS), based on van Gils et al. [1]. In the literature regarding dynamic order picking problems, some authors propose a dynamic algorithm where the picklist of order pickers is modified while a picker is moving through the warehouse. This creates considerable uncertainty for the order

pickers, however, and is hard to implement in practice. Therefore, in our algorithm, optimization happens every time a picker returns to the depot. If new orders have arrived, all future order batches and picker routes can be modified, while those in progress are considered to be fixed.

We test our algorithm on realistic problem instances while taking real-life constraints into account. This way, the benefits of using online instead of static optimization can be examined in realistic settings. Moreover, the use of a rolling horizon in warehousing and related decisions, e.g. deciding on a suitable length of this horizon, are studied. This will help to bridge the gap between existing research and practice by providing a more sophisticated and realistic IBRSP solution algorithm.

Acknowledgements

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Keywords: Warehousing, Order Picking, Metaheuristics

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Exact Routing Approaches

Tuesday, Sept. 29, 16:30-18:00

1 **An Integer Programming Model for a Food Distribution Problem with Trucks and Deliverymen**

2 **An Integer Programming Approach for the Traveling Salesman Problem with Release Dates and Completion Time Minimization**

3 **A Mathematical Model to Route Technicians for Inland Waterway Shipping**

An Integer Programming Model for a Food Distribution Problem with Trucks and Deliverymen

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Abstract. This study addresses a food distribution problem that is inspired by a real problem for a company in the city of Viña del Mar, Chile. The problem consists in determining a weekly distribution plan for a set of customers scattered in an urban area. The area is divided by the company in disjoints distribution clusters. The distribution is carried out daily by trucks and deliverymen. After choosing the distribution pattern for each customer, the specific truck sequence must be determined daily, considering a limited work shift time and truck capacity. A truck starts its route in a central depot, distributes products to different distribution clusters, and returns to the same depot. It can be noticed that each cluster has a single stop point for the trucks (parking site), due to limited stopping times in urban areas. At this stop, a deliveryman starts the distribution to a customer and returns to the same parking site. A deliveryman repeats this procedure for several customers according to the programmed schedule. Note that a truck could distribute products for more than one cluster.

Currently, the distribution schedule is built intuitively by a truck dispatcher. It is observed that, in many schedules, customers that are located very close to each other are supplied by different trucks. Subsequently, more than one truck is serving, inefficiently, the same delivery zone on the same day, carrying high transportation costs and time. Furthermore, the working time of some shifts is exceeded, which generates inefficiencies in service level and problems with unions.

Due to this problem, an improvement is required to find a better feasible solution. We propose an integer programming model to

solve real instances of the problem. First, we build distribution zones, according to a proximity criterion between clients. Then, we design an integer programming model to determine efficient distribution routes. The model determines routes among the zones (visiting parking sites) and the assignment of clients to trucks according to the weekly schedule. A deliveryman delivers products in each zone, starting and ending the trip in the same parking site. The output of the model specifies the schedule of routes for each truck and the assigned clients. The objective is to minimize the total distribution time.
Notice that, our problem is an extension of the periodic vehicle routing problem (PVRP), and the vehicle routing with deliverymen (VRPDM). The PVRP consists of determining feasible routes for a set of trucks within a periodic schedule, in minimizing the total transportation cost or time (Francis et al. ,2008; Campbell and Wilson, 2014). The VRPDM consists of determining a set of routes for vehicles with deliverymen. Each vehicle travels between parking sites, where the deliverymen walk to deliver products to customers (Pureza et al., 2012; Senarclens de Grancy & Reimann, 2015). This problem does not consider the schedule of the routes within a period of time. As opposed to the PVRP or VRPDM, in our problem, we include the weekly planning in the distribution of the products to customers considering trucks and deliverymen.

Keywords: Last-mile distribution, Periodic vehicle routing problem, Integer programming

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An Integer Programming Approach for the Traveling Salesman Problem with Release Dates and Completion Time Minimization

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Abstract. In this presentation, we address the Traveling Salesman Problem with release dates and completion time minimization (TSP-rd(time)) with an exact approach. The TSP-rd(time) tackles a key operational constraint within nowadays' last-mile logistics, partly motivated by same-day and fast deliveries. The package requested by a customer is not necessarily available at the beginning of the planning horizon, capturing the timing of its arrival to the distribution center. Thus, the vehicle is allowed to perform multiple trips to the depot in order to serve all the customers. The TSP-rd(time) is formulated as a synchronization problem, and so far neglects the effect of the vehicle capacity. Variants of routing problems with release dates have only recently been introduced in the literature and applications arise in the context of cross-docking and same-day delivery problems [1].

Formally, let G=(V,A) be a complete graph with V the set of vertices and A the set edges. A traveling time is associated with each arc (i,j) in A and it is assumed that the triangle inequality holds. The set of vertices V is composed by the vertex 0 (depot) and the set N of n customers. For each customer in N, there is an associated non-negative release date. Only one uncapacitated vehicle is available. The vehicle must wait at the depot until the latest release date of the customers it is going to serve in the next route, i.e., the next trip starting and ending at the depot and not visiting the depot in between. The objective is to serve all customers minimizing the completion time, that is, the total traveling time plus the waiting-time at the depot.

In this research, we consider the mathematical formulation proposed by Archetti et al. [2] for the TSP-rd(time), which has

been successful at solving instances with up to 20 customers. We propose an alternative formulation for the TSP-rd(time) and develop an exact algorithm following a branch-and-cut scheme, including different initial heuristics. The algorithm is able to solve instances with up to 30 customers, including several unsolved instances that have been solved to proven optimality. To the best of our knowledge, our work extends the analysis of an exact approach for the TSP-rd(time), establishes a baseline for future approaches, and opens the discussion about formulations, algorithms, and benchmark instances.

Keywords: TSP with Release Dates, Integer-Linear Programming, Branch-and-Cut

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Tuesday, Sept. 29, 16:30-18:00, Session: Exact Routing Approaches

A Mathematical Model to Route Technicians for Inland Waterway Shipping

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Abstract. Consider a depot, a set of markets and a list of items. The traveling purchaser problem (TPP) consists in determining one route that satisfies the following conditions: starts and ends at the depot; contains a subset of markets where it is possible to buy all the items present in the list; and whose cost is minimal. The cost is the sum of the traveling cost, which is related to the markets, and the purchasing cost, which is associated with the items. We know the cost of traveling between each pair of nodes (depot and markets) and also the cost of purchasing each item in each market where it is available.
In the literature there are several variants of this problem. The one that we are going to address is the one described in the previous paragraph without any extra constraints. This variant is called the unrestricted traveling purchaser problem (UTPP).
Let us consider one instance of the UTPP where the number of markets is equal to the number of items and each market only sells one type of items. Therefore, in order to purchase every item from the list we have to visit all markets obtaining as a solution an hamiltonian cycle. Since the traveling salesman problem is a particular case of the TPP we can conclude that they both belong to the same class of problems, i.e., the TPP is NP-hard, hence it is very reasonable to develop heuristic methods to solve it.
We present three different metaheuristics that are composed by a genetic algorithm and a local search procedure. The local search is based on add-and-drop techniques and it is the same for all metaheuristics while the genetic algorithms are different since they are induced by several hierarchic orderings that we can establish with the two components of the TPP: the route and the

item acquisition. One of the genetic algorithms is a conventional one and the other two are biased random key genetic algorithms. We used benchmark instances, described in the literature, to evaluate the quality of the proposed metaheuristics and to verify which is the hierarchy that performs better. There are two types of instances of the UTPP available: one with an asymmetric traveling cost matrix and another with symmetric traveling costs. Although the proposed methods were specially designed and tuned for the asymmetric version, they can also be applied to the symmetric one. Concerning the asymmetric instances, the proposed metaheuristics are able to provide feasible solutions for instances which have not been solved in the literature. The results were very satisfactory since, in the majority of cases, we obtained solutions with a percentage of a gap lower than 1% within a very reasonable CPU time. Regarding the symmetric instances we consider that the results obtained were very reasonable since our metaheuristics were able to find new upper bounds for the optimal value of instances for which the optimal value is not known.

Keywords: Time-dependent Routing, Technician Carpooling, Inland Shipping

Synchromodal Transport

Tuesday, Sept. 29, 16:30-18:00

1 **Comparison of Manual and Automated Decision-Making with a Logistics Serious Game**

2 **Learning-Based Co-Planning for Improved Container, Barge and Truck Routing**

3 **Uncertainty in Intermodal and Synchromodal Transport**

Tuesday, Sept. 29, 16:30-18:00, Session: Synchromodal Transport

Comparison of Manual and Automated Decision-Making with a Logistics Serious Game

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Abstract. This paper presents a logistics serious game that describes an anticipatory planning problem for the dispatching of trucks, barges, and trains, considering uncertainty in future container arrivals. The problem setting is conceptually easy to grasp, yet difficult to solve optimally. For this problem, we deploy a variety of benchmark algorithms, including two heuristics and two reinforcement learning implementations. We use the serious game to compare the manual performance of human decision makers with those algorithms. Furthermore, the game allows humans to create their own automated planning rules, which can also be compared with the implemented algorithms and manual game play. To illustrate the potential use of the game, we report the results of three gaming sessions: with students, with job seekers, and with logistics professionals. The experimental results show that reinforcement learning typically outperforms the human decision makers, but that the top tier of humans come very close to this algorithmic performance.

Keywords: Intermodal Transport, Serious Gaming, Reinforcement Learning, Approximate Dynamic Programming, Heuristics

Tuesday, Sept. 29, 16:30-18:00, Session: Synchromodal Transport

Learning-Based Co-Planning for Improved Container, Barge and Truck Routing

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Abstract. When barges are scheduled before the demand for container transport is known, the scheduled departures may match poorly with the realised demands' due dates and with the truck utilization. Synchromodal transport enables simultaneous planning of container, truck and barge routes at the operational level. Often these decisions are taken by multiple stakeholders who want a cooperation, but are reluctant to share information. We propose a novel co-planning framework, called departure learning, where a barge operator learns what departure times perform better based on indications from the other operator. The framework is suitable for real-time implementation and thus handles uncertainties by replanning. Simulated experiment results show that co-planning has a big impact on vehicle utilization and that departure learning is a promising tool for co-planning.

Keywords: Cooperative Planning, Synchromodal Transport, Vehicle Utilization

Tuesday, Sept. 29, 16:30-18:00, Session: Synchromodal Transport

Uncertainty in Intermodal and Synchromodal Transport

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Abstract. Intermodal transport is defined as freight transport with multiple modes where goods stay in the same loading unit. Synchromodal transport is an extension of intermodal transport with synchronized operations between carriers, which enables real-time updates following unexpected events. One key barrier to a modal shift is that road transport has higher adaptability to these unexpected events, and ,therefore, remains heavily used. This research is part of the cSBO Digital twin for synchromodal transport (DISpATch) project, of which the objective is to facilitate the implementation of synchromodal transport by mitigating the lower adaptability of other transport modes. To this end, a digital twin platform will be developed, which mimics the real system in a virtual environment. This enables the simulation of decisions and to obtain the best course of action following unexpected events.

The objective of this specific study is to develop and solve optimization models that support decisions under uncertainty in a synchromodal network. First, a literature review on planning models for intermodal and synchromodal transport with uncertainty is presented. Second, a model is developed, based on a real-life case study, to support tactical and operational capacity decisions in synchromodal transport. The literature review classifies existing literature based on the planning level, which is either strategic, tactical, or operational. For each planning level, the problem types, studied uncertainties and solution methods are analyzed.

At the strategic level, mainly hub location problems are studied. Considered uncertainties at this level are stochastic demand, transit times, and hub failures. Literature at the tactical level focuses on either service network design (SND) or network flow

planning (NFP). The review shows that stochastic demand is the most studied uncertainty for SND, whereas it is the least studied for NFP. NFP problems mostly consider uncertain transit times and capacity, while capacity uncertainty is not considered for SND problems. Studies at the operational level can also be divided into two main problem types: (real-time) replanning and resource management. Considered uncertainties for replanning problems are transit times, demand, capacity, departure times, and cancellations. Resource management problems mainly examine empty container and vehicle repositioning, and demand uncertainty is the most studied.

Few studies combine different types of uncertainty or integrate multiple planning levels, which are opportunities for further research. Both are addressed in our case study, which focuses on the capacity decisions of a real-life logistics service provider (LSP) contemplating synchromodal transport. They face the problem of determining the number of train slots to book for longer periods of time when demand is still uncertain, and where short-term capacity increases are only allowed at a higher cost. A model is proposed to determine the number of slots to book at the tactical and operational levels to minimize costs. Most studies that integrate different planning levels use two-stage models, in which decisions at the first stage are based on demand predictions and the second stage occurs when demand is known. Our model extends these with an intermediate third stage when only part of the demand is known. It includes stochastic demand and unexpected disruptions which cause capacity decreases.

This work is supported by VLAIO (cSBO project DISpATch, HBC.2016.0412)

Keywords: Synchromodal, Intermodal, Transport Planning, Literature Review

Routes & Travel Times

Tuesday, Sept. 29, 16:30-18:00

1 **Evolutionary Approach for the Multi-Objective Bike Routing Problem**

2 **Travel Time Prediction using Tree-Based Ensembles**

3 **A Heuristic Algorithm for Finding Attractive Fixed-Length Circuits in Street Maps**

Tuesday, Sept. 29, 16:30-18:00, Session: Routes & Travel Times

Evolutionary Approach for the Multi-Objective Bike Routing Problem

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Abstract. In this paper, a multi-objective approach for the bike routing problem is presented. Bike routing represents specific challenges, since cyclists have different experiences, concerns, and route preferences. Our approach considers two criteria: the total traveled distance and the cyclists' safety. Finding the optimal Pareto set is computationally unfeasible for these problems; therefore, the goal of this work is to create a non-exact method capable of producing a set of quality solutions in a timely manner. A heuristic that modifies the multi-label setting algorithm is used to create an initial population and a genetic elitist algorithm is used to find an approximated Pareto set of optimal routes. The proposed methodology is applied on a practical case study, in which real data from OpenStreetMaps (OSM) and Shuttle Radar Topography Mission (SRTM) was used to model the graph for the road network of the city of Aveiro, with 9506 nodes and 21208 edges. The results show that the approach is fast enough for interactive use in a planning tool and produces a set of quality solutions, regarding two criteria, the traveled distance and the safety of the path.

Keywords: Genetic Algorithm, Bike Routing, Multi-Objective Searching Algorithm, Heuristic

Travel Time Prediction using Tree-Based Ensembles

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Abstract. In this paper, we consider the task of predicting travel times between two arbitrary points in an urban scenario. We view this problem from two temporal perspectives: long-term forecasting with a horizon of several days and short-term forecasting with a horizon of one hour. Both of these perspectives are relevant for planning tasks in the context of urban mobility and transportation services. We utilize tree-based ensemble methods that we train and evaluate on a dataset of taxi trip records from New York City. Through extensive data analysis, we identify relevant temporal and spatial features. We also engineer additional features based on weather and routing data. The latter is obtained via a routing solver operating on the road network. The computational results show that the addition of this routing data can be beneficial to the model performance. Moreover, employing different models for short and long-term prediction is useful as short-term models are better suited to mirror current traffic conditions. In fact, we show that accurate short- term predictions may be obtained with only little training data.

Keywords: Travel time Prediction, Tree-Based Ensembles, Taxi Dispatching

Tuesday, Sept. 29, 16:30-18:00, Session: Routes & Travel Times

A Heuristic Algorithm for Finding Attractive Fixed-Length Circuits in Street Maps

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Abstract. In this paper we consider the problem of determining fixed-length routes on a street map that start and end at the same location. We propose a heuristic for this problem based on finding pairs of edge-disjoint shortest paths, which can then be combined into a circuit. Various heuristics and filtering techniques are also proposed for improving the algorithm's performance.

Keywords: k-Circuit Problem, Fixed-Length Circuits, Heuristics, Graph Theory

Sustainable Transport

Wednesday, Sept. 30, 13:00-14:30

1 **A Genetic Algorithm to Minimise the Number of Vehicles in the Electric Vehicle Routing Problem**

2 **Pricing and Quality Investments in a Mixed Brown-Green Product Market**

3 **Cumulative VRP with Time Windows: a Trade-Off Analysis**

Wednesday, Sept. 30, 13:00-14:30, Session: Sustainable Transport

A Genetic Algorithm to Minimise the Number of Vehicles in the Electric Vehicle Routing Problem

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Abstract. Electric Vehicles (EVs) and charging infrastructure are starting to become commonplace in major cities around the world. For logistics providers to adopt an EV fleet, there are many factors up for consideration, such as route planning for EVs with limited travel range as well as long-term planning of fleet size. In this paper, we present a genetic algorithm to perform route planning that minimises the number of vehicles required. Specifically, we discuss the challenges on the violations of constraints in the EV routing problem (EVRP) arising from applying genetic algorithm operators. To overcome the challenges, techniques specific to addressing the infeasibility of solutions are discussed. We test our genetic algorithm against EVRP benchmarks and show that it outperforms them for most problem instances on both the number of vehicles as well as total time traveled.

Keywords: Electric vehicle routing problem, genetic algorithm, battery constrain

Wednesday, Sept. 30, 13:00-14:30, Session: Sustainable Transport

Pricing and Quality Investments in a Mixed Brown-Green Product Market

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Abstract. Sustainable Supply Chain Management (SSCM) has assumed a position of prominence for academics and industry over the last two decades. The sustainability literature shows that typically manufacturers aim to optimize their pricing and greening level decisions in a mixed (green and brown) consumer market. In this work, we capture a manufacturer's classic dilemma on the pricing of green and brown products, and greening investments, while subject to budget constraint. We compute and analyze the variations of optimal decisions over time. Our findings underscore the importance of investing in greening technologies and learning for the survival of green products. Furthermore, we show that a manufacturer's optimal pricing strategy is to enter the market with a lower price for the green product and to increase it over time, eventually surpassing the price for the brown product. Our analysis reveals that the greening level attraction can nullify the effect of a high price on the green product, resulting in higher green demand than brown. Higher green product demand is a win-win situation for both the manufacturer and the environment.

Keywords: Green Products, Pricing, Greening Level, Learning, Sustainability, Optimal Control

Wednesday, Sept. 30, 13:00-14:30, Session: Sustainable Transport

Cumulative VRP with Time Windows: a Trade-Off Analysis

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Abstract. In this work, the Cumulative Vehicle Routing Problem (CumVRP) is studied. It is a routing optimization problem, in which the objective is to construct a set of vehicle routes with the minimum cumulative cost in terms of distance and weight over a traveled arc. The CumVRP can be defined with hard and soft time windows constraints for incorporating customer service. To tackle this problem, a matheuristic approach based on combining mathematical programming and an iterative metaheuristic algorithm Greedy Randomized Adaptive Search Procedure (GRASP) is proposed. In each step of our approach, a feasible solution (set of routes) is built using GRASP, and, afterward, the solution is optimized using a MILP optimizer. The main objective of this research is to analyze the trade-off between the environmental cost produced by the delivery of goods complying with the limits of time windows and the customer's dissatisfaction when these limits are violated at a certain time limit previously defined. The results show that the environmental cost is reduced if the violation of the upper limits of the customers' time windows is allowed. These violations generate a cost associated with penalties that are well balanced with respect to the reduction of emissions.

Keywords: Cumulative Vehicle Routing Problem, Green VRP, Time Windows, Matheuristic, GRASP, MILP

Uncertainty in Freight Transport

Wednesday, Sept. 30, 13:00-14:30

1 **Fair User Equilibrium in a Transportation Space-Time Network**

2 **Simulation Approach for Container Assignment under Uncertainty**

3 **Robust Optimization for Premarshalling with Uncertain Priority Classes**

Wednesday, Sept. 30, 13:00-14:30, Session: Uncertainty in Freight Transport

Fair User Equilibrium in a Transportation Space-Time Network

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Abstract. Central in this paper is a transportation network, in which containers are transported for multiple agents. This network is modelled by a Space Time Network, in which the travel time of modalities is fixed and independent of the occupancy of the network. To find the best allocation of containers to paths in this network, a flow problem can be solved. The System Optimal solution found then is the solution in which the total costs of the network are minimised. This paper introduces the idea of a fair User Equilibrium solution for such a problem. The proposed approach changes the network, using a toll scheme, such that the fair User Equilibrium Solution in this changed network equals the System Optimal solution in the original network. This can be used to fairly redistribute the cost of the network among the users.

Keywords: User Equilibrium, System Optimal Solution, Space Time Network, Intermodal and Synchromodal Transport

Wednesday, Sept. 30, 13:00-14:30, Session: Uncertainty in Freight Transport

Simulation Approach for Container Assignment under Uncertainty

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Abstract. In this paper an online optimisation approach is proposed which can be used to find an appropriate combined schedule and container assignment in a Network Design Problem under uncertainty. For this, a simulation-based approach on a multi-period time window is proposed, moving forward on the time window after each decision, assuming that the status of the system is updated as soon as the stochastic and unknown elements become deterministic and known. This approach provides new insight and knowledge into synchromodal and multimodal planning problems. The results of the approach are compared to the results of three simpler online optimisation methods and to the solution of the offline approach where all information is known.

Keywords: Intermodal Transport, Synchromodal Transport, Online Optimisation, Multi-Period Time Window, Simulation Algorithm

Wednesday, Sept. 30, 13:00-14:30, Session: Uncertainty in Freight Transport

Robust Optimization for Premarshalling with Uncertain Priority Classes

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Abstract. In this presentation, we consider an uncertain variant of the premarshalling problem (PMP), where items in a storage area of stacks have to be sorted for convenient retrieval (e.g., in container terminals and ships, warehouses or tram depots). Thus, the PMP is an upstream problem stage before the so-called "blocks relocation problem" (BRP) where each item has an associated priority value related to its (estimated) retrieval time and the items have to be retrieved in the priority order. Usually, the objective is to minimize the number of relocations. However in the PMP, the items also have priority values, but the items are moved inside the storage so that they can be retrieved without relocations later in the BRP.

We introduce a robust variant of the PMP where the priority values of the items are not exactly known. Our setting is motivated by the real-world situation in container terminals where containers are stored and later loaded onto ships or trucks. For each item, its estimated retrieval time is derived from the expected arrival time of the corresponding ship or truck which may be affected by different uncertainties. In this situation, a solution of the deterministic PMP may cause additional relocations since items with earlier departure times may be stored below items which are now retrieved later due to delays.

For the deterministic PMP and BRP, many papers have been published in recent years while the robust PMP is considered only in two publications. Rendl and Prandtstetter (2013) assumed intervals of possible (uncertain) priority values which are conflicting if they overlap. A constraint programming formulation is proposed solving only small instances that can be sorted without any conflicts. Tierney and Voß (2016) considered a more general

concept of a "blocking matrix" indicating item conflicts. An adapted IDA* algorithm is applied to instances with interval uncertainties to find solutions without any conflicts.
In our model, we assume that a limited number of elements in the retrieval sequence may be swapped. In contrast to previous approaches, we do not only focus on solutions without any conflicts, but compute robust solutions aiming at reducing the retrieval effort. We analyze the complexity of the robust problem and give analytical criteria when a solution without any conflicts exists. We further present different mixed-integer programming formulations that are able to determine the best possible configuration for a container storage in a robust setting. Moreover, we adapted a state-of-the-art IDA*-Algorithm from the literature that achieves such a configuration with a minimal number of relocations. In a computational study using a wide range of benchmark instances from the literature, we consider the computational effort to calculate robust solutions, evaluate the strength of the analytical existence criteria, and highlight the advantages (robustness) and disadvantages (additional relocations) of using our robust solutions.

Keywords: Logistics, Premarshalling, Robust Optimization, Storage, Container Shipping, Exact Algorithms, Mixed-Integer Programms, A* Algorithm, Complexity Results

Markov Decision Processes

Wednesday, Sept. 30, 13:00-14:30

1 **Dynamic Programming for the Time-Dependent Traveling Salesman Problem with Time Windows**

2 **Sending E-Commerce Returns straight to the Next Customer with MCTS and ADP**

3 **Deep Reinforcement Learning and Optimization Approach for Multi-Echelon Supply Chain with Uncertain Demands**

Dynamic Programming for the Time-Dependent Traveling Salesman Problem with Time Windows

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Abstract. The recent growth of direct-to-consumer deliveries has stressed the importance of last-mile logistics, becoming one of the critical factors in city planning. According to different studies, one of the key factors lies in the last-mile deliveries, reaching in some cases nearly 50% of the overall parcel delivery cost. Accounting effectively for the effects of congestion at the planning level results in more accurate distributions plans.

The Time-Dependent Traveling Salesman Problem with Time Windows (TDTSPTW) is a variant of the well-known Traveling Salesman Problem with Time Windows (TSPTW) in which travel times are not assumed to be constant. The TDTSPTW accounts for the effects of congestion at the planning level, being particularly suited for distribution problems in large cities. In this presentation, we consider the model proposed in [2] where travel times for each arc are not constant, and instead are modeled as a continuous piecewise linear function satisfying the FIFO condition. Thus, an effective approach for the TDTSPTW must handle efficiently travel times defined by functions instead of its time-independent counterpart, where they are assumed to remain constant along the planning horizon.

Our contributions are both algorithmic and methodological. Specifically: i) we propose a labeling-based algorithm for the TDTSPTW that adapts state-of-the-art features from the related (time-independent) literature (see, e.g., [4]) to the time-dependent context; ii) we propose a new relaxation specifically designed for the time-dependent context; iii) we conduct extensive computational experiments that show the effectiveness of the

overall approach and the impact of the new relaxation. In particular, the results show that our approach outperforms recent ILP-based methods for the TDTSPTW proposed by [1,3,5] as well as the one developed in [4] for the Minimum Tour Duration Problem.

Keywords: Traveling Salesman Problem, Time-Dependent Travel Times, Time Windows, Dynamic Programming, State-Space Relaxation

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Sending E-Commerce Returns straight to the Next Customer with MCTS and ADP

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Abstract. Free-of-charge product return is the new normal. To customers, it brings the dressing room to one's home. They witnessed how the service evolved from differentiator to industry-standard in a few years. To e-commerce retailers, it brings both extra sales as well as extra logistic costs and the need for mature return logistics. To society, it brings additional CO2 emissions and traffic movement. Retailers turn to preventive measures to temper return volumes, e.g. improved size advisors, digital fitting rooms, and fitting apps. These solutions are pre-purchase focussed. We modeled a post-purchase solution. We offer the returning customer an alternative for a shipment to the e-commerce retailer; a shipment directly to the next customer. We call it Customer to Customer (C2C) Return Logistics and used real-time sales data to validate a potential annual reduction in return logistics cost of up to 10%. When returning an item, the customer is asked to keep the return for a pre-determined number of days. During those days, the item is promoted on the retailer's website with a discount and the saved CO2 emission. When sold, the returning customer gets a notification to ship the package. A provided QR label goes over the returning customer's address and links to the new customer's address. Payments and refunds are still handled by the retailer. The new customer inspects the item upon receipt and gives a review. Motivators to the returning customer are loyalty program perks upon good reviews and contributing to less CO2 emissions.
We mathematically model and test this innovative concept in various scenarios, using optimization techniques and simulation. First, we formulate the C2C concept as a Markov Decision Process (MDP), in which decisions need to be made on the level of discount to offer to the customers. The outcomes are applied in a simulation sample-path to capture the financial prospects of the

C2C concept, for various levels of product demand volumes, return rates, customer participation scenarios and other model variables, based on the real-time sales data of a Dutch fashion retailer. The MDP quickly becomes too large to solve it in an exact way by using, for example, Dynamic Programming (DP). Two methods are used to tackle this issue, called Monte Carlo Tree Search (MCTS) and Approximate Dynamic Programming (ADP), arising from two different scientific fields, respectively Artificial Intelligence (AI) and Operations Research (OR). Both have interacted and intertwined their work on MDPs over the last decades. We compare both methods, based on implementation, performance, and running times, on the same use case. Interestingly, both methods combine the Bellman equations with simulation to find near-to optimal policies, and although certain aspects of the methods are comparable, they work in a substantially different way. Therefore, both methods have various advantages and disadvantages in their implementation.

Keywords: Return Logistics, E-Commerce, Innovation, Markov Decision Process

Wednesday, Sept. 30, 13:00-14:30, Session: Markov Decision Processes

Deep Reinforcement Learning and Optimization Approach for Multi-Echelon Supply Chain with Uncertain Demands

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Abstract. Deep Reinforcement Learning (RL) has been used recently in many areas achieving successful results. A multi-period supply chain operation can be viewed as a sequential decision-making problem for which Deep RL may be appropriate. Previous uses of such approach on related problems consider only serial or two-echelon supply chains with limited decision possibilities. In this research, a four-echelon supply chain with two nodes per echelon and stochastic customer demands is considered. An MDP formulation and a Non-Linear Programming model of the problem are presented. Proximal Policy Optimization (PPO2) is used in order to find a good policy to operate the entire supply chain and minimize total operating costs. An agent based on a linearized model is used as a baseline. Experimental results indicate that PPO2 is a suitable and competitive approach for the proposed problem.

Keywords: Multi-Echelon Supply Chain, Stochastic Demands Deep Reinforcement Learning, Proximal Policy Optimization

Plenary Talk II:

Container Transport: Innovative Practices meet Academic Discourse

Prof. Rob Zuidwijk

Abstract. The international transport of maritime containers employs multiple transport means, such as deep-sea vessels and trucks, or alternatively river barges and train sets. The planning and execution of combined transport operations is challenging, since resources are to be orchestrated efficiently while delivery of service must be reliable.To address these challenges, the port of Rotterdam and its hinterland have become a living laboratory, where practitioners are performing pilot studies and academics develop new methods to put innovative logistics concepts to the test. In the presentation, I will discuss how Synchromodal transport solutions offer mobility of freight instead of specific transport capacity. Containers that need to be transported are matched with transport options in a dynamic way. Practitioners have demonstrated the feasibility of the concept, while academics have elaborated on various decision models in support of e.g. network design, capacity planning, and routing. The living lab now progressively involves new modes of transport, such as semi-automated trucks that dynamically form platoons where consolidation is viable. Advanced planning concepts, where multiple modes of transport are involved, tend to be more data-intensive. However, the transportation industry is progressively recognizing the value of data as a strategic asset, not to be shared without compensation. Therefore, a proper understanding of what data is needed to enhance quality of planning is key. In some cases, a marginal improvement of data quality may already help create better prognostics and planning. In this vein, academics have been able to feed their methods and insights back to practitioners. As such, container transport connects innovative practices and academic discourse.

Fleets, Vehicles & Transfers

Wednesday, Sept. 30, 16:00-17:30

1 **The Fleet Scheduling Problem for Airlines with Stochastic Passenger Demands: Mathematical Modelling and a Genetic Algorithm Approach**

2 **Vehicle Routing with Time Windows and Stochastic Demands: a Case Study**

3 **A Shortest Path Algorithm for Graphs Featuring Transfer Costs at their Vertices**

The Fleet Scheduling Problem for Airlines with Stochastic Passenger Demands: Mathematical Modelling and a Genetic Algorithm Approach

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Abstract. An important problem that airlines are faced with is the assignment of their available fleet to a set of flight legs. This work focuses on providing an appropriate flight schedule for the aircraft of an airline leading to a small total operation cost. In this problem, there is a set of flights to be operated by a given fleet of aircraft and a set of airports which can be the origin or destination of the flights. A major difference with previous works is that in this work each aircraft is considered as a separate unit. This is due to the fact that in the real world even two aircrafts of the same size can be different in specifications and operation costs. To be more realistic, the passenger demand for each flight leg is assumed to be stochastic and follows a probability distribution. This is a symmetric distribution having its maximum at the average value and two minimums; one at the minimum and one at the maximum value.

We aim at applying a stochastic optimisation approach to the problem. First, a new mixed-integer linear mathematical model is developed for the problem. This model is coded in the GAMS platform and the exact solution process is carried out by the GUROBI solver. Random instances are generated in small to large sizes including 10 aircrafts and 50 flights to 200 aircrafts and 1000 flights. Given the long computation times, a genetic algorithm (GA) is designed to obtain good quality solutions in real-time. This GA includes some novel strategies for encoding the solutions, selection, crossover, mutation as well as handling the constraints. The Response Surface Method (RSM) is used to set the initial

parameters of our GA such as the population size, the mutation rate, the crossover rate and etc.
The performance of the proposed GA is evaluated against the results given by our exact solver within a time limit of one hour in terms of the objective values and the computational times. A non-parametric statistical test is executed to compare the results of these two methods. The analyses confirm that except for the smallest size, the GA can provide solutions of better quality in much shorter computation times.

Keywords: Airline Fleet Scheduling, Stochastic Passenger Demand, Mathematical Modelling, Genetic Algorithm

Vehicle Routing with Time Windows and Stochastic Demands: a Case Study

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Abstract. Vehicle routing problems have already been widely studied in the literature. However, the focus is mainly on deterministic problem variants where all input parameters are assumed to be known in advance (Oyola et al., 2018). Yet, different forms of uncertainty can be observed in real life, such as uncertainty in travel times, customers, service times, and demand. Stochastic problems assume that only a probability distribution is known on these uncertain parameters.

This study focuses on the VRP with time windows and stochastic demands. The problem under consideration is based on a real-life problem faced by a logistics service provider who provides personalized and integrated transport and logistics solutions across Europe. One of the problems the company is facing is that there are often deviations between the specified quantities by the customers and the actual quantities when arriving at the customer, which makes it difficult to make a reliable planning. Stochastic demands can result in an inefficient use of vehicle capacity or capacity shortages, leading to costly corrective actions when executing planned collection routes. This study quantifies the importance of this problem.

As common in literature, a two-stage stochastic programming with recourse method is applied to model the problem. This approach treats the problem in two stages. The focus is on the initial phase, where a first-stage solution is planned, based on planned routing costs and expected recourse costs for corrective actions. Decisions must be taken here based on stochastic information. However, route failures can occur when executing the planned routes and actual customer demands are revealed. These route failures can

occur at different positions in a planned route, each with a certain probability of occurring. When a route failure occurs, a corrective action (recourse) can be taken in the second stage. Different recourse policies exist such as detour to the depot, preventive restocking, and re-optimization (Oyola et al., 2018). The detour to depot recourse policy is used in this study and is mostly used in literature (Erera et al., 2010). In this policy, the vehicle returns to the depot to (un)load when a failure occurs. Afterward, it resumes its route as planned, restarting at the customer where the route failure occurred.

This study extends the state of the art by including the effect of expected violations of time windows, maximum route duration, and other time-related constraints into the recourse cost function. An iterated local search algorithm is presented to solve the problem. Moreover, different learning techniques are used and compared to estimate the probabilities of failure at every customer in a route from real-life historic data. Different widths of time windows are included in the experiments as well, since they have an effect on the construction of the routes and the recourse cost. Experimental results demonstrate that both operational costs and time window violations can be reduced by taking the expected cost of corrective actions into account when planning the routes. In some cases, different routes are constructed when the expected cost of corrective actions is not included initially in the planning compared to the first-stage planning. However, in general, this leads to higher recourse costs subsequently.

This work is supported by Data-driven logistics (FWO-S007318N).

Keywords: Stochastic vehicle routing, Stochastic demands, Two-stage stochastic programming with recourse method

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Wednesday, Sept. 30, 16:00-17:30, Session: Fleets, Vehicles & Transfers

A Shortest Path Algorithm for Graphs Featuring Transfer Costs at their Vertices

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Abstract. This paper examines the problem of finding shortest paths in graphs that feature additional penalties -- transfer costs -- at their vertices. We propose a shortest path algorithm that can cope with these additional penalties without the need of first performing a graph expansion, which is the typical algorithmic strategy. While our method exhibits an inferior growth rate compared to existing approaches, we show that it is more efficient on sparse graphs.

Keywords: Transportation, Shortest Paths, Dijkstra's Algorithm, Transfer Costs

Intermodal Transport

Wednesday, Sept. 30, 16:00-17:30

1 A Global Intermodal Shipment Matching Problem under Travel Time Uncertainty

2 Towards Self-Organized Logistics in the Last-Mile Container Hinterland Transportation: a Case Study in The Netherlands

3 Cutting Planes for Solving Logistic Flow Problems

Wednesday, Sept. 30, 16:00-17:30, Session: Intermodal Transport

A Global Intermodal Shipment Matching Problem under Travel Time Uncertainty

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Abstract. Global intermodal transportation involves the movement of shipments between inland terminals located in different continents by using ships, barges, trains, trucks, or any combination among them through integrated planning at a network level. One of the challenges faced by global operators is the matching of shipment requests with transport services in an integrated global network. The characteristics of the global intermodal shipment matching problem include acceptance and matching decisions, soft time windows, capacitated services, and transshipments between multimodal services. The objective of the problem is to maximize the total profits which consist of revenues, travel costs, transfer costs, storage costs, delay costs, and carbon tax. Travel time uncertainty has significant effects on the feasibility and profitability of matching plans. However, travel time uncertainty has not been considered in global intermodal transport yet leading to significant delays and infeasible transshipments. To fill in this gap, this paper proposes a chance-constrained programming model in which travel times are assumed stochastic. We conduct numerical experiments to validate the performance of the stochastic model in comparison to a deterministic model and a robust model. The experiment results show that the stochastic model outperforms the benchmarks in total profits.

Keywords: Global Intermodal Transportation, Shipment Matching Problem, Travel Time Uncertainty, Chance-Constrained Programming

Wednesday, Sept. 30, 16:00-17:30, Session: Intermodal Transport

Towards Self-Organized Logistics in the Last-Mile Container Hinterland Transportation: a Case Study in The Netherlands

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Abstract. This presentation focuses on the impact of different levels of self-organization on the last-mile transport of containers in hinterland logistics. Currently, the assignment of containers to trucks is executed manually by human planners in a centralized decision-making environment. However, many assignments are easy to make and do not require human evaluation. Due to various limitations in this decision-making process, the planning is often sub-optimal and unable to adapt to unexpected changes. Furthermore, due to an increasing trend in volumes, the logistics sector is facing challenges to remain competitive.

This study focuses on the collaboration of centralized and decentralized decision-making in scheduling activities. A multi-agent system is designed, where containers and trucks are represented as agents. Using sensors and local communication protocols (e.g., LoRa), real-time data are retrieved by the agents and can be shared with neighboring agents. This local, decentralized approach enables agents to schedule transports cooperatively, with little to no human involvement, and may provide more flexibility to respond to unexpected situations more quickly.

The decentralized scheduling works as follows: a container agent, requesting a pick-up, spreads a 'scent' (a certain radius around its current location), which the truck agents can 'smell', triggering bilateral communication to activate an auction bidding mechanism. Available trucks make bids on neighboring available containers. Containers communicate whether a truck has won the auction and should be directed to the container. Both agents

evaluate continuously whether new better bids are placed from new arriving agents in the neighborhood, which can overrule a current assignment. Moreover, each container has a (time-dependent) urgency level (e.g., related to the latest allowed arrival time). This urgency level should coordinate the timely pickup and delivery of all containers in the system and regulates the nervousness of reallocating containers to other agents.
The key topic of this presentation is to research the opportunities of this approach and how various levels of self-organization may improve the last-mile logistics process. To improve the current manually-planned situation, different scenarios are developed which have different levels of self-organization (i.e., degrees of human involvement). Human planners should focus on the more complex assignments and the more logical assignments should be delegated to a self-organized decision-making system. A complex situation occurs when there are multiple good assignments or no possible assignments for urgent transports. To which extent the decisions should be delegated is studied using an agent-based simulation model.

Keywords: Self-Organization, Container Hinterland, Logistics, Last-Mile, Agent-Based Simulation

Wednesday, Sept. 30, 16:00-17:30, Session: Intermodal Transport

Cutting Planes for Solving Logistic Flow Problems

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Abstract. In logistic problems, an Integral Multi-Commodity Network Design Problem on a time-space network is often used to model the problem of routing transportation means and assigning freight units to those means. In Physical Internet and Synchromodal networks an interactive planning approach is preferable, meaning that calculation times of a single planning step should be short. In this paper we provide ways to reduce the size of the problem formulation based on cutting planes, that are effective in reducing the computation time for Integer Linear Programming problem-based solution methods.

Keywords: Logistic Space Time Network, Logistic Flow Routing, Synchromodality, Cutting Planes Techniques

Bin Packing

Wednesday, Sept. 30, 16:00-17:30

1 **A Bin Packing Problem with Mixing Constraints for Containerizing Items for Logistics Service Providers**

2 **Reactive GRASP-based Algorithm for Pallet Building Problem with Visibility and Contiguity Constraints**

3 **A Solution Approach to the Problem of Nesting Rectangles with Arbitrary Rotations into Containers of Irregular Convex and Non-Convex Shapes**

A Bin Packing Problem with Mixing Constraints for Containerizing Items for Logistics Service Providers

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Abstract. Large logistics service providers often need to containerize and route thousands or millions of items per year. In practice, companies specify business rules of how to pack and transport items from their origin to destination. Handling and respecting those business rules manually is a complex and time-consuming task. We propose a variant of the variable-sized bin packing problem applicable to the containerization process occurring at logistics service providers. This novel model variant extends the bin packing problem with color constraints by adding multiple item mixing constraints. We present a binary integer program along with a first-fit decreasing heuristic and compare the performance on instances from a global logistics service provider. The numerical results indicate promising results to solve this computationally hard combinatorial optimization problem.

Keywords: Load Planning Problem, Variable-Sized Bin Packing with Color Constraints, Variable-Sized Bin Packing with Multiple-Item-Mixing Constraints

Wednesday, Sept. 30, 16:00-17:30, Session: Bin Packing

Reactive GRASP-based Algorithm for Pallet Building Problem with Visibility and Contiguity Constraints

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Abstract. In this paper, we study a pallet building problem that originates from a case study in a company that produces robotized systems for freight transportation and logistics. The problem takes into account well-known constraints, such as rotation and stackability, and other specific constraints, such as visibility and contiguity among items belonging to the same family. We formalize the problem and then solve it by means of a GRASP metaheuristic. The algorithm is based on an Extreme Points heuristic and a reactive mechanism. It uses a two-step strategy, in which items are first grouped into horizontal layers, and then layers are stacked one over the other to form pallets. The performance of the algorithm is assessed through extensive computational tests on real-world instances. The results show that the GRASP is able to create very compact packings for most of the instances with a limited computational effort.

Keywords: Pallet Building Problem, Practical Constraints, Two-Step Heuristic, Reactive GRASP, Real-World Instances

Wednesday, Sept. 30, 16:00-17:30, Session: Bin Packing

A Solution Approach to the Problem of Nesting Rectangles with Arbitrary Rotations into Containers of Irregular Convex and Non-Convex Shapes

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Abstract. This paper introduces the problem of nesting rectangles, without overlapping, into containers of irregular shapes, in order to maximize the number of items positioned. This problem occurs in tasks of loading steel sheets into empty spaces of partially occupied ship's cargo hold. This is a NP-hard problem. We present a solution approach to this problem based on the search over sequences, which are decoded by a bottom-left constructive method, and we use the Iterated Local Search metaheuristic to escape local minima. The neighborhood structure is defined by variations in the rotation of the rectangles. Non-regularized Boolean operations are used by the constructive method to compute collision-free regions. The results indicate the reliability of the proposed approach.

Keywords: Nesting Problems, Combinatorial Optimization, Heuristic Search