Book of Abstracts

13th Logistics Management Conference

September 13th-14th, 2023
Dresden

Preface

This book of abstracts contains information about the 13th conference Logistics Management (LM 2023) of the Scientific Commission for Logistics (WK-LOG) of the German Academic Association for Business Research (VHB). The LM conference series is continued every two years at different places in Germany. It aims at providing a forum for scientists and practitioners in business administration, IT, and industrial engineering to present and discuss new ideas and technical developments related to the management of logistics systems. LM 2023 is hosted by the Technische Universität Dresden. Previous LM conferences were held in Bremen (1999, 2013), Aachen (2001), Braunschweig (2003, 2015), Dresden (2005, 2021 - online), Regensburg (2007), Hamburg (2009), Bamberg (2011), Stuttgart (2017), and Halle (Saale) (2019). For this coneference LM 2023, we have invited two keynote speakers to examine ongoing developments in the area of logistics management:

- Mike Hewitt (Loyola University Chicago)
- Helmut Prieschenk (WITRON Logistik + Informatik GmbH)

In addition to the keynote talks, 39 presentations were given at LM 2023, of which 13 are printed as full papers in the proceedings as part of the book series Lecture Notes in Logistics. These papers have been selected in a careful review process involving two referees for each paper in up to three rounds of revision. The accepted full papers address a broad spectrum of facets of logistic systems with regard to digitalization, sustainability, and optimization. We hope that the contributions to LM 2023 provide new insights into the state of the art of logistics management and, thus, stimulate future research.

Dresden,
September 2023

Udo Buscher
Rainer Lasch
Janis Neufeld
Jörn Schönberger

Acknowledgements

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Prof. Dr. Christian Bierwirth, Martin-Luther-Universität Halle-Wittenberg
Jun.-Prof. Dr. Tristan Becker, Technische Universität Dresden
Prof. Dr. Ronald Bogaschewsky, Julius-Maximilians-Universität Würzburg
Prof. Dr. Udo Buscher, Technische Universität Dresden
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Prof. Dr. Guido Voigt, Universität Hamburg
Prof. Dr. Carl Marcus Wallenburg, WHU – Otto Beisheim School of Management

Session Overview - Scientific Program

Wednesday 13.09.2023 - Part I			
12:00 - 13:00	M-A: Arrival & Lunch *5th Floor, HÜL-N*		
13:00 - 13:15	M-B: Opening Ceremony R. Lasch *Wiwi-Festsaal Faculty of Business and Economics*		
13:15 - 14:45	M-C-1: SC Management C. Thies *Wiwi-Festsaal*	M-C-2: Transportation 1 K. Fischer *H-S386*	M-C-3: SC Operations 1 E. Pesch *H-S186*
	Analyse der Ursachen von Fehlmengen und Überbeständen in Supply Chains – Ein systemdynamisches Modell *L. Wöhlert*	Robots at your service: covering the last mile in omnichannel retail *T. Huf, M. Ostermeier*	Solving Real-world Order Batching Problems in Manual Order Picking Systems Using Variable Neighborhood Search *S. Wagner, L. Mönch*
	Engineering Change Management – A Case Study on IT, Processual, and Organizational Requirement *T. Gollmannn, R. Gangel, T. Gruchmann*	A Pareto-optimization model for economic and ecological intermodal freight transportation planning with transshipments, terminal uncertainties, and product value applications *A. Rudi, F. Schultmann*	A Dirty Little Secret? Conducting a Systematic Literature Review Regarding Overstocks *B. Asdecker, M. Tscherner, N. Kurringer, V. Felch*
	The effect of weather for flight on-time-performance *A. Lange*	Potentials of automated public transport in rural areas *T. Alscher*	A comparison of alternative approaches to zoning and item-to-zone assignment in pick-and-passorder picking systems *R. Gössinger, R. Thelen*
14:45 - 15:15	M-D: Coffee Break *5th Floor, HÜL-N*		
15:15 - 16:15	M-F: Keynote 1 Consolidation-Based Modeling for the Scheduled Service Network Design Problem M. Hewitt *Wiwi-Festsaal Faculty of Business and Economics*		
16:15 - 16:30	M-D: Coffee Break *5th Floor, HÜL-N*		

* presentations held in German are indicated by

Wednesday 13.09.2023 - Part II		
16:30 - 18:00	M-G-1: Network Design J. Dethloff *Wiwi-Festsaal*	M-G-2: Parcel Logistics E. Sucky *H-S386*
	Dynamic Service Network Design *A. Bode, M. Hewitt, D. Mattfeld, M. Ulmer*	Planning parcel deliveries with outbound and-inbound demands and heterogeneous parcel lockers *B.A. Neumann Saavedra*
	Planning of CO2 Pipeline Networks under Uncertainty with Extended Scenario Analysis *S. Bogs, A. Abdelshafy, C. Yeates, G. Walther*	A Heuristic for Planning Mobile Parcel Locker Operations with Individual Customer Service *R. Kötschau, N. Soeffker, J.F. Ehmke*
	Designing Pipeline Networks for Carbon Capture and Storage of CO2-sources in Germany: An Industry Perspective *A. Bennæs, M. Skogset, T. Svorkdal, K. Fagerholt, L. Herlicka, F. Meisel, W. Rickels*	Locker Box Location Planning Under Uncertainty in Demand and Capacity Availability *M. Gansterer, S. Mancini, C. Triki*
18:15 - 19:30	M-H: Messting of the WK Logistik A. Lange, F. Meisel *Wiwi-Festsaal Faculty of Business and Economics*	
20:00 - 22:30	M-I: Social Event Dinner at the Feldschlösschen Stammhaus *Feldschlösschen Stammhaus (Budapester Str. 32 - 01069 Dresden)*	

Thursday 14.09.2023 - Part I		
08:30 - 10:00	D-A-1: Hydrogen SC R. Lasch *Wiwi-Festsaal*	D-A-2: Transportation 2 J.O. Schönberger *H-S386*
	Pricing and Greening Level Decisions in a Two-Stage Hydrogen Supply Chain Considering State Subsidies and Taxes *M. Beranek, A. Schütze, U. Buscher*	How Autonomous Vehicles Shape LSP Business Models *K. Horvat, A. Lange*
	Green Hydrogen Supply Chains in Latin America – A Research Approach for Partnership Projects with Europe *S.G. Suarez, T. Witt, N. Schlauch, M. Klumpp*	Import Diversification in the Transport Network Design for Green Hydrogen *L.V. Sroka, F. Meisel*
	Evaluation of hydrogen supply options for sustainable aviation *K. Ohmstede, C. Thies, A. Barke, T.S. Spengler*	The interdisciplinary research of innovations in intermodal rail freight transportation – How does research address innovations? *R. Elbert, R. Hackober, J. Monios, A. Mahfouz, R. Bergqvist, G. Stefansson*
10:00 - 10:30	D-B: Coffee Break *5th Floor, HÜL-N*	
10:30 - 12:00	D-C-1: Transportation 3 D. Mattfeld *Wiwi-Festsaal*	D-C-2: SC Operations 2 J.S. Neufeld *H-S386*
	Development of heterogeneous rail supply chain strategies for international rail transport *J. Shan, J. Schönberger*	Integration of additive manufacturing – the perspective of logistics service providers *R. Pergande, A. Bade, R. Lasch*
	Data-driven identification and quantification of influencing factors for robust planning in rail passenger transport *S. Hocke, J.S. Neufeld, L.A. Wesselink, U. Buscher, K. Hainrich*	Enhancing E-Commerce Fulfillment Operations: Machine Learning Approaches for Order Forecasting and Cost Reduction *L.A. Baunach, S. Spinler*
	Succes factors for implementing a sustainable strategy in the transport infrastructure sector - Best-practices analyses of European transport infrastructure companies *S. Knöchel*	An approach to optimization-based order release in engineer-to-order systems – model derivation and performance evaluation *R. Gössinger, J. Philips*
12:00 - 13:30	D-D: Lunch *5th Floor, HÜL-N*	
13:30 - 14:25	D-E: Keynote 2 Multi-dimensionale Lager- und Distributionslogistik im Lebensmitteleinzelhandel H. Prieschenk *Wiwi-Festsaal Faculty of Business and Economics*	

Thursday 14.09.2023 - Part II		
14:25 - 14:30	D-F: Prospects LM 2025 A. Lange *Wiwi-Festsaal Faculty of Business and Economics*	
14:30 - 14:45	D-G: Coffee Break *5th Floor, HÜL-N*	
14:45 - 16:15	D-H-1: SC Operations 3 M. Wichmann *Wiwi-Festsaal*	D-H-2: Transportation 4 A. Hübner *H-S386*
	Energy-Efficient Production Scheduling: Insides from Academia and Practice *D. Dolch, R. Lasch*	Train Load Planning for Intermodal Rail Operators in a Hub-and-Spoke Network *E. Ralf, Y. Tang*
	Carbon-efficient scheduling in distributed permutation flow shops - An analysis of cause-effect- relationships *M. Schönheit*	Operations of container shipping alliances *N. Podichetty, A. Lange*
	Lot Streaming in Hybrid Flow Shop Manufacturing Systems *J. Neufeld, S. Maecker, L. Shen, R. Ruiz, U. Buscher*	Collaboration Benefits in Port Hinterland Transportation *N. Rückert, K. Fischer, P. Reinecke, T. Wrona*
16:15 - 16:30	D-I: Coffee Break *5th Floor, HÜL-N*	
16:30 - 18:00	D-J-1: SC Operations 4 U. Buscher *Wiwi-Festsaal*	D-J-2: Urban Logistics M. Gansterer *H-S386*
	The order and rack sequencing problem in robotic mobile fulfillment systems *E. Pesch, J.-E. Justkowiak*	Urban Mobility and Logistics - Past, Present, and Future *C. Cleophas, F. Meisel*
	Communities of Practice in Purchasing Management – Evidence on motivators for participation and usage among purchasing managers *A.L. Simonovic*	Planning of Large-Scale Car-Free Zones *V. Stadnichuk, M. Schiffer, G. Walther*
	The Impact of Consumer Picking on Food Waste: A Data-driven Approach *A. Hübner, T. Winkler, F. Schäfer, K. Hoberg*	Combining multiple delivery systems for urban logistics by ALNS-based route planning *B. Himstedt, F. Meisel*
19:30 - 23:00	D-K: Social Event Conference Dinner in the Carolaschlösschen *Carolaschlösschen (Querallee 7, 01219 Dresden)*	

Keynote talks

Two keynote talks will be given. The keynote sessions are scheduled for 60 minutes including 10-15 minutes of discussion.

- Wednesday 13.09.2023, 15:15-16:15, Wiwi-Festsaal Faculty of Economics
  Link: *Keynote 1 - LM 2023*

  Prof. Mike Hewitt (Loyola University Chicago, United States of America)
  Consolidation-Based Modeling for the Scheduled Service Network Design Problem
  Chair: Udo Buscher

- Thursday 14.09.2023, 13:30-14:25, Wiwi-Festsaal Faculty of Economics
  Link: *Keynote 2 - LM 2023*

  Helmut Prieschenk (WITRON Logistik + Informatik GmbH) 
  Multi-dimensionale Lager- und Distributionslogistik im Lebensmitteleinzelhandel
  Chair: Udo Buscher

Contributed Talks

The contributed talks to the conference are gouped by subject into seven thematic streams:

- Supply Chain Management
- Transportation
- Supply Chain Operations
- Network Design
- Parcel Logistics
- Hydrogen Supply Chain
- Urban Logistics

Contributed talks are presented in parallel sessions, each session respectively consisting of three individual talks.They should be no longer than 25 minutes to allow a short discussion after each talk. Talks annoted with the german flag will be held in german.

Supply Chain Management

Session M-C-1 SCM:
Wednesday 13.09.2023, 13:15-14:45, Wiwi-Festsaal Faculty of Economics
Link: *M-C-1: Supply Chain Management - LM 2023*
Chair: Christian Thies

- Lydia Wöhlert (Technische Universität Ilmenau)
  Analyzing the Causes of Shortages and Overstocks in Supply Chains – A System Dynamics and Behavioral Model 🇩🇪

- Tim Gruchmann (Westcoast University of Applied Sciences)
  Engineering Change Management – A Case Study on IT, Processual, and Organizational Requirements

- Anne Lange (Frankfurt University of Applied Sciences)
  The effect of weather for flight on-time performance

Transportation

Session M-C-2 Transportation 1:
Wednesday 13.09.2023, 13:15-14:45, H-S386
Link: *M-C-2: Transportation 1 - LM 2023*
Chair: Kathrin Fischer

- Tobias Huf (Universität Augsburg)
  Robots at your service: covering the last mile in omnichannel retail

- Andreas Rudi (Karlsruhe Institute of Technology (KIT))
  A Pareto-optimization model for economic and ecological intermodal freight transportation planning with transshipments, terminal uncertainties, and product value applications digitalization of procurement

- Tim Alscher (IAV GmbH)
  Potentials of automated public transport in rural areas

Session D-A-2 Transportation 2:
Thursday 14.09.2023, 08:30-10:00, H-S386
Link: *D-A-2: Transportation 2 - LM 2023*
Chair: Jörn Schönberger

- Kristof Horvat (University of Luxembourg)
  How Autonomous Vehicles Shape LSP Business Models

- Louis Vincent Sroka (Christian-Albrechts-University of Kiel)
  Import Diversification in the Transport Network Design for Green Hydrogen

- Raphael Hackober (Technical University Darmstadt)
  The interdisciplinary research of innovations in intermodal rail freight transportation – How does research address innovations?

Session D-C-1 Transportation 3:
Thursday 14.09.2023, 10:30-12:00, Wiwi-Festsaal Faculty of Economics
Link: *D-C-1: Transportation 3 - LM 2023*
Chair: Dirk Mattfeld

- Jing Shan (Technische Universität Dresden)
  Development of heterogeneous rail supply chain strategies for international rail transport

- Stephan Hocke (Technische Universität Dresden)
  Data-driven identification and quantification of influencing factors for robust planning in rail passenger transport

- Sebastian Knöchel (University of Freiburg)
  Succes factors for implementing a sustainable strategy in the transport infrastructure sector - Best-practices analyses of European transport infrastructure companies.

Session D-H-2 Transportation 4:
Thursday 14.09.2023, 14:45-16:15, H-S386
Link: *D-H-2: Transportation 4 - LM 2023*
Chair: Alexander Hübner

- Yuerui Tang (Technical University Darmstadt)
  Train Load Planning for Intermodal Rail Operators in a Hub-and-Spoke Network

- Neeraj Podichetty (University of Luxembourg)
  Operations of container shipping alliances

- Nicolas Rückert (Hamburg University of Technology)
  Collaboration Benefits in Port Hinterland Transportation

Supply Chain Operations

Session M-C-3 SCO 1:
Wednesday 13.09.2023 13:15-14:45, H-S186
Link: *M-C-3: Supply Chain Operations 1 - LM 2023*
Chair: Erwin Pesch

- Stefan Wagner (FernUniversität in Hagen)
  Solving Real-world Order Batching Problems in Manual Order Picking Systems Using Variable Neighborhood Search

- Vanessa Felch (University of Bamberg)
  A Dirty Little Secret? Conducting a Systematic Literature Review Regarding Overstocks 🇩🇪

- Regnina Thelen (University of Dortmund)
  A comparison of alternative approaches to zoning and item-to-zone assignment in pick-and-pass order picking systems

Session D-C-2 SCO 2:
Thursday 14.09.2023 10:30-12:00, H-S386
Link: *D-C-2: Supply Chain Operations 2 - LM 2023*
Chair: Janis Neufeld

- Richard Pergande (Technische Universität Dresden)
  Integration of additive manufacturing – the perspective of logistics service providers 🇩🇪

- Ludwig Albrecht Baunach (WHU - Otto Beisheim School of Management)
  Enhancing E-Commerce Fulfillment Operations: Machine Learning Approaches for Order Forecasting and Cost Reduction

- Jana Philips (University of Dortmund)
  An approach to optimization-based order release in engineer-to-order systems – model derivation and performance evaluation

Session D-H-1 SCO 3:
Thursday 14.09.2023 14:45-16:15, Wiwi-Festsaal Faculty of Economics
Link: *D-H-1: Supply Chain Operations 3 - LM 2023*
Chair: Matthias Wichmann

- Darleen Dolch (Technische Universität Dresden)
  Energy-Efficient Production Scheduling: Insides from Academia and Practice 🇩🇪

- Martin Schönheit (Technische Universität Dresden)
  Carbon-efficient scheduling in distributed permutation flow shops - An analysis of cause-effect- relationships 🇩🇪

- Janis Neufeld (Technische Universität Dresden)
  Lot Streaming in Hybrid Flow Shop Manufacturing Systems

Session D-J-1 SCO 4:
Thursday 14.09.2023 16:30-18:00, Wiwi-Festsaal Faculty of Economics
Link: *D-J-1: Supply Chain Operations 4 - LM 2023*
Chair: Udo Buscher

- Erwin Pesch (University of Siegen)
  The order and rack sequencing problem in robotic mobile fulfillment systems

- Adina Lucia Simonovic (University of Stuttgart)
  Communities of Practice in Purchasing Management – Evidence on motivators for participation and usage among purchasing managers

- Alexander Hübner (Technical University of Munich)
  The Impact of Consumer Picking on Food Waste: A Data-driven Approach

Network Design

Session M-G-1 Network Design:
Wednesday 13.09.2023, 16:30-18:00, Wiwi-Festsaal Faculty of Economics
Link: *M-G-1: Network Design - LM 2023*
Chair: Jan Dethloff

- Alexander Bode (Technische Universität Braunschweig)
  Dynamic Service Network Design

- Stephan Bogs (RWTH Aachen University)
  Planning of CO2 Pipeline Networks under Uncertainty with Extended Scenario Analysis

- Lisa Herlicka (Christian-Albrechts-Universität zu Kiel)
  Designing Pipeline Networks for Carbon Capture and Storage of CO2-sources in Germany: An Industry Perspective 

Parcel Logistics

Session M-G-2 Parcel Logsitics:
Wednesday 13.09.2023, 16:30-18:00, H-S386
Link: *M-G-2: Parcel Logistics - LM 2023*
Chair: Eric Sucky

- Bruno Albert Neumann-Saavedra (Technische Universität Braunschweig)
  Planning parcel deliveries with outbound and inbound demands and heterogeneous parcel lockers

- Rico Kötschau (University of Vienna)
  A Heuristic for Planning Mobile Parcel Locker Operations with Individual Customer Service

- Margaretha Gansterer (University of Klagenfurt)
  Locker Box Location Planning Under Uncertainty in Demand and Capacity Availability

Hydrogen Supply Chain

Session D-A-1 Hydrogen SC:
Thursday 14.09.2023, 08:30-10:00, Wiwi-Festsaal Faculty of Economics
Link: *D-A-1: Hydrogen Supply Chain - LM 2023*
Chair: Rainer Lasch

- Maria Beranek (Technische Universität Dresden)
  Pricing and Greening Level Decisions in a Two-Stage Hydrogen Supply Chain Considering State Subsidies and Taxes

- Silvia Guillen Suarez (Georg-August-University of Göttingen)
  Green Hydrogen Supply Chains in Latin America – A Research Approach for Partnership Projects with Europe

- Karen Ohmstede (Technische Universität Braunschweig)
  Evaluation of hydrogen supply options for sustainable aviation

Urban Logistics

Session D-J-2 Urban Logistics:
Thursday 14.09.2023, 16:30-18:00, H-S386
Link: *D-J-2: Urban Logistics - LM 2023*
Chair: Margaretha Gansterer

- Catherine Cleophas (Christian-Albrechts-Universität zu Kiel)
  Urban Mobility and Logistics - Past, Present, and Future

- Vladimir Stadnichuk (RWTH Aachen University)
  Planning of Large-Scale Car-Free Zones

- Barbara Himstedt (Christian-Albrechts-Universität zu Kiel)
  Combining multiple delivery systems for urban logistics by ALNS-based route planning

Abstracts

Supply Chain Management

Analyzing the Causes of Shortages and Overstocks in A System Dynamics and Behavioral Model

Lydia Wöhlert

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Abstract Supply chains are complex dynamic systems characterized by stocks and flows of material and information, feedback loops and delays. Autonomously acting agents in the supply chain base their decisions on the available information about the cur-rent system state. With their decisions, they influence future system states and, consequently, future decisions.

In complex environments, human decision makers tend to rely on heuristics. Besides, they are guided by their individual preferences, e. g. regarding risks. In the overall result, their order quantity decisions are often suboptimal for the total system. These errors accumulate from stage to stage, thereby distorting the demand information more and more. This phenomenon, commonly observed in real-world supply chains and well-known as the bullwhip effect, leads to fluctuating inventories culminating in shortages or overstocks associated with excessive costs.

However, the inventory level at a particular stage of the supply chain is not only affected by the order quantity decisions of the agent belonging to that stage. It also depends on the orders of his or her direct customer and on his or her direct supplier's ability to deliver. Furthermore, due to the complex structures and interactions described above, there are many other influencing factors that have to be considered.

A currently ongoing doctoral project addresses this issue by performing a detailed causal analysis. The research combines the disciplines of supply chain management, system dynamics, and behavioral economics. The case under consideration is a four-stage supply chain with limited information sharing, as in the Beer Distribution Game. A formal explanatory model based on inventory balance equations is developed to identify the causative factors leading to the current inventory levels in the supply chain.

The key idea of the model is that changes in inventory at each stage of the supply chain are composed of several partial changes. Each partial change can be unambiguously traced back to the causative agent – or more precisely, to his or her errors in order quantity decisions. The model establishes linkages between the individual decisions. In order to reveal the causes of an unsatisfying delivery performance of the direct supplier, the model depicts the changes in inventory at upstream stages recursively.

Ultimately, the model is able to separate the effects of a particular agent's actions from those of all other agents in the supply chain. Accordingly, the model explores a new avenue by explaining actual changes in inventory with errors unambiguously attributable to the causative agent, thereby extending existing approaches with a similar intention.

This conference presentation provides insight into the research work described above. The essential notions and formal relationships of the developed model will be introduced. For illustrative purposes, a numerical example based on empirical data from a Beer Distribution Game conducted at the Technische Universität Ilmenau will be included.

Considering the relationships revealed by the model, it is possible to reallocate sup-ply chain costs in accordance with the cause-and-effect criterion. Existing approaches with similar basic ideas omit such an in-depth causal analysis. In addition, the explanatory model has the potential to become a design model. Specifically, it could be used to support decision-making with the aim of correcting errors already committed by other agents before taking negative effect in the future. Thus, the model is not only interesting for researchers who want to measure the bullwhip effect and probe its causes, but also for practitioners.

Engineering Change Management – A Case Study on IT, Processual, and Organizational Requirements

Thomas Gollmann[1], **Raphaela Gangl**[2], **Tim Gruchmann**[3]

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Abstract The implementation of Engineering Change Management (ECM) practices challenges companies as it impacts organizational, processual, and IT levels simultaneously. We analyzed the ECM implementation in a selected case company from the medical device industry, answering the research question of which leading practices support their ECM process. We characterized and systemized related practices based on twelve expert interviews. The interviews were conducted based on an interview topic guide, transcribed, and analyzed with the help of qualitative content analysis. Our analysis provides deep insights into strategies for implementing or changing processes, IT systems, and organizational structures.

The effect of weather for flight on-time performance

Anne Lange

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Abstract Bad weather causes important parts of primary airline delays. For instance, Eurocontrol reports for Q1 2023 that out of the 14.5 minutes of average delay of a flight, 8.24 result from primary delays and thereof about 9,8 % are caused by weather (Eurocontrol, 2023). Borsky & Unterberger (2019) explicitly estimate the effects of sudden and slow onset weather events for flight on-time performance and observe a significant increase in delays in such cases.
In the scope of developing models to estimate on-time performance, it is common to control for bad weather. However, extant literature has used a variety of proxies to describe weather. Those include for instance dummy variables to indicate the presence of rain, fog, haze, snow, thunderstorm, or freezing temperature during the day of operations (e. g. Mazzeo, 2003; Bubalo & Gaggero, 2015), total precipitation during the day (Nicolae et al., 2017), average daily windspeed (Hansen & Hsiao 2005). In a nutshell, the proxies all highlight that delays increase in bad weather. At the same time, the proxies differ in their usability. In order to provide a structured methodological support for future work, we implement an extensive set of such weather proxies and use them to estimate departure delays of scheduled passenger flights. We report on our observations.

Abstracts
Transportation

Robots at your service: covering the last mile in omnichannel retail

Tobias Huf, Manuel Ostermeier

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Motivation Due to the booming e-commerce, the number of online orders and home deliveries is ever increasing. This trend is nowadays not restricted to standard shopping but comprises a versatile product spectrum which results in a high volume of online orders and likewise a variety of delivery modes and channels. Retailers and logistic service providers establish omnichannel networks to address these challenges. Goods are not only supplied via central warehouses but increasingly delivered direct from stores. This enables a timely delivery (e. g., same day) and a satisfying shopping experience for customers, but it also contributes to traffic congestions and increasing emissions in urban areas. The flexible delivery services for customers further go hand in hand with complex logistics and a growing planning effort for retailers and logistic service providers. This calls for efficient solutions for the last mile of deliveries and the integration of new delivery concepts to overcome the additional challenges. We therefore propose a concept that combines delivery trucks with autonomous guided robots to fulfill customer demands from stores together with standard deliveries.

Problem Description The combination of trucks with autonomous robots is known as the truck-and-robot delivery concept (Boysen et al. 2018). The concept uses small robots to serve each customer by transporting a single package. The robots move at pedestrian speed but are flexible with respect to their departure time- and location. They are therefore combined with specialized trucks to enable fast and timely deliveries in urban areas. The truck covers the longer distances and carries both robots and parcels for delivery. Robots are then released in customer proximity to travel the last mile. The concept potentially offers an efficient, cost-effective, and sustainable alternative for last-mile deliveries.
We extend the prevailing truck-and-robot concept by integrating store locations and corresponding pickup and delivery requests in the network. This means that a truck transports goods from a warehouse together with robots, and additionally picks up deliveries requested by stores on the route. The concept relies on an infrastructure of robot depots and drop-off locations. Robot depots are used by the truck to pick up new robots for later deliveries but also serve as a potential starting point for robots. The store locations serve as additional drop-off locations that can be used for robot

release, but which must also be visited to pick up customer orders. Moreover, the use of robot depots combined with autonomous robots and store deliveries enables the use of different delivery modes such as direct pickup and delivery by robot (i. e., without truck). This delivery option increases the flexibility of the system but also adds to the complexity as we need to determine, which customers are supplied directly by robots and from where the corresponding robots start.
Prevailing literature highlights the potential of the truck-and-robot concept with respect to reduced costs and emissions (see e.g., Heimfarth et al. 2022). The body of literature on autonomous robot deliveries is growing and the use of robots and alternative technologies (e. g., drones) in different settings has received increasing attention over the last years. We contribute to this stream of literature by integrating the concept into an omnichannel environment. In detail, we decide on i) the delivery mode (truck-based robot or direct robot delivery), ii) the stop locations of the truck (i. e., the number and type of stops), iii) the routing of the delivery truck, and iv) the starting point of robot deliveries depending on the delivery mode.
The combination of truck and robots with pickups and deliveries leads to a complex routing problem of ensuring predecessor relationships between stores and customers in addition to truck-robot synchronization and the routing of the truck. We formulate the resulting problem as a mixed integer program (MIP), and propose a tailored solution approach to solve large scale instances needed for an application in industry.

Solution Approach The truck-and-robot concept is a variant of the well-known Traveling Salesman Problem (TSP), which is proven to be an NP-hard optimization problem. Thus, even small instances cannot be solved with commercial solvers in polynomial time. Our concept extends a classic TSP as the locations of the truck route are not predetermined but part of the decision problem. This means, that we need to determine the number of stops and the actual stop locations used (e. g., drop-off points, robot depots, store locations). As such, there is no off-the-shelf solution approach for TSPs that can be directly applied. We consequently propose a tailored solution approach to address these issues. Our approach is based on a novel recombination-based search, the Adaptive Genetic Algorithm (AGA). The network locations can be visited more than once or not at all, and it is not possible to use standard operators of a Genetic Algorithm (GA) for the recombination (crossover, mutation) since no descendants can be formed in a meaningful manner. The AGA proposed therefore splits the search in two search phases. In the first search phase, we use customized recombination operators that are specially tailored for our pickup and delivery problem with truck and robots. Through a guided adaptation of the GA, the problem of multiple visits is reduced during the search process to a classic TSP, i. e., we identify promising stop locations for the truck routing. The second phase then uses the stop locations identified to solve the related TSP and to optimize the robot assignment to stop locations.
This procedure allows us to generate optimal results for small instances in comparable time to a standard solver. In further numerical experiments, we compare the performance of our solution approach to existing approaches in literature and analyze the advantages of integrated store deliveries in the network.

A Pareto-optimization model for economic and ecological intermodal freight transportation planning with transshipments, terminal uncertainties, and product value applications

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Motivation Transportation services are a key component of the supply chain in ensuring the efficient and timely availability of goods between geographically separated suppliers and consumers. Across the globe, road transport remains the most dominant mode of transport, emitting significant amounts of GHG emissions. In this context, an expansion of intermodal freight transport, i. e. a shift of freight transport to rail and/or inland waterways, can contribute significantly to mitigate GHG emissions. Faced with the challenge of balancing sustainability, cost efficiency, and timely services, carriers and shippers formulate strategies to address strategic goals. Despite economic and environmental advantages of intermodal freight transportation, unimodal solutions remain the preferred option in many cases. This is due to the increased complexity of intermodal transportation processes compared to unimodal transportation, resulting from the combination of different transportation modes including transshipment operations and the need for enhanced coordination among various operators along the transportation chain. An increased planning effort is required to determine the capacities and schedules of individual transportation services and to identify cost-effective and reliable services through global networks.

Problem statement The optimization of freight transportation chains is gaining attention from globally operating freight forwarders and manufacturers due to the expansion and interconnection of global production networks. Efficient freight transportation requires an integrated planning approach that considers various factors influencing the use and management of each mode of transport in order to enable cost-effective, fast, and environmentally friendly transport of goods. In addition to the higher complexity of intermodal transportation planning, economic and environmental criteria objectives must be integrated in the planning decisions of transportation networks.
Within the concept of green logistics, not only economic (i. e., cost) but also ecological (i. e., CO_2e emissions) criteria and other negative impacts of transportation processes on society (e. g., accidents, noise, traffic jams, land consumption) must be

taken into account, often leading to a trade-off between implied objectives. This gives rise to the research field of this study and leads to the problem statement of making tactical intermodal transportation planning highly efficient with respect to the criteria objectives while combining the strengths of the individual transportation modes. In terms of the problem statement, an integrated approach to decision-making in tactical freight transportation planning is suggested, which takes into account competing economic and ecological criteria and intermodal transportation constraints. Solving this problem under consideration of capacity uncertainties constitutes the scientific problem of this study.

Approach The present study introduces a holistic multi-criteria optimization model for solving intermodal transportation planning problems. The aim is to choose an optimization approach to calculate a large number of efficient solutions and thus obtain a Pareto efficient frontier. The calculated transportation plans should efficiently represent the three competing objectives of cost, time, and GHG emissions in order to provide the decision maker with Pareto-optimal solutions. Furthermore, the integration of the transportation modes of road, rail, inland waterway, maritime, and air is carried out. The optimization model enables a selection of transportation modes and forwarders at transhipment terminals. The first step describes a deterministic MILP formulation of the model. The second step incorporates capacity uncertainties with a stochastic modelling component to account for capacity fluctuations when determining optimal intermodal transportation decisions. By applying a robust epsilon-constraint method, the Pareto front of the associated MILP problem formulation is derived to analyze and evaluate the trade-off between each objective function.
Taking into account Pareto-optimal solutions, the transportation chain is assessed by a posteriori weighting of the criteria objectives to provide decision support for shippers, logistics service providers and infrastructure operators as well as to investigate transportation policy initiatives. Building upon the considerations of a former study, a capacitive multi-commodity network flow model is formulated that can solve multi-criteria intermodal transportation planning problems. The AUGMECON-R method is chosen as a solution approach for multi-criteria optimization, which offers high efficiency and performance. Furthermore, this approach allows for useful configuration options for the optimization execution by controlling the efficient solutions generated. Therefore, depending on the solution requirements for the defined optimization problem, a suitable number of grid points is passed to the algorithm.

Results The model formulation is tested in three exemplary intermodal transportation scenarios making an important contribution to freight transportation planning and supporting the complex decision-making process in the tactical selection of a robust transportation plan that meets decision-makers preferences via a posteriori assessment of Pareto optimal solutions. While the first scenario investigates a national network of road, rail and inland shipping, the second adds maritime shipping in an international network, and the third adds air freight in a global network. Compared to a former study, these scenarios enhance the model application to solve multi-criteria intermodal transport planning problems.

Potentials of automated public transport in rural areas

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Problem statement Human mankind is fighting against serious threads of climate change. Therefore, a transformation of mobility behavior is necessary. Changing the individual motor car traffic from combustion engines to emission-free solutions won't bring a sustainable long-term solution. In fact, public transport must be strengthened in all manners. People need to be motivated to use public transport rather than maintaining private vehicles. Attractive public transport solutions may bring the solution. Today urban transport systems are already on an excellent level, whereas rural systems are mainly designed to perform pupils' service (Gipp et al., 2020) . In rural areas families are used to own more than one private vehicle. Nearly every journey is done by car. To convince people using the bus instead of the own vehicle the following qualities (Gipp et al., 2020) must be ensured:

- narrow distances between stops
- short frequencies and/or service on demand
- short journey time
- low prices
- connection to urban networks and inter urban rail services.

The question is, how to improve the public transport service in rural areas under economically terms? Today, staff costs claim a share in total cos of ownership of at least 50 %. What if vehicles could be operated driverless? The saved budget could be used to establish an entirely new service concept in public transport.

Perspective of automated driving Latest developments of automated driving show, that driverless public transport services may become reality within a few years (example: FLASH in Northern Saxony). Additionally German law of automated driving (Straßenverkehrsgesetz StVG in connection with its executive order AFGBV) permits driverless services on certain, pre-defined routes, which meets the characteristics of public transport as it is operated in certain areas. For automated driving the so-called *operative design domain* (ODD) is defined by:

- characteristic of road pathway, such as: track width, curve ratings, number of lanes, allowed maximum speed, etc.

- infrastructure layout: traffic lights, cross-walks, bar gates, etc.

The automotive industry (but also high-tech industry) is developing automated people mover under high pressure. In almost every pilot project a human safety driver on board still ensures safety for the passengers. But - according to the law of automated driving in Germany – there are control room solutions under development, which will ensure a remote control of the driverless vehicles. In this context, a technical detail needs to be emphasized: the vehicle will perform the driving task independently. The control room operator will only interfere with the vehicle control when there is a "need help" signal from the vehicle. In this way, it will be possible to realize a mentoring ratio of approximately five to six vehicles per supervisor. So, the saving of personnel expenses seems to bee feasible within the next years. German public transport agencies (PTA) are eager to deploy driverless systems according to the Verband Deutscher Verkehrsunternehmen (VDV) (Leonetti, 2023).

Future operating strategies in rural public transport There are several aspects to be considered regarding driverless operation in public transport. First, the ending of human drivers in public transport allows timetables independent from working time regulations. The automated people mover must only stop for regaining energy (usually recharging batteries) and maintaining issues (cleaning up, general maintenance). In other words, a day and night operation becomes realistic. But a key question of the layout of future people mover is the optimal transport capacity. Today buses are provided according to the peak load periods (e. g., pupil service in morning hours), as the limited availability of drivers sets boundaries. The perspective of driverless operation opens the possibility of setting up platoons to manage peak loads. Afterwards the platoon could be split up to perform different services during the day.

Open questions and further research demand Besides the achievement of a real driverless operation there a several other challenges to be accepted. For example, to establish a full extent alternative service to private owned cars the automated people mover must be able to transport the shopping of groceries for a whole family. Mixed applications must be considered.
Other than that, there are economic questions. How much savings will be left over at the PTAs, after completely new control room functionalities were implemented and expensive automated people mover were purchased?

How Autonomous Vehicles Shape LSP Business Models

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Abstract Autonomous vehicles (AV) are one of the core pillars of the fourth industrial revolution (Dhamija et al., 2016). The body of research in this domain is growing (Faisal et al.,2019) and the interest of logistics service providers (LSP) is increasing as well (Simpson et al.,2019). The majority of papers concentrate on topics such as adoption rate (Sindi & Woodman, 2021), analysis of an impact on an Original Equipment Manufacturer (OEM) (Lind & Melander, 2021) or assessing the consumer acceptance of AVs (Kapser & Abdelrahman, 2020). However, how LSP business models react to the challenges resulting from AVs remains unexplored to date.

LSPs are facing forces of business model disruptions such as the servitisation trend (Borgström et al., 2021), potential entrants from big technology companies such as Amazon (Monios & Bergqvist, 2020) and in-creased pressure on developing new IT capabilities (Schramm et al., 2019). Fritschy & Spinler (2019) adopt a broader approach by analysing the potential impact of AVs on the business models of not only the logistics industry but also the automotive sector. The authors conclude that OEM business models will undergo the most significant change. Notably, the experts in the study do not anticipate a rapid disruption of LSP business models. Monios & Bergqvist (2020) put forth a conceptual framework outlining potential changes in the industry landscape due to AV implementation. They also introduce a new potential role in the value chain called "network operator".

AVs present a compelling opportunity to optimise operations, enhance fuel efficiency, and reduce human-induced errors, leading to significant cost savings and environmental benefits (Bagolee et al., 2016; Shladover, 2018; Zhang et al., 2019).

This research explores how the integration of AVs will influence value creation (Zott et al., 2011) and value capture (Teece, 2018a).

We address the objective in two research questions:

RQ1: What opportunities and risks do the adoption of AVs present for the current business models of LSPs in the road transportation industry?

RQ2: How will the newly created value be distributed in the market following the adoption of AVs?

The study will offer valuable insights for managers making strategic decisions regarding their companies' future positioning and potential new entrants seeking a holistic understanding of the most vulnerable aspects of the LSP business model. Moreover, the findings will benefit the scientific community by enriching the existing knowledge base in this field and providing a solid foundation for future research.
To investigate this phenomenon, we apply a case study methodology, primarily adopting Yin's methodological framework (Yin, 2013) with the case being defined as an LSP business model. To collect relevant data, we conduct open-ended interviews to gain a deep understanding of how various stakeholders perceive business model transformation. Additionally, we perform taxonomy research to understand the market positions of specific participants. The taxonomy development process will fol-low Nickerson et al.'s (2013) approach, which is also useful for obtaining direct access to information in challenging areas.
To achieve this, interview participants will include not only decision-makers from LSP companies but also policymakers, potential new entrants, and OEMs.
Different frameworks help to facilitate the development and change of the business model (Dijkman et al., 2015). We plan to apply a dynamic capability framework (Teece, 2018a; Teece, 2018b) to focus on a view from the LSP perspective. If we consider the company's external environment, Osterwalder et al. (2005) mention legal environment, social environment, competitive forces, customer demand, and technological change that may influence the business model of a company. Some of the influences, such as competitive forces, are as well within the scope of the research.
Based on the initial results of the interviews and taxonomy research, we provide preliminary insights, which shape the subsequent steps of our research. In this paragraph, we discuss the synthesis and potential future research applications.

On Standardisation To scale a network, the standardisation of vehicles is essential. Vehicles must be able to communicate with each other, regardless of type. The more fragmented the market (including fuel types), the greater the barrier to disrupting existing business models.
New Ecosystem Roles With the reduction in manufacturing process value, interchangeability, lack of need for vehicle drivers, and disincentives to own trucks, new ecosystem roles may emerge. Future research will explore whether LSPs are the most suitable to take this role or if new entrants may emerge.
Electrification reduces the barrier to entry and puts pressure on OEMs to move directly towards shippers As electric vehicles become more commoditised, more companies will enter the market. The initial value proposition of designing trucks shifts from hardware to software and data management. This change may compel OEMs to move directly into relationships with shippers, bypassing LSPs.
Closed environments and private fleets will be adopted first, more pressure on LSPs It is easier to adopt AVs within private fleets and closed environments, such as mining facilities. LSP providers may lose volume against growing private fleets.

Private fleets would not require high CAPEX, which is currently an entry barrier.

Further research is needed to provide a comprehensive picture of how AVs will influence the business model change of LSP and drive potential new entries on the market.

Import Diversification in the Transport Network Design for Green Hydrogen

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Abstract Hydrogen is a much-discussed potential solution for decarbonizing the transport and energy sectors. If this alternative energy carrier is produced with the help of renewable energies, it is considered climate-neutral and is referred to as "green hydrogen". However, a sustainable energy economy built on green hydrogen is a major challenge for most countries: Their limited renewable energy resources and low production capacities alone will not suffice to meet the opposing high demand. This limitation necessitates the exploration of alternative approaches to fulfill their demands. While sustainable energy supply through imports seems plausible, recent geopolitical events have underscored the importance of considering factors beyond cost and environmental aspects, such as dependency on exporting countries.

Overreliance on a single exporting country for a sustainable energy supply can lead to various complications, including political, financial, and moral concerns, which can hinder the realization of a future sustainable energy economy. Consequently, establishing a large-scale hydrogen import system necessitates a strategy that avoids strong singular dependencies through supplier diversification. By incorporating this diversification, we aim to ensure a robust and resilient energy supply infrastructure.

To address these challenges, we propose an optimization model that determines an optimal multinational transport network for the import of green hydrogen. The model includes three key elements: 'supplier diversification', 'transport diversification' and 'transportation balances'. Supplier diversification is expressed by the requirement for a minimum number of export countries on both the first level (source countries) and the last level (direct suppliers of the importing country) of the supply chain. Transport diversification establishes limitations on transportation flows for each transport link to mitigate disruption risks. Moreover, our model accounts for transportation balances expressed by transportation losses, such as boil-off, as well as conversion factors that affect the overall efficiency of the system.

To illustrate the effectiveness of our proposed approach, we present computational results from a case study focused on the import of green hydrogen to Germany. The results demonstrate the impact of diversification on the sourcing decisions and the total cost of a diversified hydrogen import network. By exploring different sourcing options and considering multiple exporting countries, our model provides insights

into how supplier diversification and transport diversification can influence the overall cost-effectiveness of the import infrastructure for green hydrogen.
The ultimate goal of our research is to contribute to the establishment of a sustainable import infrastructure for green hydrogen – one that is both cost-efficient and offers a certain level of independence from exporting countries. By mitigating the risks associated with overreliance on a singular source, we aim to support the decarbonization efforts in the energy and transportation sectors. Our approach acknowledges the need for a comprehensive and diversified strategy to create a resilient and sustainable energy future, emphasizing the importance of a global perspective in the transition to a greener economy.

The interdisciplinary research of innovations in in-termodal rail freight transportation – How does research address innovations?

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Introduction and Research Gap Intermodal freight transport is becoming increasingly important and can help shift freight transport's modal split towards more environmentally friendly transport modes to achieve climate targets (Pinto et al., 2018). In intermodal transport, entire loading units are transshipped from one transport mode to the other to exploit the advantages of the different transport modes (Agamez-Arias & Moyano-Fuentes, 2017). In combined transport, as a part of intermodal transport, rail freight transportation is an essential part of many transport chains (Economic Commission for Europe (UN/ECE), 2001). Innovations in rail freight can therefore help to achieve improvements in combined transport and thus improve the attractiveness of rail freight. To focus on rail freight innovations, only freight wagon sector innovations are considered in this publication. The reason is that freight wagons are a key component in combined rail freight transport, and dependencies are highly visible. Due to the transshipment of entire loading units in intermodal transport, the loading units and the associated freight wagons have multiple interfaces to different actors and areas in the transportation process (e. g., terminals, shippers, railway undertakers).

In recent years, several innovations in freight wagons have influenced intermodal transport (Hecht, 2014; Islam & Blinge, 2017; Bonekoning & Konings, 2004). These innovations often impact different areas in the transportation process, e. g., via vehicles, planning, and transshipment (Binsbergen et al., 2014). Areas in this perspective mean different research disciplines in the transport process; these disciplines can be Vehicles, Management and Infrastructure. However, research literature often only examines the impacts on one specific research discipline and neglects the dependencies and effects on others. E. g., the introduction of a technical innovation, like a new freight wagon, can also have an impact on the planning of transports as new planning requirements occur. In this example, new planning methods are also needed to oper-

ate the innovative freight wagon efficiently. That example reveals that if innovations are only be studied to a limited extent, the potential of innovations may not be fully explored and exploited (Di Febbraro et al., 2016). Therefore, innovations should also be studied in the research literature using an interdisciplinary approach.
For this purpose, we want to show by a literature review that innovations in rail freight transportation have broad impacts on various transport processes but that these impacts are not comprehensively considered in the research literature. To the best of our knowledge, there has been no study of how innovations in rail freight are examined in the research literature.

Research design and methodology A systematic literature review is conducted to investigate the research disciplines on the topic of innovations in rail freight transport. In the literature review, papers examining innovations in the freight wagon sector are sought. For this purpose, the following search string is used: (Freight OR Container) AND (Rail OR Train) AND Innovation AND wagon. In addition, synonyms of all search terms were included. The systematic literature search was done on Web of Science. Proceedings are not considered in the literature review. Furthermore, there were no other restrictions in the literature review.
The papers found were then reviewed and selected if they contained freight wagon-specific innovations. To make the selection of the papers as objective as possible, the analysis was conducted with the author's team of six international researchers in the field of rail freight transport and intermodal transport. At least two authors reviewed each paper. Only if a paper was selected twice, it was included in further analysis. In the case of different assessments, the author team discussed whether the paper should be considered further, and a consensus decision was made. With the systematic literature search, 247 papers were found, of which a total of 67 papers were selected for further analysis. The selected papers are then categorized according to their research disciplines. The papers could be classified into three research disciplines: Vehicles, Management, and Infrastructure. The disciplines were chosen to cover all possible research disciplines in the transport sector; thus, all papers can be assigned to them. The papers could be classified into up to all three disciplines.

Analysis of Papers The disciplines were then evaluated according to the number of assigned papers. It was examined whether the papers dealt with only one discipline or also included other disciplines. It could be shown that the papers found mostly deal with only one single research discipline and that there are almost no papers that include different disciplines.
Nine papers were solely assigned to the infrastructure discipline, 24 to the vehicles discipline and 29 to the management discipline. Of the 67 selected papers, just five papers have been categorized into two different disciplines: Two papers were assigned to infrastructure and management. Three papers were assigned to the disciplines of infrastructure and vehicles.

Conclusions and limitations The results of the first literature analysis show that the focus in research is usually placed on a disciplinary perspective to investigate rail freight wagon-specific innovations. However, by examining innovations too specifically, essential impacts on areas outside the fields of study might be neglected.

However, there are also limitations in the analysis of the papers. Since many innovations emerge from industry, innovations are often not addressed in the research literature. It therefore makes sense to include the industry perspective as well. Our further research therefore addresses the integration of the industry perspective through an interview study in the railway industry. The perspectives from the industry will then be compared with the results of this literature review.

Development of heterogeneous rail supply chain strategies for international rail transport

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Abstract As the diversity of goods structure and logistics services has increased, international rail needs a detailed understanding of the heterogeneity of freight service demand, and railroads could benefit from market segmentation and differentiated international rail services will help rail transportation integrate into the global supply chain. Eurasian railway transport has great advantages for long-distance shipments, however it is less diversified when compared with sea and air freight transport. This paper suggests using a Lean and Leagile framework to develop rail supply chain strategies that can effectively meet the needs of the global supply chain. It is believed that these strategies will lead to an improvement and diversification of international rail services, ultimately contributing to its integration into the supply chain. Managers of rail companies and logistics companies will also benefit from this research by gaining a better understanding of the value creation process, as well as the specific characteristics of international rail transport and the requirements of global supply chains.

Data-driven identification and quantification of influencing factors for robust planning in rail passenger transport

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Abstract DB Regio AG performs its annual and in-year planning through four successive steps: timetabling, vehicle scheduling, crew planning, and crew rostering. These subtasks are highly interdependent and vary significantly in their influenceability and objective criteria, making these tasks particularly challenging. During the train operation, this planning system will be subject to various uncontrollable external factors, including the infrastructure's capacity utilization, bad weather, mechanical failures, and staff absences due to illness (Hauck and Kliewer, 2020; Li et al., 2021). As a consequence, train delays cannot be avoided altogether. However, robust planning can deal with minor disruptions, i. e., a few minutes can be absorbed, or the delay propagates as little as possible. Otherwise, delays lead to traffic disturbances that complicate the operational management of the railway company and decrease the company's reliability and customer attraction. So, reducing train delays is highly desirable for the railway company (Marković et al., 2015).

An essential step in this endeavor involves establishing a functional relationship between train delays and different planning parameters and the railway system, e. g., vehicle schedules and crew rostering. This relationship would enable planners to assess the impact of changes in their planning on delays, thereby aiding them in identifying the most cost-effective changes to reduce delays. There are numerous approaches to analyzing train delays in various fields. In statistics, time series analysis (Wen et al., 2020) and regression models (Hauck and Kliewer, 2020; Wang and Work, 2015) are widespread to interpret empirical data, whereas, in simulation, researchers employ Markov chains (Şahin, 2017) and time event graphs (Goverde,

2010) to model and analyze the trains' flow through the railway network. In machine learning and data mining, predictive models such as random forests (Kecman and Goverde, 2015) or support vector machines (Marković et al., 2015) estimate delays based on various input factors, aiding in proactive decision-making on the operational level and effective resource management on the tactical level.

We use machine learning to cluster trains based on their planning features, exogenous sources (weather conditions, infrastructure), and their realized punctuality or delays, respectively. In this study, we combine data from different sources. Precisely, we include a train's planning features from all four DB Regio AG planning stages, era5 weather data (Hersbach et al., 2020), and OpenStreetMap infrastructure data (OpenStreetMap contributors, 2017). As the eventual clustering incorporates a train ride's characteristics and performance, one could call the approach presented here supervised clustering. By including the delays (response) in the clustering, we can derive performance statements from the resulting clusters, which helps identify patterns and potential causes of delays. Classifying the trains into clusters related to more likely or greater delays can provide a valuable decision-support tool for planners. In addition, it would be desirable to know which planning features the planner should address to change the assigned cluster of a train. For this purpose, we employ different methods of interpretable machine learning to provide local anchors (i. e., a rulebased explanatory note about why a train is its assigned cluster (Ribeiro et al., 2018)), and a rule-of-thumb for each cluster (i. e., a rule-based explanatory note about when a train is assigned to the cluster at hand (Goix et al., 2020)).

By doing so, we make the following contributions. We investigate the relation between the planning stages and train delays and evaluate how each stage contributes to the overall delay. In this regard, we also discuss essential interactions between the various stages. This enables us to identify combinations of planning features that are more or less likely to cause delays. Here, we can create awareness among planners of situations that increasingly lead to delays. In response, earlier stages of the planning process could show consideration of downstream planning steps and, for example, keep the subsequent stages' scope of action as flexible as possible through their own planning actions. Moreover, we assess how robust a train's planning is regarding the weather conditions and underlying infrastructure characteristics. The local anchors allow the planner to react to external events beyond its control adequately in advance on the tactical level. The advantage here is that the planner does not need any knowledge about machine learning. Lastly, the rule-of-thumb of each train cluster can simplify the sophisticated multi-stage planning system of DB Regio AG and potentially increase their planning's robustness and realized punctuality in the future.

Succes factors for implementing a sustainable strategy in the transport infrastructure sector - Best-practices analyses of European transport infrastructure companies.

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Abstract The aim of this research project is a investigation of potentials for the successful green transformation of European transport infrastructure companies as sustainable transport infrastructure operators. In particular, the existing challenges for an increased or more ambitious utilization of sustainable measures, e. g. the integration of concepts like circular economy, for transport and infrastructure are to be identified and corresponding action strategies developed on how the transformation the transport infrastructure as well as the cooperation between the modes of transport or between the sectors can be managed.

Train Load Planning for Intermodal Rail Operators in a Hub-and-Spoke Network

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Abstract Combined road/rail freight transport (CT) refers to a special form of intermodal freight transport approach that utilizes standardized loading units (e.g., containers, swap bodies, semi-trailers) to integrate the environmental sustainability and high transport volumes characteristic of railways with the versatility provided by the road freight transport by covering long distances of the main carriage on rails (Ambrosino & Caballini, 2019). A critical point of cost generation is the transshipment from truck to train and vice versa at terminals. As the train sets and schedules in combined transport cannot be easily altered at the operational planning level, capacity is limited. Customer orders can only be allocated to one of the available slots on a train. Orders that cannot be planned must either be declined or delayed, which leads to lost revenue or increased transportation time. Enhancing capacity utilization holds the potential to increase the volume of rail freight transport on transport relations with defined timetable and fixed capacity, ensuring the operation can become profitable for the operators and cost-efficient for its customers.
Our objective is to determine the current status of load planning for CT trains, identify the load planning methods employed, and pinpoint potential areas for optimization. Our research objective is explorative, and therefore, we have opted for a qualitative approach. Incorporating current literature, we have conducted interviews with multiple stakeholders in the CT transport chain in 2022, such as the IT director of a CT operator, a project manager in finance/controlling and IT of a terminal operator, and the head of digital products of a freight wagon owner, thereby gaining practical insights for our findings.
Based on the results of the conducted focus group interviews, we identified three distinct planning levels. Subsequently, we further explore and contextualize these levels within the existing literature and state of the art: load planning of a single wagon, load planning of an entire CT train, and the continuous load planning of CT trains within the rail freight transport network, such that the loading unit arrives at the destination terminal within the requested delivery time.
First, at the most detailed level of loading optimization, each individual wagon of a CT train must be loaded correctly according to technical framework conditions. Wagons of different types have, among other specifications, different lengths, numbers of axles, maximum loads, and connection pin positions to accommodate varying

loading units. The feasibility of placing a loading unit is primarily verified by calculating the resultant axle loads (Bruns et al., 2014). However, the assignment of a loading unit to the loading bay is carried out in operational planning according to loading schemes, which are specially calculated for each wagon type. Consequently, the possible combinations of loaded loading units on a wagon are finite and can be replicated in optimization models (Bruns & Knust, 2012). Furthermore, based on our interviews, we have discovered that some stakeholders can even utilize Excel spreadsheets for their operational planning. Integrated solutions are offered by software such as BLU (Berghof Automation GmbH, 2023), which has effectively addressed this problem domain and has been extensively implemented in practice. Consequently, there is no urgency for further research in this area from the viewpoint of CT operators.

Second, at the level of load planning for an entire train, the literature presents the Train Loading Problem (TLP, also known as the Train Load Planning Problem). The TLP addresses the optimization of train loading, incorporating a wide range of considerations during the booking and planning stages (Nehring et al., 2021). According to Heggen et al. (2016), different objectives, constraints, and planning environments can be distinguished. While objectives, such as minimizing cost and/or time (Corry & Kozan, 2006; Dahite et al., 2018; Mantovani et al., 2018), or maximizing utilization (Anghinolfi & Caballini, 2017; Corry & Kozan, 2008), are primarily influenced by the type of operator responsible for formulating and revising the load plan, constraints and planning environments are primarily determined by technical and environmental conditions (Heggen et al., 2017). Our interviewees, especially the CT operator, emphasized several real-world constraints, such as transport time limitations, and varying weight and length restrictions for multiple types of loading units, train sets, and carriages.

Third, At the aggregated level of integrated load planning, we consider the capacity utilization of the entire service network. A key aspect is deciding whether to transport goods on direct or gateway trains. While direct trains facilitate expedited transportation by avoiding detours through hubs, they may not be accessible for every origin-destination pair, or the appropriate loading slots on the direct train could already be reserved. Consequently, it becomes crucial to determine which loading units should be routed via which trains and the most efficient way to do so. This ensures that each loading unit can be assigned to an appropriate slot during each leg of the journey without disrupting the plans of other loading units or being held itself at transshipment hubs due to lack of loading capacity on any of its connecting trains. According to our interviews, it is an often occurrence that connecting trains are fully loaded and loading units must be left standing. This issue of operational capacity utilization has received relatively less attention compared to strategic decision problems such as the Hub Location Problem and Service Network Design Problem (Woodburn, 2015), despite extensive research on load planning for individual trains.

In summary, the wagon level addresses technical implementation, whereas the train level concentrates on solving the TLP with various constraints. These two problem domains are well-known, and the solutions are readily implementable for CT operators. The research opportunity resides at the network level, for which, to the best

of our knowledge, no optimization models currently exist. Addressing this challenge through load planning optimizations would enhance the overall efficiency and capacity utilization of CT networks. Investigating mathematical optimization and discrete simulation models, as well as utilizing machine learning algorithms for order prediction based on historical real-world traffic, are some of the possible approaches to fill this research gap and enhance the sustainability and cost-effectiveness of freight transportation solutions.

Operations of container shipping alliances

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Abstract Over 80 % of international trade (by volume) in goods is carrier by sea (UNCTAD, 2021). Container liner shipping plays a vital role in the ocean transportation. Two-thirds of the value of global seaborne trade is transported by liner shipping industry (WCS 2023). Volume of cargo transported by sea is predicted to triple by 2050 (OECD, 2022). Liner companies are faced with challenges such as overcapacity of vessels, rising fuel costs, and fluctuating freight rates. They have increasingly turned to form alliances as a strategic approach to improve the efficiency of their operations. The first such global maritime alliance was established in the 1990s with the formation of the grand alliance, the global alliance and Maersk-SeaLand. Due to the market conditions and different management approaches of the liner companies, alliance stability has been an issue. Alliances have evolved over time and currently there are three alliances, 2M agreement, Ocean Alliance, and THE alliance. With the decision of Maersk and MSC, in January 2023, to discontinue their 2M agreement from the year 2025, the container liner shipping industry will see yet another major revision in the alliance operations.

Although liner companies can form alliances with the partners of their choice, they have to deal with competition and trust among members, resource allocation, operational integration, difference in organizational cultures, management styles and decision-making processes, customer service and service level agreements. Companies must also follow regulations laid down by authorities such as United States Federal Maritime Commission (FMC, 2023), European Commission (EC, 2023) and Chinese Ministry of Commerce (MOFCOM, 2023). These regulations are on international scale and are affected by the geopolitical situation of the countries between which the trade takes place and of the countries to which the liner companies belong. Therefore, alliance management becomes a complex task and understanding the operations behind these alliances is vital for the container liner logistics management scholars to effectively manage their supply chain operations and to leverage the advantages of collaboration.

The main objective of this paper is to analyse the operations of the three existing (2M, Ocean and THE) container ship alliances. Literature has explored container liner shipping alliances from strategic, tactical and management decision making

level (Chen et al., 2022), and from various collaborative perspectives (Agarwal & Ergun, 2010; Chen et al., 2017, 2021, 2023; Chen, Xu, et al., 2022; Chen, Zhuang, et al., 2022; Chen & Yahalom, 2013; Liu et al., 2021; Lu et al., 2010; Tan & Thai, 2014) however, studies focusing solely on the operations are very limited. Ocean shipping carriers use various forms of collaborations such as Slot Charter Agreements (SCA), Vessel Sharing Agreements (VSA) and Global Alliances (GA) (Ghorbani et al., 2022). This study find the differences and similarities of the operations of the current alliances. We analyse container ship information such as geographic container trade regions, services offered by various carriers and alliances, vessel description and ports served provided by AXS Alphaliner platform. We also study the service agreements of the three alliances and validate our findings.

We find that the top nine container ship operators are part of one of the three alliances. Since the beginning of these alliances the number of vessels in each alliance has increased. Alliances have given the opportunity to the top operators to invest in bigger vessels (Merk et al., 2018) and our analysis identifies that certain carriers/alliances lead the industry in new-building orders in terms of technology and vessel size. Furthermore, we see across all alliances that the existing and newly commissioned ULCVs and MGX vessels are mostly deployed on east-west trades, which push the existing medium-sized vessels to smaller sectors. Our analysis also shows that the alliances do not serve North-South trade lanes, and we see similarities across all three alliances in terms of the trade lanes serviced, the vessel sizes deployed and the frequency of services. Finally, the output of this analysis provides future research agenda such as potential and scope of alliances on the other trade lanes, impact on market concentration within the industry, influence on service reliability and effect on freight rates and pricing dynamics.

This research contributes to the growing body of literature on the operations of collaborative agreements in container shipping industry. These findings provide evidence that collaboration has a positive impact on the operations of container vessels and shipping firms acts similar to their counterparts. Understanding the dynamics of collaborative vessel operations is crucial for stakeholders in the maritime industry to effectively navigate the evolving landscape of container shipping alliances and to ensure a balanced competitive environment, benefitting both shippers and carriers.

Collaboration Benefits in Port Hinterland Transportation

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Abstract Port hinterland transportation with trucks is an important part of the maritime supply chain as a significant part of supply chain costs are generated here, e. g. due to empty container transportation. Horizontal collaboration among carriers offers potential for cost reduction, but needs to be set up in a way which is fair and advantageous in the long-run for all carriers involved. In this work, a new model is developed which takes these and other realistic requirements into account. The results allow to quantify the benefits of collaboration for different collaborating group sizes and under different fairness mechanisms.

Abstracts

Supply Chain Operations

Solving Real-world Order Batching Problems in Manual Order Picking Systems Using Variable Neighborhood Search

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Introduction and Motivation We discuss three different order batching problems arising in manual order picking systems (MOPS). Although warehouses apply more and more automated material handling equipment in recent years, e. g. automated case picking systems, manual warehouses are globally still the predominant warehouse type. But even in automated warehouses, there are also areas where MOPS are used, e. g. for picking bulky items. Since even the basic variant of the order batching problem is NP-hard, we propose a very fast variable neighborhood search (VNS) scheme to tackle large-sized problem instances. Computational experiments demonstrate that the VNS scheme outperforms best performing approaches from the literature for benchmark instances. We also consider large-sized problem instances from a real-world e-commerce warehouse. Moreover, we demonstrate that a warehouse setup with heterogeneous pick devices is highly beneficial with respect to operating cost savings. From a managerial point of view, we recommend implementing VNS as a straightforward solution method in warehouse management system (WMS) software packages to reduce operating costs and to deal with the expanding labor shortages.

Problem Settings Order picking deals with retrieving items from their storage locations in a warehouse to satisfy customer requests. It accounts for around 55 % of the total effort in a warehouse. Order batching deals with the question of grouping customer orders so that they can be picked in parallel on a single picking tour (order batch). Grouping appropriate orders into a batch has a significant impact on picking productivity by reducing travel effort. To support the workforce in picker-to-parts MOPS, technical equipment is in use: Vehicles such as motorized order pick trucks enable the warehouse staff to travel larger distances in a short time to stick to time windows whereas pick devices such as roll cages and picking carts enable the transport of large orders/batches. In this research, we analyze, model, and solve the following three order batching problems:

1. Conventional Order Batching Problem (OBP) with homogenous pick devices/order types: Pick devices are characterized by its sizes allowing to transport a specific

number of orders during a picking tour in parallel. The OBP assumes an unlimited/sufficient number of resources, e. g., workforce, pick devices, for a specific planning period resources. The goal is to minimize the total travel distance/time.
2. Dedicated heterogeneous OBP (DHOBP): Motivated by a real-world setting, we assume that it is not necessarily possible to transport each customer order with each pick device. Thus, the DHOBP considers heterogenous pick devices having different compartment sizes. For example, devices with a larger number of compartments but with smaller compartment sizes can transport many orders in parallel. However, they cannot transport more bulky order types. The number of pick devices per type is finite and the planning needs to take into account hard time windows.
3. DHOBP with batch assignments to pickers and the sequencing of the batches assigned to a picker (DHOBPSAP): To cope with truck departure schedules and different order priorities, e. g. express orders, we extend the DHOBP by adding due dates to minimize the total number of weighted late orders.

For all these problem settings, the routing of the order pickers is based on predefined strategies commonly used in warehouses, namely S-shape, largest-gap, and an extended S-shape routing considering a one-way traveling policy and short-cuts between different blocks of storage locations.

Proposed VNS Schemes The idea of VNS is to enrich a simple local search method to enable it escaping from local optima. This is ensured by restarting the local search from a randomly chosen neighbor of the incumbent solution. This shaking step is carried out by applying neighborhood structures of increasing size. For the OBP and the DHOBP, we use nine different move types to form the neighborhood structures for the local search and shaking phase, e. g. shifting an order between batches, destroy-and repair-mechanisms. For DHOBSAP, we enrich the VNS by nine additional move types to make assignment and sequencing decisions, e. g. swapping batches between different pick devices, decomposition heuristics for a partial exact enumeration of sequencing solutions. Beside the VNS scheme, we also design savings-based and list scheduling algorithms based on the Apparent-Tardiness-Cost (ATC) and the Weighted Modified Due Date dispatching rules for benchmarking purposes. For small-sized instances, we compare the VNS with results obtained from mixed integer linear programming (MILP) formulations. The VNS computing time is limited to 1 minute even for instances with up to 1,000 orders. To further improve the solution quality of the VNS, we make use of a straightforward independent multi-search parallelization (VNS-IMS). On top of that, we hybridize the VNS approach with a set partitioning formulation (VNS-SP). When the VNS method terminates, a MILP solver is applied to solve an SPP instance. The number of batches for the SPP is kept small using only promising batches from previous VNS iterations to obtain tractable MILP instances.

Computational Results For the OBP, computational results demonstrate that recent state-of-the-art algorithms from the literature can be outperformed, e. g. Adaptive Large Neighborhood Search hybridized with Tabu Search for instances with up to 600 orders. The VNS yields improvements of around 30 % in terms of the total

travel distance over an order batching approach used in a real-world e-commerce warehouse. In addition to comparing VNS to other metaheuristics, it creates often optimal solutions. In average VNS deviates from the exact solutions of the MILP solver by less than 0.1 % for OBP instances with up to 100 orders. Even for the much more difficult DHOBP instances with up to 80 orders, the VNS deviates less than 0.4 %. For the DHOBP, we demonstrate by experiments that the number of different pick device types is crucial for the performance. For example, when comparing a warehouse with only one pick device with nine compartments to a warehouse with six pick devices with varying number of compartment sizes between 4 and 36, the heterogeneous pick device warehouse leads to 23 % shorter travel distances. For DHOBSAP, the VNS provides large improvements over commonly used due date-based algorithms from the scheduling domain. We can see that an appropriate sequence of neighborhood structures and the intensity of applying sequencing moves is crucial for both the solution quality and computing time. Even though only minor performance improvements are observed for the VNS-IMS compared to the sequential VNS version, on average <1 %, it does not require additional computing time, and it is able to reduce the volatility of metaheuristics with stochastic components. When using the VNS-SP scheme in addition, it is possible to increase the solution quality by up to 1.65 % for large-sized instances.

Conclusions Considering different pick device types and using VNS schemes to batch orders, assign, and sequence batches result in advantages for warehouses operating MOPS. The DHOBSAP tackles a variety of warehouses challenges in the area of productivity and due-date adherence. MOPS do not require large financial investments into warehouse equipment, e. g. conveyor-belts or crane-supplied pick faces. They can deal with different delivery structures, e. g. varying workload, different article characteristics, load-stability of the picked goods. Moreover, they can handle seasonal order-intake peaks. To lower operational costs, we recommend VNS schemes to solve OBP in WMS software to gain the benefits of MOPS and/or to optimize warehouse operations before considering switching to fully automated warehouses.

A Dirty Little Secret? Conducting a Systematic Literature Review Regarding Overstocks

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Abstract Due to numerous media reports, overstocks in supply chains have recently attracted growing attention alongside the public sustainability debate. The goal of this paper is to aggregate the current body of knowledge and develop a better understanding regarding (1) the quantification of overstocks (what?), the management approaches used (how?), and the drivers of managing overstocks (why?). The review synthesizes 21 relevant publications that were systematically gathered from three of the leading scientific databases. From the results of the review, a research agenda is derived that identifies nine particularly promising avenues for future investigations. Furthermore, the review shows that the existing knowledge about overstocks and the way they are managed is not only limited, but also very fragmented. A holistic perspective is missing, which motivates this paper to call for a conceptualization in the sense of an "overstock management" function. To initiate this process, a definition of the term is proposed.

A comparison of alternative approaches to zoning and item-to-zone assignment in pick-and-pass order picking systems

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Abstract Order picking is the warehousing process of consolidating stored items according to customer orders. Since it is one of the most costly and labor intensive operations, managing these activities is a key driver of warehouse performance. Our focus is on pick-and-pass systems, where the warehouse is divided into zones, with each picker only working in one zone and a sub-set of the items being stored in each zone. Hence, order-related containers are routed along a sequence of zones to be filled with the items needed for order fulfillment.

When designing a pick-and-pass system, two organizational problems need to be solved: While the zoning problem (ZP) deals with the question of how the zones should be formed, the storage location assignment problem (SLAP) refers to the question of which item should be assigned to which zone. The SLAP can be solved at different levels of aggregation. In the most detailed case, the individual items are allocated to bin locations. At the aggregate level relevant to the reasoning in the intended paper, the items are assigned to zones without specifying the bin location within the zone.

The interdependence of zoning and storage location decisions in respect of duration or distance minimization objectives can be traced back to the following relationships. The path length within a zone increases with the number of bin locations (zone size), since the dimensions of the zone increase and the bin locations contained in a zone-internal picking route are more widely dispersed. The strength of this effect is influenced by the item-to-zone assignment, which is typically based on both the frequency of item demand and the cross-correlation between the demand for different items. In this way, items with high demand frequency should be assigned to zones closer to the I/O point. Also, items with high positive correlation should be stored in the same zone or adjacent zones to minimize the number of zones that need to be crossed for order fulfillment. Both principles reduce the path length of cross-zone picking routes, but the zoning unfolds an ambivalent impact: The effectiveness of frequency-based item-to-zone assignment decreases with the zone size. The opposite effect arises with regard to the effectiveness of correlation-based

item-to-zone assignment.
In the literature, these two problems are tackled through a sequential approach where the SLAP is solved after the ZP has been solved. This enables short solution times, but does not guarantee optimal solutions, since the neglected influence of storage location decisions on zoning decisions leads to coordination deficits.
In contrast, we propose a decision model that treats ZP and SLAP simultaneously. The objective is to minimize the expected makespan, which consists of two different time components: the time it takes to forward a container between zones (inter-zone forwarding time) and the time it takes in a zone to put the required items in the container (intra-zone forwarding time). Both components are dependent on the warehouse design as well as the decisions on zoning and item-to-zone assignment. In terms of warehouse design, we focus on a specific pick-and-pass system. The shelves have the same length l and are arranged in a single row. I- and O-point are situated in the middle of the shelf row and the container flow through the system is bidirectional. In each zone, the container stays at the centered home position as long as all relevant items are picked. Required items are picked individually and sequentially.
The decision model is solved for a set of problem instances using both an exact approach and variants of the fix-and-optimize heuristic. In order to evaluate both the model and the solution approaches in terms of solution quality, solution time and solution structure, we conduct a full-factorial numerical study and analyze the results by statistical means. For this purpose, two kinds of parameters are varied, which are hypothesized to have an impact on evaluation criteria and solution structure: First, parameters of warehouse configuration, i. e. the number of articles and the maximum zone size. Second, parameters of the order situation, i. e. the number of orders and the heterogeneity of orders.
Our analysis contributes to the current state of research in several ways: The results of the numerical study provide insight into the potential of the simultaneous approach. Based on the observed computing times, it can be assessed whether the improvements in solution quality justify the additional computational effort. In addition, we gain insights into the performance of the fix-and-optimize heuristic and draw conclusions on how to tune it to solve the problem at hand.

Integration of additive manufacturing – the perspective of logistics service providers

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Abstract Additive manufacturing (AM) is one of the most promising industry 4.0 technologies that has gained significant interest from researchers and practitioners in the last four decades. It is characterized by slicing digital 3D models and building the physical models by printing and simultaneously connecting each slice. This allows the construction of very complex parts by also reducing the amount of the used materials. Besides design freedom, AM enables decentralized production by relying on digital models that can be transferred worldwide. Because of this, it has often been described as a "disruptive" technology. With the development of new AM technologies and various materials like plastics or metals, AM established itself in industries like the automotive or medical sector. Although it is still mainly used to produce prototypes, an increasing amount of additively manufactured products for the end user can be observed.

By establishing in different industries and having the potential to be disruptive, researchers already tried to observe the implications for supply chains and, in this regard, the logistics industry. Therefore, decentralized production is expected to drastically reduce transport distances, resulting in risks for parts of the logistics industry, like logistics service providers (LSP). LSPs play a vital role in supply networks by specializing in transportation, handling, or warehousing tasks. In doing so, LSPs fulfill an intermediary role within supply chains connecting different actors. Being an established partner, LSPs also have the opportunity to take advantage of their position and extend their services by including AM. Various researchers have already described this behavior. Namely, Pause and Marek (2019) conceptualized five scenarios for LSPs to integrate services regarding AM, and Friedrich et al. (2022) structured LSPs by their current AM activities into six clusters. But the literature still needs qualitative empirical data that focuses on different LSPs views about AM concerning the integration process and the impacts on internal and external structures. Thus, we aim to close this research gap with a multiple holistic case study approach answering the following research questions: How do LSPs integrate AM? And how does the integration of AM impact internal and external structures of LSPs?

To identify possible differences, nine LSPs representing different types regarding

their service portfolio were selected as individual cases. We purposely chose four LSPs that are still in a waiting position and five LSPs that have already integrated AM to identify factors that impact the integration process. For the data collection, we conducted nine semi-structured interviews with representatives from the LSPs. Following the data triangulation approach, we also validated and complemented the interview data with documentations like information on websites or whitepapers, which are openly accessible. The interview data were analyzed following the qualitative content analysis described by Kuckartz and Rädiker (2022).

The within- and cross-case-analysis results show that the integration process and impact on internal and external structures depend on the similarities to previous services and whether AM is implemented for internal or external use cases. However, it was observed that LSPs follow a similar process in the beginning. Starting with one or several motivational factors, LSPs investigate and try to identify possible business cases. The decision to implement AM depends on several challenges that LSPs face and their capabilities to conquer them. Especially the lack of use cases has been pointed out by several interviewees as being a significant challenge. LSPs implementing AM integrate it for internal or external use cases. Depending on that, the integration process differs and impacts the changes in the internal and external structures. Integration for internal use cases could be observed at LSPs with high-maintenance facilities and technical staff to maintain them. Because they already have staff members with a technical background, they don't need external knowledge. Thus, the impact on internal structures is negligible since the new activities can most likely be implemented in an existing business field.

In comparison, the integration process for LSPs with external use cases depends on the similarity to current activities. If the services regarding AM are very similar to previous activities, for example, the transportation of additively manufactured products, LSPs can also rely on internal resources rather than integrating external know-how. Therefore, the changes in internal structures are nearly identical to the prior mentioned LSPs with internal use cases. However, if the desired AM services differ significantly from previous activities, LSPs need external know-how. This results in integrating new employees with specific knowledge regarding AM and creating a new business field for the particular AM services.

Focusing on external structures and processes, LSPs most likely remain in their intermediary role since parts production is often outsourced to manufacturing firms specializing in AM. Next to these firms, LSPs also find new partners in consulting firms, research institutes, universities, and raw material suppliers. If LSPs try to additively manufacture parts by themselves, it is more likely that the production capabilities will be centralized in one place for bundling use cases. However, if the LSPs outsource the production, a decentralized position from the perspective of the LSP is possible. Concerning customers, LSPs with external business cases can extend their client base and take a step into new markets.

Based on the gathered information, six guidelines are proposed for LSPs to give helpful insights into the integration process at different stages. The results help researchers understand the processes behind AM integration and identify future research opportunities.

Enhancing E-Commerce Fulfillment Operations: Machine Learning Approaches for Order Forecasting and Cost Reduction

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Abstract This study employs various machine learning methods to improve order demand forecasting for a German fulfilment company. Rather than focusing only on standard metrics, this research also incorporates forecast error distributions as inputs to a stochastic program, which optimizes weekly workforce planning across multiple warehouses. The ultimate goal is to assess the potential cost savings that could arise from the implementation of these methods in operations.

Our research partner is a digital fulfilment provider (DFP) based in Germany, operating within the e-commerce sector. The operational challenge stems from the complex nature of order processing. On a typical day, the DFP receives tens of thousands of product orders from hundreds of e-commerce shops. These orders are then forwarded to the external warehouse operator responsible for fulfilling them. Currently, an ARIMA-based forecast is generated every Friday to facilitate workforce planning for the upcoming week. The warehouse operator schedules their workers based on the aggregated DFP's planning. However, the current forecasting model often produces high error rates, leading to operational difficulties such as high backlog rates and subsequent increased service fees from the warehouse operator.

Given the contrasting interests between the DFP and the warehouse operator - the former's preference for a larger workforce to ensure 24-hour order fulfillment versus the latter's preference for a leaner workforce to maximize worker capacity and profits - accurate demand forecasting and effective workforce planning become critical. This conflict of interest necessitates weekly staffing negotiations, making it crucial to improve the accuracy of demand forecasts to guide decision making when allocating manpower over the time horizon.

Today, statistical forecasting methods range from classical time series models such as ARIMA or Exponential Smoothing (ES) to more advanced machine learning techniques like Support Vector Regression or Gradient Boosting Machines (GBM), as well as deep learning approaches like Long Short-Term Memory (LSTM) or N-HiTS. While deep learning-based models or hybrid models that incorporate traditional approaches have been popular in the literature, practice tends to favor classical

time series models and GBM's. For instance, LightGBM, a variant of GBM, has demonstrated superior performance in several forecasting competitions (e. g. M5 forecasting competition) and is highly favored due to its computational efficiency and performance.

This study aims to employ LightGBM as the primary model to enhance order demand forecasting and compare its performance against other state-of-the-art models, including NAIVE methods, ES, ARIMA, ARIMAX, ExtremeGBM, LSTM and N-HiTS.

We use insight from our daily forecasts in the validation and test set to sample forecasting scenarios for each of the methods. Model estimates and their standard deviations are used to construct multiple forecasting scenarios. For each scenario, we simulate both the actual and predicted demand for a one-week period. In every scenario a stochastic program will be optimizing weekly workforce planning in multiple warehouses minimizing cost at a given service level. In total, we construct 4000 scenarios per method, using Monte Carlo sampling with variance reduction techniques. Finally, we compare labor cost distributions for each method to provide insights into the potential impacts of implementing a new forecasting algorithm.

Preliminary results do show lower RSME and MAPE scores for LightGBM compared to ExtremeGBM, LSTM and classical time series models. Next, N-HiTS will be applied. Lastly, we will quantify cost effects of the different algorithms using the described simulation method.

An approach to optimization-based order release in engineer-to-order systems – model derivation and performance evaluation

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Abstract In engineer-to-order (ETO) systems, some of the incoming orders are characterized by a specification that is only completed at an unknown point in time after the order has been accepted. Therefore, in addition to the uncertainty about the order arrival, production planning is confronted with uncertainty about the order specification. This also affects the planning of order releases, which as a subtask of production planning is responsible for initializing the execution of orders that have already been accepted. Two sources of order-related uncertainty become relevant here, namely the period in which the order specification will be completed (specification time uncertainty) and the manufacturing process (capacity requirements uncertainty). In this situation, opposing ways of order release can be used to cope with this uncertainty. On the one hand, order release could be limited to orders with complete specifications. This would make release plans more robust, but waiting for the complete specification would also shorten the time between order release and delivery date. Consequently, it would be more expensive (e.g. overtime and backorder costs) to balance capacity supply and demand. On the other hand, order release could include orders with both complete and incomplete specifications. As a result, delayed completions of specifications could require a replanning of order releases and thus increase inventory holding costs (WIP, FGI). However, the processing of orders whose specification is completed by the expected date could start earlier, since the required capacities have already been reserved. Hence, it would be less costly to balance capacity supply and demand.
In this context, the research question arises as to whether it is possible to increase the performance of order release by considering the incompletely specified orders in addition to the completely specified ones. This gives rise to several sub-questions: What modifications need to be made to order release planning approaches developed for make-to-order (MTO) systems to account for the different types of uncertainties and information updates? Which formal changes need to be made to the optimization model? How can the performance of the proposed planning approach be measured? What are the (dis-)advantages of the proposed planning approach compared to an

approach that ignores incompletely specified orders?
To answer these questions, an approach to order release planning in MTO systems is further developed in such a way that it considers completely and incompletely specified orders as well as information updates. Incomplete specifications are taken into account by dividing the orders into components (work packages), so that completely specified components can be finally released, whereas incompletely specified components are provisionally released. For incompletely specified components, more information is provided at a later, yet unknown point in time. These information updates, as well as those related to order arrival and fulfillment are incorporated into planning using a rolling horizon approach. As a result, the plan is continuously adapted to the actual situation.
For reasons of solvability, the planning problem is hierarchically decomposed into two sub-problems that aim to minimize the sum of inventory holding (WIP, FGI) and backorder costs as well as costs of providing additional capacity (e. g. for overtime). The first sub-problem is to determine the amount of additional capacity for those periods in which capacity requirements are expected to exceed standard capacity. The second sub-problem deals with planning the release periods of the individual order components, assuming that the planned additional capacity is available. Both sub-problems are modelled as MILP, in which the uncertainties concerning specification period and capacity requirements of a component are considered with chance-constrained estimations. Therefore, for each uncertainty type, a probability threshold needs to be set in advance.
In order to receive feedback on the implementation of the order release plan, the processing of orders released for the frozen period is (re-)scheduled in detail using priority rules (FIFO or SPT/SL). The orders are then executed (by simulation) taking into account the realizations of the random variables of specification period and capacity requirements. As soon as the end of the frozen period is reached, information on order fulfillment and capacity utilization is reported back to the related sub-problems.
An extensive full-factorial numerical study is conducted to measure the performance of the proposed approach in terms of costs, robustness and solution time. Considering robustness is very important to evaluate the performance of the proposed approach compared to a direct order release approach restricted to completely specified orders. Therefore, two dimensions of robustness are observed. While cost robustness is measured by the relative deviation of the actual from the planned cost, plan robustness is based on the number of changed component releases. To gain deeper insights into the influence of considering ETO-specific uncertainties, a special focus is placed on the influence of the probability thresholds to be set in advance. As these estimates also relate to capacity requirements, different levels of capacity requirements are considered. In addition, the number of incoming orders and the priority rules for detailed scheduling are varied systematically. Regression analyses shed light on the impact of these factors on the observations of both the proposed and direct order release approaches.

Energy-Efficient Production Scheduling: Insides from Academia and Practice

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Abstract Energy efficiency is a topic that has become central among many consumers and industries. Companies need to minimize production costs and, at the same time, reduce energy consumption and follow policy measures to reduce greenhouse gas emissions. One possibility to contribute to the sustainable design of production processes is the inclusion of energy consumption as a parameter in the optimization technique used during production planning. Although energy-efficient machine scheduling and optimization have become a scientific focus in production planning, practical applications are limited. The motivation of this paper is to extract energy-efficient production scheduling mechanisms from the literature using a literature review and to discuss the concepts with experts from the field. Finally, discrepancies between the needs of the industry and the scientific literature are revealed, and solution approaches to remedy the differences are proposed.

Carbon-efficient scheduling in distributed permutation flow shops - An analysis of cause-effect relationships

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Abstract A critical challenge increasingly becoming part of the day-to-day industry business is reconciling competitiveness and profitability with the sustainability of industrial value creation. With the increased frequency of natural disasters caused by climate change, customers' awareness of sustainability is changing. Consequently, the sustainability of a company is gradually becoming a purchasing criterion. Additionally, governments are increasingly taking regulatory action to limit harmful effects of climate change. Sustainable scheduling represents a short-term potential for companies. Moreover, due to globalization, sustainable scheduling in production networks is attracting significant research interest. The complexity of these optimization problems is high because of a large number of influencing factors, e. g., the geographical location of the customers, the number and the heterogeneity of the factories. As a result, causal relationships often overlap and cannot be separated. In this article, effects are ascertained separately with the help of single-factor experiments in an extensive computational experiment for a distributed permutation flow shop scheduling problem by using a lexicographic mixed-integer-linear-programming model and fast construction heuristics. Consequently, reasoning about the cause-effect relationships and the integration of problem-specific knowledge to promote an efficient design of metaheuristics is enabled. Furthermore, valuable insights for management and research result from the derivation of implications.

Lot Streaming in Hybrid Flow Shop Manufacturing Systems

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Abstract In traditional machine scheduling, the focus is on determining the sequence of jobs on the machines. Meanwhile, the logistical question of how to organize the transport process between production stages frequently remains in the background. In this article, however, we consider lot streaming, offering the possibility to forward units to the next production stage before the entire production lot has been completed. Specifically, we analyze lot streaming in a hybrid flow shop where the aim is to minimize the makespan. For this purpose, two mixed-integer optimization models are developed and compared with respect to their solution quality. Based on the superior formulation, we analyze the influence of the configuration of the hybrid flow shop in terms of the number of production stages, the number of machines on the stages, and the length of the processing times on the makespan for moderate problem sizes. The results obtained highlight the importance and effect of different lot streaming scenarios in scheduling, and, in particular when the increased complexity of scheduling with sublots is worthwhile.

The order and rack sequencing problem in robotic mobile fulfillment systems

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Abstract In robotic mobile fulfillment systems, which are warehousing technologies that follow the parts-to-picker concept, the order picking process involves two interconnected decisions. First, there is the decision of how to schedule the processing of orders. Second, there is the decision of how to sequence the racks that are lifted and transported by automated guided vehicles (robots) to the picking station in order to supply the requested items (referred to as rack-visits). Existing literature demonstrates that minimizing the number of rack-visits is highly effective for operating a picking station efficiently. This approach reduces robot utilization and the overall time required for processing customer orders (makespan). In this study, we propose a heuristic solution approach for solving the order-scheduling and rack-sequencing problem at a single picking station.

Our approach utilizes column generation to partition the set of orders into batches. The goal is to minimize the number of rack assignments to these batches, which in turn minimizes the rack-visits. The generated batches possess a specific property that allows for the straightforward derivation of an order-processing schedule and rack sequence.

To further improve the solution, we refine the heuristic approach by rearranging the processing of batches and their assigned racks. We conducted a comprehensive and comparative computational study to evaluate the performance of our approach. The results demonstrate that our method outperforms several other heuristics in terms of both solution quality and runtime on the majority of instances. Additionally, our heuristic yields satisfactory results when embedded into a framework designed to solve the problem across multiple picking stations, particularly for small-case data.

Communities of Practice in Purchasing Management – Evidence on motivators for participation and usage among purchasing managers

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Abstract Recently, crises such as the COVID-19 pandemic or critical disruptions due to the climate change have proven that communication and exchange of knowledge both within and outside of companies are essential to counteract the complexity that has arisen. This is equally related to all sectors and departments within companies as new challenges emerge that require closer cooperation, both for companies and employees. Further, these general findings are confirmed within the supply chain and purchasing management. Thus, in past decades, economic, political and technological factors have increasingly transformed purchasing management from a local to a strategic, global and complex level resulting in changes in purchasing managers' occupational profile. Furthermore, there is a shortage of skilled workers and a lack of vocational training for purchasing management in Germany. This requires both further education of existing purchasing managers and the development of young professionals. Consequently, knowledge exchange and sharing of experiences seem to be a promising way for managers involved in professional purchasing management activities. Such exchange is not limited to take place within organizations, but can also take place between them – which is the focus of the project.
Within so-called Communities of Practice (COPs) and Virtual Communities of Practice (VCOPs), managers have the opportunity to exchange and share their knowledge and experiences – even across companies. According to Lave & Wenger (1991), a COP is defined as a knowledge community that is connected in terms of content by a common interest, a common activity, a common effort and by social relations. Regarding virtual forms of COPs (VCOPs), these experiences are predominantly shared via online platforms and the corresponding communication occurs mostly virtually rather than physically (Wenger & Snyder 2010). With regard to professional purchasing management, it can be stated that there already exist formal as well as informal interorganizational COPs and VCOPs that focus on purchasing management related issues and exchange bases on a common interest and content (e.g. within professional associations or specific groups on social media). Within these existing (V)COPs in purchasing management the participants are connected by their actual common professional experience and activities which they share across companies. However, the

question remains to what extent such information and knowledge exchange among purchasing managers takes place outside of their companies and what motivators drive participation, since this is a highly competitive professional group that could be assumed to consciously hoard job-related information.
Hence, the aim of the project is to investigate the behavior of purchasing managers with regard to their participation and usage of interorganizational (V)COPs. This leads to the following research questions:

1. What kind of (V)COPs can be identified in the field of purchasing management and to what extend are they actually used by purchasing managers?
2. What are the main motivators for purchasing managers' willingness to participate in (V)COPs?
3. What are barriers that prevent purchasing managers from participating?

The methodological approach of this project is an exploratory qualitative study which is carried out by conducting guideline-based interviews. In total, 15 interviews were conducted with two distinct samples, which enables the inclusion of different perspectives on the topic: (1) the perspective of purchasing managers and (2) the perspective of organizers and founders of COPs and VCOPs in the field of purchasing management. A category-based qualitative text analysis using MAXQDA was chosen for the analysis and interpretation of the interviews. Furthermore, websites of identified COPs and articles and comments posted in LinkedIn groups, which were identified as VCOPs, were used as secondary data to complement information. First results indicate that trust and perceived benefits play a main role as motivators and preconditions for participation. There are also first indicators that personal characteristics (e.g. age, professional experience, job engagement) of the interviewees might influence participation in (V)COPs.
The study follows up on previous empirical research on usage and participation in COPs and VCOPs that have already been conducted in different industrial sectors (e. g. Ardichvili 2008; Sedighi et al. 2017; Haas et al. 2020; Lee-Kelley & Turner 2017). With the inclusion of virtually based COPs and the perspective of the professional environment of purchasing management and its particularities, the project extends prevailing research. The study also offers new insights into the behavior and knowledge exchange among purchasing managers between organizations and complements findings that have dealt with behavioral purchasing and supply management.
As further research a quantitative survey of purchasing managers can be conducted to validate and extend the previous findings. The descriptive results of the qualitative preliminary investigation can serve as a basis for a quantitative investigation by deriving initial propositions.

The Impact of Consumer Picking on Food Waste: A Data-driven Approach

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Abstract Food waste is a pressing global issue that has significant ethical, environmental, and economic implications. This makes the identification of the drivers of waste and its management a top priority of retailers [Akkaş & Gaur, 2022]. A particular problem we cover in this paper arises from the interaction between grocery retailers and customers. The strive for high on-shelf availability induces high replenishment frequencies by the retailer. To avoid out-of-stock situations and associated revenue losses, products from upstream distribution centers or external suppliers are continuously pushed into the store before the remaining inventory is completely depleted. This common retailers' restocking practice leads to multiple expiration dates of the same product at the same price on the shelf. Retailers order the products in the shelf by expiration date and put the products with the closer expiration date at the front. However, consumers tend to prefer fresh(er) products [Tsiros & Heilman, 2005], i. e., the products with a longer shelf life that have been replenished later. Actually, 81 % of customers 'always' or 'often' check date labels when shopping for groceries and preparing meals [European Commission, 2015]. However, the more consumers choose the fresher products, the greater the risk that the remaining older products will exceed their expiration date and become food waste over time. This opportunistic withdrawal of products with a longer shelf life is termed "consumer picking".

The undesirable customer behavior of opportunistic picking for products with longer expiration dates is prone to be a major root cause for food waste at the retail stage [see e. g., Akkaş & Gaur, 2022]. The withdrawal behavior is also an important input factor for analytics and modeling approaches [see e. g., Akkaş, 2019]. Even though qualitative surveys among retailers and inventory management studies indicate a connection between customer withdrawal behavior and food waste, consumer picking

as a food waste driver has not yet been empirically quantified. Prevailing literature quantifying waste drivers focuses e. g., on case pack size [see Akkas et al., 2018], grocery store density [see Belavina, 2020], or promotions [see Wu & Honhon, 2022]. Our fundamental aim is to explore this open research area by answering the following research questions:

RQ1 How much of food waste is caused by consumers picking for expiration dates?

RQ2 What factors within stores and products influence consumer picking behavior?

The major cause of this absence of research is a lack of transparency regarding expiration dates at the store level. Barcodes at the products do not include expiration date information [see e. g., Bronnenberg et al., 2008]. To overcome these limitations, we partnered with a leading European retailer and managed to gain expiration date visibility in our project for all batches shipped to the stores. We achieved this by integrating an additional step in the operational warehouse processes. Directly after receiving a new delivery at the warehouse, expiration date information for each batch are manually entered in the retailer's IT system. When orders are then picked for distribution to the stores, the batch identifier allows us to connect expiration dates to store shipments. A further complication arises from the time lag between shipment to the store and the actual product expiration. To identify that food waste is connected with consumer picking, it is necessary to trace back what happened in the store from the day of delivery until the day of expiration and the booking as waste. As the time lag can be up to 50 days, even for fresh products (e. g., cheese), a conglomeration of expiration dates from different batches and uncertainty about the withdrawal sequence for the retailer are the consequence.

We take a two-step approach to answer our research questions. First, we develop an approach to classify waste bookings in the panel data set (transactional data on a store-SKU-day level) received from the retailer. Our panel data analysis always considers a new delivery entering the store as starting point. We connect the waste bookings within a range of days around the expiration date to the new delivery. Subsequently we sum up the sales up to the expiration date and compare it to the initial inventory when the new delivery entered the store. In case we find a waste booking within the range and the sales are higher than the initial inventory, we classify this waste as caused by consumer picking. We further test a set of boundary conditions to validate our classification. In the second step, we build on this approach to investigate in store and product-related determinants of waste caused by consumer picking. We, therefore, match complementary master data to our panel data and apply a hierarchical linear model (HLM), which can deal with the multilevel structure we find in our data, namely delivery, store and product level. As we cannot assume that observations drawn from the same store nor those from the same product (category) are uncorrelated, the approach is especially suitable for our research setting.

We analyze 1,207 perishable products from 14 product categories in 233 stores over a period of nine months. With regard to RQ1, we find that on average 20 % of food waste in stores is caused by consumer picking. Customer picking causes

waste in all investigated categories. The product category most prone to picking waste is milk with 32 %, and the lowest share is observed for cream cheese with 10 %. Results on a product level indicate not only a difference between but also within product categories. As we are only able to detect picking that causes food waste, we can assume our results as a lower bound for actual consumer picking in stores. Next, we aim to understand store and product-related determinants of picking waste (RQ2). We show that the problem arises in particular for fast-moving products with high delivery frequencies. The number of different expiration dates for the same product available in a store at the same time has a direct positive effect on picking waste. Results indicate that the effect weakens with an increasing number of expiration dates, i.e., the effect from two to three is higher than the effect from six to seven expiration dates. Further, we find a direct effect of the remaining shelf life on picking waste. Products with short shelf life (i. e., 3–14 days), and especially organic products prove to be critical in this regard. Compared to more shelf-stable products, those are more complex to handle and food waste is a much more present issue in general. With regard to the store impact, we identify a positive association between assortment size and store size on picking waste. Further, we show that the picking waste is 15 % higher in urban compared to rural areas. We checked our results for robustness concerning different boundary conditions of our model and sub samples of our panel data. All findings are robust concerning these manipulations.

Our paper is the first to empirically quantify consumer picking as a food waste driver. We thereby contribute to the novel stream of literature on studying food waste drivers in grocery retail. We enhance the understanding of the sources of waste and confirm the link between consumer instore behavior and food waste. Furthermore, we provide detailed insights into which product categories are particularly at risk, and, based on our store and product-related determinants, we derive insights for store operations decisions. In retail practice, our results can be leveraged to create awareness for the problem and the method developed can be adopted by other retailers to estimate their picking waste. Based on our results retailers can design mitigation measures, e.g., dynamic discounts, optimized delivery patterns or extended shelf merchandising, to prevent retail food waste in the future.

Abstracts

Network Design

Dynamic Service Network Design

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Abstract The general cargo industry is characterized by a growing competitive market and the transport of goods, that are small in relation to the size of the vehicle. Planning models usually presume perfect known of shipments and their destinations to prescribe a plan minimizing costs. In practice, however, such shipments are dynamic and stochastic, meaning that only part of the information is revealed to the planner. In this talk, we consider a setting in which only shipments that appear in the current planning period are known, whereas future information is revealed over time and must be incorporated into the planning process. For this purpose, we define the problem as a sequential decision process and use a cost function approximation to determine whether a shipment should be stored for the planning period or sent to the next location.

Planning of CO2 Pipeline Networks under Uncertainty with Extended Scenario Analysis

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Abstract Carbon infrastructure will be indispensable to link the captured CO_2 sources with the storage sites. However, there are many uncertainties in terms of the potential emitters, pipeline routes and locations of carbon sinks which will have an impact on the associated costs. One the one hand, the various industries have different roadmaps on how and when to mitigate their CO_2 emissions, which are strongly impacted by the development of the carbon market and decarbonization costs. This means that they will connect at different times to the prospective CO_2 network and changes in policies, energy availability and technologies might deter them completely from joining it. Also, changes in capacities of carbon sinks as well as their prices might not allow the sinks to be available or economically feasible as expected.

On the other hand, pipeline infrastructure is not easily adaptable. Pipes cannot be upgraded to one with a bigger diameter later, without incurring extremely high costs. More likely parallel loops are built to increase capacity, which reduces the economy of scale. Thus, it might be advantages to build bigger pipelines in an earlier period even if they are not fully utilized. However, building oversized pipelines leads to unnecessary costs in construction, operation and maintenance. Especially if potential emitters decide not to join the network at a later point.

Hence, this study presents an approach to model the future CO_2 backbone in Germany and investigate the impact of different scenarios on the route and costs. The developed model is based on extensive datasets and sophisticated optimization scheme to yield more realistic and optimally designed outcomes. Beside geographical features like nature reserves, terrain slope, waterways and lakes, the derived framework considers infrastructure like highways, railways, and already existing pipelines as well as population data. In total, the costs of the investigated scenarios range between 1.5 and 3 billion EUR. The results also demonstrate that the different scenarios have an impact on the configuration, total and specific transportation costs with different intensities.

Moreover, the contribution outlines a model extension that allows building the network in an incremental manner over multiple periods. It can account for these specific construction restrictions as well as allowing for each period to assume a set of scenar-

ios. The focus is that it then gives recommendations on what kind of network to build at the start of a period to reduce regret in a later period, considering all possible scenarios. Hence, the outcomes are important for academia, industry and policymaking for the ongoing discussions regarding the development of carbon infrastructure.

Designing Pipeline Networks for Carbon Capture and Storage of CO_2-sources in Germany: An Industry Perspective

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Abstract In order to reach the two-degree target set by the Paris Agreement and to avoid rising costs due to CO_2 allowances and taxes, CO_2 intensive industry sectors like cement, steel and chemicals may opt for Carbon Capture and Storage (CCS) solutions. CCS involves capturing CO_2 emissions at the source points, transporting it to geological storage sites and storing it their permanently. In this context, our study investigates howto design CCS-pipeline networks that connect German cement, steel and organic chemical industries to the geological storage formations provided by the Longship project, Norway. We propose a mixed-integer programming model for the design of a corresponding on- and offshore pipeline network, where seaports serve as intermediate compressor stations for the offshore pipelines. Our results show that the supply chain costs vary significantly across industries due to differences in capture costs, CO_2 volumes and the spatial distribution of the point sources. The supply chain costs range from 49.3 Euro per tonne for the organic chemical industry to 83.0 Euro for the steel industry and 108.7 Euro for the cement industry, respectively.With the anticipated increase in the carbon prices in the coming years, CCS might soon become economically desirable for all these industry sectors.

Abstracts

Parcel Logistics

Planning parcel deliveries with outbound and inbound demands and heterogeneous parcel lockers

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Abstract This talk addresses a parcel delivery problem with multiple depots, parcel stations with lockers of different sizes, a fleet of delivery vehicles as well as outbound and inbound demands. The goal is 1) to deliver outbound parcels to the stations specified by customers and 2) to pick up inbound parcels from stations. Sending outbound parcels to alternative stations is possible but leads to service dissatisfaction. Decisions involve the number of vehicles required for delivery operations and the location to deliver each outbound parcel. To take those decisions, we propose a mixed-integer linear program model based on a time-expanded network formulation that minimizes operational costs and costs related to service dissatisfaction and unfulfilled demand. In our computational study, we consider instances with different sizes in terms of the number of locations, lockers, and demand to assess the structure of (near) optimal solutions.

A Heuristic for Planning Mobile Parcel Locker Operations with Individual Customer Service

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Abstract The ongoing growth of e-commerce deliveries has led to a significant increase in last-mile delivery volumes. New technologies are being investigated to provide these deliveries efficiently and in a customer-friendly manner. To avoid the high cost of deliveries and failed deliveries, stationary parcel lockers are increasingly gaining importance for logistics service providers in last-mile deliveries. A new and innovative service is offered by mobile parcel lockers (MPLs) which can change their location several times during operation. These MPLs can be technically realized in a variety of ways, such as mounted or loaded with fixed drivers, swap drivers, or autonomous driving. We investigate MPLs which can be parked for temporary collection of items at predefined parking locations, keeping the pickup distance to the customer short and avoiding high infrastructure costs. We compare MPLs and attended home delivery services with an extended mobile parcel locker service, combining both functionalities. The combination merges the possibilities of serving multiple customers with a longer stop if they indicate a higher willingness to walk and the delivery to conservative or remote customers with shorter stops at their doorstep. The objective is to maximize the number of served customers with a given fleet, deciding which customers should be served individually at their doorstep (attended home delivery service) and which customers are served collectively through pickup points (mobile parcel locker service). We assume that customers have individual requirements regarding flexibility, and we want to accommodate these requirements. Two types of customers are considered, with different levels of willingness to pick up their item (reflected by the allowed maximal distance to the pickup location) and with varying pickup flexibility (reflected by the length of pickup time windows). We present the mathematical model for this problem and introduce an iterated local search heuristic (ILS) to solve it efficiently. This ILS is inspired by solution approaches for the team orienteering problem with time windows and adaptations address in particular the efficient incorporation of MPL services. To evaluate the ILS performance, we compare the runtime and results with exact solutions and analyze the impact of different instance characteristics. For this purpose, the sensitivity of

instance features as customer distributions, service area, time horizon and number of available mobile parcel locker parking locations is examined.

Locker Box Location Planning Under Uncertainty in Demand and Capacity Availability

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Abstract E-commerce has experienced a considerable growth during the last decade, which has been further accelerated by the pandemic situation that caused long lockdown periods for physical shops. Online shopping and last-mile delivery of parcels is becoming a huge business that will continue to grow worldwide by 10 % per year during the coming decade. The huge number of requests needed to be fulfilled every day makes last-mile delivery a very critical issue for logistics companies. A relatively new last-mile delivery concept involves unattended delivery to shared locations, named locker box stations. If served by a locker box, customers have a few days to pick up their parcel, after which it is returned by the logistics provider to a distribution center. Obviously, customers will not accept this delivery option if the locker boxes are not conveniently accessible for them. In our study, we focus on the strategic/tactical decision level of locating locker stations. Customers' locations are assumed to be known in advance, whereas the specific demand to be served varies from one day to the other. In addition, available capacity is considered uncertain as a locker box can be temporarily unavailable, due to customers not picking up their parcels on time. We introduce, thus, the facility location problem with uncertain demand and uncertain capacity availability.

The problem aims at determining the best location for a fixed number of locker stations. Each locker station is composed of several locker boxes. A set of demand scenarios is considered. In each scenario, a set of potential customers has to be served either by home delivery or by a locker station, where only locker stations located within a maximum radius from the customer's delivery address are considered as compatible. The number of customers assigned to a locker station, within the same demand scenario, cannot exceed its capacity. A set of capacity reduction scenarios is

defined. In each scenario, the capacity of each locker station is reduced by a quantity that represents a temporal unavailability. The primary objective of the problem is to determine the locker station locations which maximize the average number of customers served by locker box delivery. A secondary objective, which intervenes only in case of a tie, aims at minimizing the average travel distance from customers' locations to the locker stations to which the customers have been assigned.

We propose a new matheuristic framework for solving large and challenging instances. In this framework, we initially select a set of facilities to be added to an initial core. Keeping fixed the facilities to open, the decision problem turns into an assignment problem, in which each combination of demand and capacity scenario can be solved separately. The optimal solution for the global problem is then obtained merging the optimal solutions of each single combined scenario. After this preliminary phase, a local search procedure is run. At each iteration, a facility not included in the core is added to the core. The resulting restricted optimization problem is solved to optimality. We propose a consensus-based version of this framework and compare it with two versions in which classical search strategies are embedded. Since these standard strategies yield to a premature convergence toward local minima, we embed them in a metaheuristic framework, equipped with diversification mechanisms, such as Iterated Local Search and Variable Neighborhood Search. An important difference to the newly proposed approach is that, in the latter, no diversification is needed.

Our computational experiments tackle several aspects. First, we analyze how instance parameters affect the difficulty of the problem and how they impact the computational times required to solve it to optimality. Second, in order to assess the performance of the newly proposed method, we compare it against (i) classical approaches, and (ii) the performance of a solver applied to the exact model. Third, we analyze the importance of considering uncertainty in this problem, rather than solving its deterministic counterpart. This is performed by calculating problem specific indicators as well as two well known uncertainty indicators in this problem: (i) the Expected Value of Perfect Information and (ii) the Value of the Stochastic Solution. Fourth, we conduct experiments regarding unavailability probabilities. This is based on the assumption that, if a facility is always underutilized, the probability to find an unavailable box in this facility is very low. For this part of the computational study, we modify the model by taking into account that the probability of unavailability depends on the number of assigned customers to lockers. Finally, we present experiments based on real-world data from the city of Turin.

Abstracts

Hydrogen Supply Chain

Pricing and Greening Level Decisions in a Two-Stage Hydrogen Supply Chain Considering State Subsidies and Taxes

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Abstract Green hydrogen as an energy carrier is a beacon of hope to achieve climate goals because of its potential to reduce carbon emissions. Currently, the hydrogen demand cannot be met entirely with green hydrogen. Thus, non-green hydrogen cannot yet bewaived. Consequently, this paper considers a two-stage hydrogen supply chain (SC) consisting of three manufacturers producing green, partially green, and non-green hydrogen and a retailer. In addition to retail and wholesale prices, the manufacturer of partially green hydrogen must determine how green its produced hydrogen should be. The players are under the influence of governmental instruments, i. e., taxes on producing non-fully green hydrogen and subsidies for the retailer for selling green hydrogen. In a manufacturer-led Stackelberg game, we observe that it is more purposeful to promote green technologies through incentives than to force them by taxes. For the partially green manufacturer, relying exclusively on green hydrogen is advantageous if its market share is high, if the additional costs for the conversion to green hydrogen are comparatively low, or if the green sensitivity of the customers is high.

Green Hydrogen Supply Chains in Latin America – A Research Approach for Partnership Projects with Europe

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Abstract The transition from fossil to climate-neutral energy sources and supply chains has become a pressing challenge. Green hydrogen is expected to play an important role in the decarbonization of the global economy because of its specific versatility. Given the recent imminent energy shortages in Europe, supply of green hydrogen becomes an even more important topic for European countries. Therefore, an informed search is required for international business partners supporting European energy supply in a carbon-neutral economy setting. This could include for example Latin America with access to hydrogen production, based on renewable energy. This paper outlines the green hydrogen production landscape of Latin America and current partnership projects with Europe. The collaboration between these two regions is interesting and selected for the potential in hydrogen production capacities as well as cultural and political closeness in terms of democratic rule and property right as basic requirements for successful long-term collaborations for energy supply chains. While a large number of European companies are planning to use green hydrogen, few Latin American countries like Argentina and Chile are currently producing it. Both, consumption and production capacities are expected to increase in the next years, making the design of green hydrogen supply chains an eminent topic for Latin America and Europe. For this reason, cooperation projects are deemed beneficial to both, European and Latin-American companies and institutions. In most of the observed partnership projects within this paper, European actors contribute the technology know-how and Latin American actors offer a variety of large-scale clean energy resources for future green hydrogen supply chains. Additionally, an overview of the representation of hydrogen in Latin America compared to Europe in global energy scenario studies is presented, indicating a major research gap in linking the global scenario analysis level with the described specific project and supply chain design and development level. The results obtained for the specific collaboration of Europe with Latin America can be transferred to other global regions and cooperations.

Evaluation of hydrogen supply options for sustainable aviation

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Abstract From an environmental perspective, green hydrogen is a promising alternative energy carrier for short-to middle-range flights. Furthermore, hydrogen produced from renewable energy releases no carbon dioxide emissions during production and use. Therefore, hydrogen is a potential solution for reducing aviation-related emissions. Besides, the economic competitiveness of hydrogen against conventional fuels, mainly influenced by the hydrogen supply chain design, will be a key determinant for future hydrogen deployment. The supply chain consists of production, compression, transportation, and liquefaction, but these components' exact order, sizing, and location are still insecure. Different transport options exist, which are associated with various economic impacts during their purchase and use, as well as various supply chain configurations result in different overall expenses. We analyze demand and distance scenarios using an expense-oriented economic evaluation with CAPEX and OPEX to determine the best transport configuration. The total expenses of hydrogen are highly influenced by the expenses caused by energy and transport volume. Here, pipeline transportation is a promising option, as well as liquid hydrogen truck transportation in cryogenic tanks. It turns out that distance and demand for hydrogen strongly influence the choice of transportation.

Abstracts

Urban Logistics

Urban Mobility and Logistics - Past, Present, and Future

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Abstract This essay reflects on the changes in urban mobility and logistics over time. It sheds light on the past, present, and potential future developments. Particular examples are provided for the city of Kiel, Germany. Eventually, we suggest a more holistic research perspective for the logistics management community to contribute successfully to developing future urban mobility and logistics systems.

Planning of Large-Scale Car-Free Zones

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Abstract Car-free zones (CFZs) are vital for sustainable, people-centred cities. By designating specific areas as car-free, cities can prioritize pedestrians, cyclists, and public transit, resulting in numerous benefits. As cities aspire to achieve sustainability goals in the transport sector, city authorities actively strive to expand existing or to establish new CFZs. Nonetheless, CFZs may adversely impact businesses and restrict access for individuals relying on private vehicles for mobility. As a result, selecting CFZs corresponds to a complex planning problem, where the positive and negative impacts must be evaluated from the perspective of all stakeholders involved. Herein, the planning process involves two primary stakeholders: the city authorities that decide which areas to transform into CFZs, and the citizens as the primary users of the city's transport network. The stakeholders act in a hierarchical manner, with the city authorities first taking decisions on where to create CFZs, and the users then reacting to these decisions by adjusting their travel behavior.
Note that the relationship between the city authorities and the users is non-cooperative. While the car is seen as an unsustainable mode of transportation by city authorities who therefore want to force users to use more sustainable mobility modes, users aim at minimizing travel time and therefore want to use the car as the (often) fastest mode of transportation. In summary, city authorities are trying to create new CFZs that achieve the positive effects discussed and prevent negative effects by creating a transport network that remains attractive to users. Therefore, creating CFZs requires careful planning to weigh the city's and transportation users' benefits and drawbacks.
Quantitative decision support on the design of new CFZ is still very sparse. While some studies exist that are able to determine suitable areas for new CFZs, their methodologies are not able to account for potential interactions between multiple CFZs. Hence, when there is a need to install multiple independent CFZs simultaneously, these approaches have limited applicability. This can be overcome by

simulation-based approaches that are able to measure the impact of multiple CFZs simultaneously. However, each simulation run can only consider a fixed cluster of CFZs. If the number of potential CFZ clusters is large, it may be impractical or even impossible to simulate all potential combinations. Hence, although there are first approaches that provide quantitative decision support on the design of CFZs, there is a research gap regarding a methodology that is able to determine best locations, account for interdependencies between CFZs, and still regards for the impact on the users simultaneously.

Against this background, we develop a bilevel decision support model that incorporates not only the location planning of CFZs, but anticipates also the users' reactions as well as the interdependencies between CFZs in the decision-making process. The approach determines a CFZ cluster by selecting the number and location of CFZs from a finite set of sub-selected potential CFZ. This cluster of CFZs can be computed efficiently regarding users' reactions and interdependencies. The impact of policies can be analyzed by tuning certain parameters, e.g., the desired size of the CFZ cluster or the maximal allowed car traffic shift.

In this context, we make the following contributions:

1. We design a quantitative bilevel optimization model taking into account the underlying hierarchical decision-making structure to study the conflicts and synergies between CFZs.
2. To make our model computationally tractable, we derive novel acceleration techniques to improve the runtime significantly.
3. To validate our approach, we apply our optimization model to the city of Munich, Germany, to derive recommendations on selecting areas that are suitable to become car-free in the future.

A key finding of our study is that initially optimal smaller CFZ clusters cannot necessarily be expanded into optimal large CFZ clusters in an iterative process. We also observe the expected result that there is a clear correlation between the impact of the zone on external costs and the extend of the modal shift. However, this only holds as long as the total area covered by the CFZs is small. With increasing total CFZ area, there is a threshold from which modal shifts become almost negligible.

Combining multiple delivery systems for urban logistics by ALNS-based route planning

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Abstract For decades, delivering parcels in urban areas was mainly done by diesel-powered vans. However, with parcel volumes rising and environmental awareness increasing, there is a strong desire to address the externalities such as congestion and pollution associated with traditional delivery. Delivery service providers are therefore considering to switch to innovative and environmentally friendly vehicles, such as cargo bikes, delivery robots, or drones. However, relying on a single delivery system may not be practical or effective, as some customers may not be able to receive autonomous deliveries, or certain systems may not be suitable for larger parcels. Moreover, simply shifting delivery modes to footpaths, bike lanes, or even the sky may unintentionally transfer traffic congestion to these alternative routes and create new social conflicts or additional environmental problems.

Faced with these challenges, this talk aims to investigate whether a mixed deployment of delivery systems could constitute a viable solution. To this end, we propose an optimization model that focuses on minimizing delivery costs and optimizing the efficiency of parcel distribution. The variety of possible distribution systems in urban logistics is represented by adopting a modified version of the two-tier vehicle routing problem. As is typical, parcels are delivered by larger vehicles such as vans to the delivery area, and designated satellites are utilized to transfer them to smaller vehicles of the second echelon. In our model, we allow for heterogeneous vehicles and apply additional location characteristics for the second echelon: Some of these vehicles can be stationed within the delivery area, as is common for cargo bikes, for example. Other types of vehicles such as robots or drones can be kept outside the city and be brought in when needed by the first-echelon vans. We also permit second-echelon vehicles to pick up parcels at satellites multiple times to enhance the system's efficiency and prevent unnecessary empty runs. Furthermore, we designed our model to meet customers' specific needs and give each customer the flexibility to choose the vehicle types that suits them best. For instance, drone delivery can be excluded for customers who lack a suitable landing site, while traditional delivery by van can be selected for those receiving large parcels. Thus, unlike in strict two-echelon routing problems, we also allow for direct delivery by the first-echelon

vans. This modification enables us to benchmark the efficiency of other systems against traditional delivery where no second echelon exists. Cost-efficient delivery is provided by making decisions regarding vehicle selection, their starting positions, route planning, and timing, as well as satellite utilization.

To solve this optimization problem, an Adaptive Large Neighborhood Search (ALNS) heuristic is applied. Starting from an initial solution, the basic idea of this algorithm is to remove particular parts of the solution in each iteration and subsequently reinserts them at a new position. Various removal and insertion operators are applied to tailor this process to our problem. These operators include, among others, random removal of a certain number of customers, partial tours or even whole tours, as well as random and greedy insertion of removed elements. We also consider the importance of activating satellites for efficient routing and incorporate them in the removal and insertion process. Additionally, operations that invert parts of tours are integrated to enable the algorithm's application to asymmetric networks. For an adaptive search, a mechanism is applied with respect to both the frequency of the operators and the acceptance of new solutions obtained. Based on the search progress, this mechanism increasingly considers particularly successful operators and adopts corresponding cost-effective solutions for further search for improvements.

We conduct a series of experiments in which we investigate different delivery areas using real-world infrastructure and population data from Hamburg, Germany. Each of these areas is tested with eight different delivery scenarios, including traditional delivery by van, delivery supported by cargo bikes, autonomous robots, or drones and combinations thereof. Distance and time parameters are extracted from Open Source Routing Machine (OSRM), while cost and other parameters are derived from the relevant literature.

To evaluate the efficiency of the developed ALSN heuristic, our model is implemented in IBM ILOG CPLEX, and the resulting solutions are compared for instance sizes of up to 30 customers. This comparative analysis shows the high performance of our algorithm for all considered delivery scenarios. Particularly in mixed scenarios, where multiple types of vehicles can be used simultaneously, the algorithm demonstrated clear advantages, as CPLEX often failed to find an optimal solution within the given computational time, even for a small size of 20 customers. In these cases, the heuristic finds high-quality solutions within just a few seconds.

Further ALNS-results are presented for instances with up to 250 customers. As expected, traditional delivery is the most expensive option for parcel distribution, followed by delivery with vans supported by cargo bikes. In comparison, deploying autonomous robots or drones at the second echelon can significantly reduce costs, even if only two-thirds of customers are willing to receive deliveries by them. In fact, cost savings of up to 40 percent can be achieved in the scenario with the support of robots and drones compared to delivery by vans only. If the customer density in the delivery area is high, delivery by a combination of all vehicles, i.e. vans, cargo bikes, robots, and drones, proves to be the most cost-effective. In this case, a significant exploitation of the cargo bikes' capacity offers leverage for further cost reductions. Combining the strengths of different delivery systems thus offers a promising solu-

tion not only to mitigate the externalities associated with traditional van deliveries but also for enhancing cost efficiency.