Wednesday, 9:00-10:30

**WA-01**

Wednesday, 9:00-10:30 - Aula

Opening Ceremony and Plenary Lecture

Stream: Plenaries

Chair: Andreas Fink

Chair: Martin Josef Geiger

1 - Perspectives on Research in Humanitarian Operations
Luk Van Wassenhove

Research in Humanitarian Operations has increased exponentially in recent years with hundreds of papers, several books and quite a few survey articles. At the same time, the problems faced by humanitarian organizations have grown in complexity. Their case load has increased substantially and funding is being reduced. The type and frequency of disasters changes (e.g., due to climate change and urbanization) and technology offers new perspectives (e.g., social media or drones). It is therefore important to ask the question whether current research is relevant and impactful, and what are burning research questions. Humanitarian Operations take place in specific contexts that are often very different from commercial operations: destroyed infrastructure, failing information systems, insufficient funds and assets, dynamic and chaotic situations, multiple stakeholders with diverging objectives, conflicts and fighting parties, security issues, and so on. It is therefore crucial to understand the impact these contextual elements may have on the problem at hand and whether our standard OR tools are readily applicable or not. In many cases, they are not, i.e., new approaches and perhaps methodologies are needed. In short, a new science of humanitarian operations needs to be developed to provide support in conditions where our classical tools simply do not apply. The first principle of humanitarian operations is “Do no harm.” It is very tempting to use our classical OR tools and state the results will help humanitarians. The truth, however, is that without proper knowledge of the context, the outcomes of our tools can easily be misleading or even downright wrong. Context is important and in this research area, perhaps more than in many other ones, it is fundamental to carefully check assumptions, data, method, and output with humanitarian experts, to triangulate things and verify results and potential impact before making strong claims or recommendations. This presentation will attempt to present the specific context of humanitarian operations, introduce some key issues and research questions, and illustrate these with some examples from successful studies.

Wednesday, 11:00-12:30

**WB-02**

Wednesday, 11:00-12:30 - Hörsaal 1

Exact Approaches for Mixed-Integer Nonlinear Optimization (i)

Stream: Discrete and Integer Optimization

Chair: Franziska Liers

1 - Global Optimization of Ideal Multi-component Distillation Processes by Problem specific Bound Tightening
Nick Mertens, Achim Kienle, Christian Kunde, Dennis Michaels

A central question in chemical engineering deals with determining a cost-optimal design of separation processes. Such questions can be formulated as mixed integer non-linear optimization problems, that have to be solved to global optimality. That task is, in general, extremely hard and costly in terms of time. Therefore, there is a need to develop problem specific optimization techniques.

In this work we focus on multi-component distillation columns with constant relative volatilities. We apply a suitable variable transformation resulting in a monotonic structure that enables us to strengthen the model formulation, and allows us to define a problem specific bound tightening procedure which can be incorporated in a branch and bound based global optimization framework. We provide computational results that demonstrate the influence of the bound tightening procedure. In particular, the results show a reduction of the solution time compared to the standard model formulation.

2 - Multiple Choice Problems under Staircase Compatibilities
Maximilian Merkert, Andreas Bärmann, Thorsten Gellermann, Oskar Schneider

We consider a multiple choice feasibility problem where the items chosen in a solution have to fulfill a given pairwise compatibility relation. This is motivated by two applications where such a problem is contained as a substructure. One of them is on optimization of railway timetables while the other is in the context of piecewise linearization of nonlinear problems on transportation networks. In this talk, we focus on structural properties of the problem. Our definition of staircase compatibility generalizes a common property of both special cases which allows for a totally unimodular linear programming formulation of linear size. Furthermore, computational results show that for the two applications mentioned above, there is great benefit from using those totally unimodular reformulations for representing the inherent multiple choice substructure.

3 - Penalty Alternating Direction Methods for Mixed-Integer Optimization: A New View on Feasibility Pumps
Martin Schmidt, Björn Geissler, Antonio Morsi, Lars Schewe

Feasibility pumps are highly effective primal heuristics for mixed-integer linear and nonlinear optimization. However, despite their success in practice there are only few works considering their theoretical properties. We show that feasibility pumps can be seen as alternating direction methods applied to special reformulations of the original problem, inheriting the convergence theory of these methods. Moreover, we propose a novel penalty framework that encompasses this alternating direction method, which allows us to refrain from random perturbations that are applied in standard versions of feasibility pumps in case of failure. We present a convergence theory for the new penalty based alternating direction method and compare the new variant of the feasibility pump with existing versions in a numerical study for mixed-integer linear and nonlinear problems.
Stream: Discrete and Integer Optimization

Chair: Joost de Kruijf

1 - Recursively stacking items with variable height in a tube packing application

Stephen Maher, Ambrós Gleixner, Benjamin Müller, João Pedro Pedroso

Tubes of various diameters and lengths are packed into the one container for transportation. Given the different lengths and the possibility to stack smaller tubes on larger ones introduces a difficult stacking/packing problem. Currently only heuristic approaches are available to solve the tube packing problem, which combines aspects of the bin packing, cutting stock and knapsack problems. An exact solution approach will be presented that is developed from a unique graph formulation of the packing problem. Using properties from the graph formulation, column-and-row generation is applied. This talk will demonstrate the ability of the graph and a column-and-row generation solution algorithm is capable of producing exact solutions for many difficult tube packing problems.

2 - A Parallel Branch-and-Price Algorithm for Unrelated Parallel Machine Scheduling with Setup Times in High Performance Computing Environments

Gerhard Rauchecker, Guido Schryen

Scheduling problems are essential for decision making in many academic disciplines, including operations management, computer science, and information systems. Since many scheduling problems are NP-hard in the strong sense, there is only limited research on exact algorithms and how their efficiency scales when implemented on parallel computing architectures. We address this gap by (1) modeling a strongly NP-hard parallel machine scheduling problem on unrelated machines with sequence- and machine-dependent setup times by means of a binary linear program, (2) adapting an exact branch-and-price algorithm to solve the model, (3) improving the adapted algorithm, (4) parallelizing the improved algorithm using state-of-the-art shared-memory and distributed-memory parallelization paradigms, and (5) conducting extensive computational experiments in a modern high performance computing (HPC) environment. With our experiments, we show that both parallelization approaches can be combined straightforwardly and that execution times can be reduced substantially so that even moderately large-scale instances with up to 1,000 jobs on up to 1,000 machines can be solved in a modern HPC environment in less than one minute. Furthermore, we found that the relative impact of both parallelization types varies with instance sizes. These insights result in size-dependent recommendations for researchers and practitioners who need to select a suitable HPC environment that solves their particular problem instances most efficiently.

3 - Integer programming models for the mid-term production planning of high-tech low-volume industries

Joost de Kruijff, Cor Hurkens, Ton de Kok

We studied the mid-term production planning of high-tech low-volume industries. Mid-term production planning (6 to 24 months) allocates the capacity of production resources to different products over time and coordinates the associated inventories and material inputs so that known or predicted demand is met in the best possible manner. High-tech low-volume industries can be characterized by the limited production quantities and the complexity of the supply chain. Our MILP models can handle general supply chains and production processes that require multiple resources. Furthermore, they support semi-flexible capacity constraints and multiple production modes.

First, we introduce a model that assigns resources explicitly to release orders. Resulting in a second model, we introduce alternative capacity constraints, which assure that the available capacity in any subset of the planning horizon is sufficient. Since the number of these constraints is exponential we solve the second model without any capacity constraints. Each time an incumbent is found during the branch and bound process a maximum flow problem is used to find missing constraints. If a missing constraint is found it is added and the branch and bound process is restarted. Results from a realistic test case show that utilizing this algorithm to solve the second model is significantly faster than solving the first model.

Stream: Energy and Environment

Chair: Hannes Hobbie

1 - Optimal Renewable Energy Deployment in Germany: Combining Portfolio Theory with Fundamental Electricity Market Modelling

Hannes Hobbie, Dominik Möst

Germany’s electricity system is currently undergoing significant changes with substantial investments in renewable energy capacities. In this context, it is of interest to determine where to install which generation capacities and how to configure optimal portfolios. Optimal portfolios not only consider the local market but take into account that the stochastic nature of renewables increases cost for electricity supply. When modelling investment decisions with fundamental market models these interactions are endogenously part of the solution. However, high computational requirements limit the granularity of renewable energy representation. An alternative approach with less computational effort involves Mean Variance Portfolios (MVP). The basic idea is to minimize the variance of any desired level of expected portfolio return composing of different assets, taking into account that a higher return is coupled with a higher risk, which is represented by a higher variance of expected return. This approach can be transferred to energy system planning in such a way, that an optimal combination of fluctuating feed-in from different regional locations and renewable technologies can lead to a reduced fluctuation of the total feed-in and hence smoothen the residual load. In this contribution, the expansion of renewable capacities in Germany is modelled applying MVP. In a second step, the capacities from the MVP approach are taken to calculate and analyse system price effects with a fundamental electricity market model which derives the cost optimal power plant dispatch with an hourly resolution for a one year time-frame. Results will show the optimal regional and technologic composition of renewable energies and their impact on system costs in the near future.

2 - Interaction of power plant dispatch and capacity expansion models for the European energy system considering high shares of intermittent sources

Hasan Ümitcan Yılmaz, Quentin Bchini, Dogan Keles

In the context of growing wind and PV capacity in Europe, the fluctuation of renewables and the flexibility of conventional power plants must be modelled applying a high time resolution. However, increasing time resolution affects the complexity and the execution time of the model exponentially as a high number of variables are related to the time structure. The aim of this study is to find ways to increase the complexity of the model only where it is necessary, while simplifying the problem elsewhere. The main necessity in this analysis is to model volatile electricity feed-in and dispatch more accurately. Therefore, an optimization model for the European power system (PERSEUS-EU) has been split into two different models: a detailed dispatch model which optimizes the hourly resolved unit commitment for a whole year and a capacity expansion model which optimizes the capacity expansion and unit commitment, but in this case only for representative time slices. Afterwards, an algorithm is developed to couple both models. First, the results of the expansion model for year t, among others the power plant capacity, is used to dispatch the dispatch model which optimizes the unit commitment of that year. If the energy mix derived from both models does not converge, the energy mix generated with the dispatch model is used as input/requirement within the expansion model. Afterwards a new iteration with the described interaction of both models is started. If a certain level of convergence in the results of both models is reached, the iteration loop is stopped. The same procedure is used for the forthcoming years t+1 to T. Such a modelling environment allows among others an in-depth assessment of the need for flexibility options without affecting considerable the execution time.

WB-03
Wednesday, 11:00-12:30 - Hörsaal 2
Exact Algorithms for Hard Combinatorial Optimization Problems

WB-04
Wednesday, 11:00-12:30 - Hörsaal 3
Model Based Energy System Planning

OR 2016 - Hamburg
3 - Linearized Optimization Models for Decentralized Energy Supply Systems
Martin Comis, Björn Bahl, Andre Bardow, Arie Koster, Sebastian Gederbauer

Decentralized energy systems have advanced to a highly popular concept to satisfy the demand for local, sustainable, and cost-efficient energy. The problem of synthesizing such energy systems by combining units of various energy conversion technologies in order to meet time-varying electric and thermal demands is addressed by the Decentralized Energy Supply System Synthesis Problem (DESSSP). To account for the nonlinear investment costs and part-load performance of the involved energy conversion technologies, the DESSSP is naturally modeled as mixed-integer nonlinear program (MINLP). In this talk we present different mixed-integer linear programs (MILP) for the DESSSP obtained through appropriate reformulation and approximation by means of (multivariate) piecewise linearization techniques. We identify four classes of embedded nonlinearities and develop tailored reformulation strategies exploiting present structures. Moreover, we point out a mutual influence between two considered energy conversion technologies which necessitates a separate consideration of one of these classes in the first place. Subsequently we present computational results obtained on a set of realistic test instances of various sizes. In contrast to previous MINLP formulations, our MILP formulations can be solved in a reasonable amount of time even for large DESSSP instances. Furthermore, the results suggest that the approximation error in the technologies' performance models is well controllable by means of the triangulation granularity and the obtained energy systems are structurally similar to those synthesized using a MINLP formulation.

WB-05
Wednesday, 11:00-12:30 - Hörsaal 4
Behavioral Operations Management (I)
Stream: Game Theory and Experimental Economics
Chair: Anna-Lena Sachs

1 - How Negotiations Improve Performance in the Buyback Contract
Michael Becker-Peth, Elena Katok, Ulrich Thoenemann

Human decision makers do not order optimally under the buyback contract and therefore full channel efficiency is not achieved. Previous experimental studies used an ultimatum offer setting, i.e., the supplier makes a take-it-or-leave-it offer to the retailer who places an order quantity and only the retailer was a human decision maker. We extend the literature in two ways: First, we use a human-human design as a baseline, having a human supplier offering a contract to a human retailer who decides on the order quantity. Second, we introduce a negotiation phase, where retailers and suppliers can offer contracts to the other party and accept other’s offer at any time. If no agreement is made after a certain time, the supplier makes an ultimatum offer and the retailer places an order quantity. Firstly, our experimental results show that the overall SC efficiency in the human-human ultimatum game is below the single decision maker setting (0.69). This is due to suboptimal contract proposals (0.82) and suboptimal retailer rejections and order quantities. The efficiency loss accounted to the retailers is comparable to previous single decision maker studies. Secondly, we show that introducing an upfront negotiation phase increases SC efficiency significantly to overall 0.82. This is due to the periods where subjects agreed on a contract in the negotiation phase (0.97). Mainly the retailer benefits from the efficiency gains; the supplier’s profit is comparable to the ultimatum treatment. The profit split in the negotiated agreements is fairly equal (54% vs 46%). If no agreement is made, ultimatum offers are comparable between the two treatments, but retailer request higher profits to accept the offer. Finally, we analyze the drivers of successful negotiations.

2 - Diagnostic Accuracy in Congested Environments
Mirko Kremer, Francis de Veciquort

We investigate decision-making and judgments in the context of diagnostic services. As an example, consider a triage nurse who orders diagnostic tests and makes diagnoses for patients. Accumulating information by running additional tests on a patient is likely to improve the diagnosis, and diagnostic accuracy affects the value of the service provided. However, additional tests take time and thus increase congestion in the system. The service provider (e.g., a nurse) thus needs to weigh the benefit of running an additional test against the cost of delaying the provision of services to others.

For systems without congestion, diagnostic accuracy has been well explored in the literature on sequential hypothesis testing, both theoretically and empirically. This paper investigates the effect of congestion on diagnostic accuracy. We conduct controlled laboratory experiments to test the predictions of a formal sequential testing model that captures the key trade-off between accuracy and congestion in the context described above.

WB-06
Wednesday, 11:00-12:30 - Hörsaal 5
Business Track 1
Stream: Business Track
Chair: Marco Lübbecke

1 - E2E NetSim: Daimler Trucks’ Approach Using OP-TANO to Manage the Global Powertrain Network
Thomas Schmall

This talk presents the recent challenge of managing Daimler Trucks’ global powertrain network at the tactical level. The goal of the project is to shift from local factory planning to centralized network planning. Challenges include data integration of master data and live data from different mainframe data sources, particularly SAP. A linear network model with hierarchical optimization is chosen to match the management target picture. It is integrated in a user friendly planning software and is able to cover operational details such as weekly time periods, inventory and transit times.

2 - End-to-end value-based supply chain optimization at Aurubis
Bianca Springub

Aurubis is one of the leading copper producers and the world’s largest copper recycler. Our core business is the production of marketable copper cathodes from copper concentrates, copper scrap and recycling raw materials. In order to manage the associated supply chain complexity, Aurubis decided to introduce an end-to-end value-based optimization tool that supports purchasing and production planning decisions. We give an overview how Aurubis modeled its supply chain incorporating technical restrictions, market restrictions and all relevant financial terms. We will highlight the key success factors that ensured a successful implementation in Aurubis’ supply chain organization.
3 - Detecting location routing problems in geomarketing, sales force optimisation and task planning; specific challenges of real-life instances

Werner Heid

When companies attempt to optimise their sales force and task planning many decisions have to be taken and related operations must be carried out. Wrong decisions generally result in high costs and competitive disadvantages. High quality solutions allow the sales representatives to spend less time on the roads and more time with the customers. Professional applications for supporting decision-making in practice need to meet a wide range of different requirements: - Sales and delivery areas must be optimised. Desired results are characterised by geographically compact areas that are equally balanced regarding e.g. turnover potential or workload. - Solutions have to provide daily and weekly visit schedules for the planning period and exact visit sequences taking into account all relevant restrictions and customer specifications. - Alternative scenarios must be assessable in cases of business expansion and consolidation. - All results are based on reliable travel time and distance calculations.

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

4 - State-of-the-art in industrial application of discrete-event simulation

Sven Speckermann

Discrete-event simulation is an operations research method, which is widely accepted in industrial practice with a variety of applications. The presentation gives an overview of the state of simulation applications in production and logistics and considers the extent of the simulated systems (entire factory sites, supply chain) as well as different sectors (automotive, chemical industry, intralogistics, shipbuilding). The importance of different simulation tools and current trends in the tool development will be discussed. We will also describe the interplay of simulation and optimization in practical applications. Finally, the presentation illustrates the importance of the provision of a broad theoretical foundation with basics in computer science, operations research and statistics for the professional use of simulation in practice.

WB-07

Wednesday, 11:00-12:30 - Hörsaal 6

Bilevel Network Games and Online Optimization (i)

Stream: Game Theory and Experimental Economics

Chair: Jannik Matuschke

1 - Improvements on Online Machine Minimization

Kevin Schewior, Lin Chen, Nicole Megow

We consider the problem of online machine minimization in which jobs with hard deadlines arrive online over time at their release dates. The task is to determine a feasible preemptive schedule on a minimum number of machines. It was open whether an O(1)-competitive algorithm exists, even when the number of machine the optimum uses is a known constant m>1. We settle this question in the two settings where jobs can be migrated among machines and where they cannot: If migration is however not allowed, we can show that every weakly re-routable flow can be transformed into a strongly re-routable flow. We also devise a surprisingly simple combinatorial algorithm that decides whether we can send a unit-value weakly re-routable flow. A consequence of this algorithm is that if the answer is yes, there always exists a half-integral solution. In contrast, re-routable flows of value larger than 1 can be arbitrarily fractional.

1 - Beyond the chaos: How to store items in the warehouse of an online retailer

Felix Weidinger

Scattered storage is a storage assignment strategy where units loads are purposefully broken down into single items, which are distributed all around the warehouse. This way, the probability of always having some item per SKU close-by is increased, which is intended to reduce the unproductive walking time during order picking. Scattered storage is especially suited if each order line demands just a few items, so that it is mainly applied by B2C online retailers. In this talk a storage assignment problem supporting the scattered storage strategy is formulated. We provide suited solution procedures and investigate important managerial aspects, such as the frequency with which refilling the shelves should be executed.

2 - Compact MIP Models for the Resource-Constrained Project Scheduling Problem

Alexander Tesch

In the Resource-Constrained Project Scheduling Problem (RCPSP) a set of jobs is scheduled non-preemptively subject to multidimensional resource and precedence constraints. The objective is to minimize the project duration (makespan). Most common Mixed-Integer Programming (MIP) formulations for the RCPSP are based on a discretization of the planning horizon. For large time horizons the size of such time-discrete models becomes computationally intractable. In this case, one would like to have alternative formulations that are time-independent. This talk investigates compact MIP models for the RCPSP whose size is strongly polynomial in the number of jobs. In addition to two improved compact models from the literature we present flow interdiction problem asks: how small can one make the maximum s-t-flow in a graph upon removing any k edges?

This talk starts at the 2003 pseudo-approximation algorithm for network flow interdiction by Burch et al., which returns either a 2-approximation or a super-optimal but infeasible solution within twice the budget. First, we will see that similar methodology can be applied to a whole host of other interdiction problems. Second, we will revisit network flow interdiction and discover that finding a true approximation, that is one that always respects the budget, is really hard. To this end, I will describe an approximation hardness theorem for network flow interdiction and then produce the first true approximation algorithm.

3 - Re-routing network flows in case of link failures

Jannik Matuschke, Thomas S. McCormick, Gianpaolo Oriolo

We introduce and investigate a version of network flows that can be re-routed when links in the network fail. Given a capacitated network with a dedicated source and sink, a flow on source-sink-paths is re-routable if after failure of an arbitrary arc in the network, we can re-route the interrupted flow from the starting point of the failing arc to the sink only using residual capacities in the remaining network. We distinguish two variants, depending on the definition of residual capacities: For a strongly re-routable flow, the re-routing can only use capacities that have not been used at all by the original nominal flow. For a weakly re-routable flow, we can additionally use all capacity used by flow that traversed the failing arc before.

We show that a strongly re-routable flow of maximum value can be found using a compact LP formulation, whereas the problem of finding a maximum weakly re-routable flow is NP-hard in general, even when all capacities are 1 and 2. However, for the case of unit capacities, we can show that every weakly re-routable flow can be transformed into a strongly re-routable flow. We also devise a surprisingly simple combinatorial algorithm that decides whether we can send a unit-value weakly re-routable flow. A consequence of this algorithm is that if the answer is yes, there always exists a half-integral solution. In contrast, re-routable flows of value larger than 1 can be arbitrarily fractional.

WB-08

Wednesday, 11:00-12:30 - Seminarraum 101/103

GOR Master Thesis Prize

Stream: Prize Awards

Chair: Stefan Ruzicka

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3 - Integrated Location-Inventory Optimization in Spare Parts Networks
Patrick Zech

This Master’s thesis is concerned with integrated location-inventory optimization in spare parts networks. A semi-Markov decision process (SMDP) is developed, formulated as linear programming (LP) model and finally, embedded into a set-covering problem framework. The resulting model is a mixed integer linear program (MILP) which integrates (1) strategic facility choice, (2) tactical base-stock level setting and (3) operational sourcing decisions. The three-layered decision model exploits the potential benefits associated with pooling inventory physically or sharing inventory virtually among multiple facilities during the design phase of a supply chain network. Due to the model’s special structure and its linearity, Benders’ decomposition (BD) is applied to solve the problem. Several valid inequalities are added to the master problem in order to expedite convergence of the BD algorithm. Furthermore, we address the issue of combinatorial complexity inherent in large-scale SMDPs and thus, propose an exact method to effectively reduce the SMDP state space in each BD iteration. Numerical experiments confirm the efficiency of BD in comparison to the brute-force approach branch and bound (BB). Furthermore, experimental results emphasize the value of the integrated MILP compared to the sequential ‘location-first, inventory-second’ approach. The cost savings are particularly high in networks with low fixed facility location cost, high shipment cost and high demand rates as virtual inventory sharing opportunities increase in these cases.

WB-09
Wednesday, 11:00-12:30 - Seminarraum 105

Finance I

Stream: Finance
Chair: Marcus Brandenburg

1 - IPOs, the Level of Private Equity Engagement and Stock Performance Matters: Empirical Evidence from Germany
Tim Herberger, Andreas Oehler, Matthias Horn, Henrik Schalkowski

We extend the existing IPO literature by focusing on stock performance matters combined with companies’ ownership structures and, in particular private equity ownerships capital engagement, for the first time. The unique dataset on German IPOs from 2004 to 2014 allows us to identify companies’ ownership structures before and after the IPO. We address on mainly two questions in our work. First, do companies that were (partially) owned by private equity investors prior the IPO show lower short-term stock returns after the IPO than companies without prior investments of private equity investors? Second, is the companies’ long-term stock performance after the IPO better when private equity investors’ involvement is higher at the IPO? We find that the level of private equity investors’ shareholding prior the IPO predicts future returns, particularly in the longer run. Furthermore, we document that the stronger the private equity investors reduce their engagement the stronger is the performance of the issued stock. Our findings are robust to IPOs’ industrial sectors.

2 - The Impact of Central Clearing on Credit Default Swap Spreads - Evidence from the North American and European Corporate Credit Default Swap Market
Benjamin Hartl, Andreas Oehler

We contribute to the emerging debate on the joint dynamics of the markets for Credit Default Swaps (CDSs) and the central clearing functions of Central Counterparties (CCPs) by using a unique dataset of 155 North American and 151 European corporate name CDSs for the period from late 2009 to early 2014. By applying three different analytical methods, we find that CDS spreads increase around the commencement of central clearing. We argue that the spreads’ increase is due to higher transaction costs and a reduction in counterparty risk, which in turn increases the values of the underlying contracts.

3 - A longitudinal DEA study on financial performance evolutions in the automotive supply chain
Marcus Brandenburg

A data envelopment analysis (DEA) is presented to assess financial performance evolutions in the automotive supply chain. A sample of 33 decision-making units (DMUs), 17 globally operating automotive manufacturers and 16 suppliers, is in focus of this analysis in which cost levels and capital requirements are put into relation to sales volume and profitability. Cost of goods sold, operating capital and net fixed assets represent the financial input of a company while sales and earnings before interest and taxes (EBIT) reflect the financial output. The financial performance of a firm is indicated by its efficiency, calculated by an input-oriented variable returns to scale model.

In order to reveal performance evolutions over time, a longitudinal DEA approach is chosen that covers the years from 2003 and 2012. In order to assess the stability of relationships between performance leaders and followers over time, changes in the links between peer DMUs and follower DMUs and the strength of each link are assessed in a graph theory approach. A multiple linear regression analysis reveals which operational performance factors are predictors of financial performance. In this context, geographical and structural specifics of different DMU groups, such as performance differences between European, Asian and US companies or between original equipment manufacturers (OEMs) and suppliers, are taken into account.

WB-10
Wednesday, 11:00-12:30 - Seminarraum 108

Flexibility in Revenue Management
Stream: Pricing and Revenue Management
Chair: Jochen Gönsch

1 - Implications of Strategic Customer Choice for Revenue Management with Flexible Products
Sebastian Vock, Catherine Cleophas, Natalia Kliewer

Flexible products offer a way to handle uncertain demand while still implementing successful revenue management. Generally, the underlying models assume myopic customer choice. However, websites such as betterbidding.com or biddingtraveler.com suggest that increasingly, customers approach even flexible products strategically. Therefore, customers’ expectations about the actual manifestation of a flexible product can diminish revenue benefits.

Our research formalizes and evaluates a model of strategic customer preferential choice with regard to flexible products’ manifestations. We show that randomly allocating flexible products to manifestations can help to counteract strategic behavior. Our results demonstrate that strategic customers can significantly reduce the revenue gains otherwise attainable through flexible products, depending on the reliability of customers’ expectations and on customers’ risk-affinity.

2 - Overbooking in network revenue management with supply-side substitution
Sebastian Koch, Jochen Gönsch, Claudius Steinhardt, Robert Klein

In this talk, we consider the combined overbooking and choice-based capacity control problem in the presence of supply-side substitution. The problem is briefly summarized as follows: As a result of price discrimination, a firm offers a variety of differently priced products over a booking horizon. Customers arrive successively and stochastically over time with each customer purchasing at most one unit of a product. Within the booking horizon, the firm can continuously adjust the availability of the products by means of capacity control. Service provision takes place after the booking horizon, using several substitutable
Managing Inventory Systems

1 - Optimizing Machine Spare Parts Inventory Using Condition Monitoring Data
Sonja Dreyer, Jens Passlick, Daniel Olivotti, Benedikt Lebek, Michael H. Breitner

In the manufacturing industry, storing spare parts means capital commitment. Therefore, reducing the spare parts inventory is a real problem in the field. Especially in the case of large machines with numerous components or complete machine parks, a precise determination of the necessary spare parts is a major challenge. In addition, the complexity of determining the optimal amount of spare parts increases when using the same type of component in different machines.

To find the optimal spare parts inventory, the right balance between storage costs and the risk of machine down times has to be found. Several factors are influencing the optimum quantity of stored spare parts including the failure probability, the delivery times of the spare parts, storage costs, the costs of machine down times and the necessary machine availability. Therefore, an optimization model addressing the explained requirements is developed with the purpose of being easy to use in practice. Determining the failure probability of a machine component or an entire machine is a key aspect when optimizing the spare parts inventory. By means of condition monitoring the uncertainty of determining this failure probability is reduced decisively. Condition monitoring leads to a better assessment of the component’s failure probability. This results in a more precise forecast of the optimal spare parts inventory according to the actual condition of the respective component. Therefore, data from condition monitoring processes play an important role in the developed optimization model.

2 - Managing an Integrated Production and Inventory System Selling to a Dual Channel: Long-Term and Walk-In Markets
Mohsen Elhafsi

We consider a manufacturer making and selling a single product to long-term and walk-in markets. The manufacturer’s objective is to coordinate pricing, production scheduling and inventory allocation decisions in a dynamic setting. Demand for the product fluctuates due to varying state of the world conditions which we describe through a finite state Markov chain. Orders from both markets arrive continuously over time one unit at a time with stochastic inter-arrival times. Walk-in demand materializes according to an independent homogeneous Poisson process while long-term demand materializes according to a k-stage Erlang distribution. Units are produced one at a time in a make-to-stock fashion in anticipation of future demands with stochastic production times. If an order is fulfilled, the manufacturer instantly collects the sales revenue. However, if an order cannot be fulfilled immediately, the manufacturer incurs a backorder cost penalty if the order is from the long-term market otherwise the sale is lost if it is from the walk-in market. We formulate the problem as a Markov decision process and characterize the structure of the optimal policy. We show that the optimal policy, in addition to specifying the optimal walk-in market sale price, is characterized by two state-dependent thresholds: one specifies how to allocate inventory among the two markets and the other specifies how to schedule production. We also treat the special cases of static and state of the world dependent walk-in market pricing as well as the case of a spot market where the price is exogenously set. Finally, through numerical experiments, we offer managerial insights.

New Approaches

1 - Multi-agent stochastic diffusion search algorithm for optimization problems
Mümin Emre Şenol, Adil Baykasoğlu

Although the nature of the optimization problems is usually varying they are generally modelled as static problems. One of the reasons behind this may be related to the difficulty in devising dynamic optimization algorithms by making use of the classical structured programming approaches. Another interesting observation is related to the realization of the metaheuristic algorithms; although the natural phenomenon where the analogy is made is usually dynamic and varying these algorithm’s internal structures are actually static. In this research we try to implement a metaheuristic algorithm which is known as Stochastic Diffusion Search (SDS) as a truly dynamic optimization algorithm by making use of the multi-agent modelling and programming approach. In the proposed SDS algorithm solution vectors (agents) can communicate with each other for search direction determination, they can decide to disappear; new agents can appear (so the population size is not fixed) etc. In other words, the proposed algorithm has an inherent dynamic structure so it can be more easily adapted to dynamic optimization problems. The proposed algorithm is developed in JACk multi-agent development environment. Several optimization problems like single machine scheduling, project scheduling are modelled as solved, preliminary results are very encouraging.

2 - A nature-inspired approach for addressing large-scale optimization problems
Eduardo Lalla-Ruiz, Eduardo Segredo, Stefan Voss, Emma Hart, Ben Puechter

Nature-inspired algorithms have been extensively used for tackling optimization problems. Some of these approaches have been successfully used for addressing well-known combinatorial problems such as the quadratic assignment problem, knapsack problems, machine scheduling, among others. In this talk we present a novel algorithmic adaptation to continuous optimization of a recently proposed population-based meta-heuristic based on the collective behavior of migrating
1 - Solving bilevel optimization problems being polyhedral on the lower level
Alexandra Rittmann, Andreas Löhne

It is well-known [Fülpö, 1991] that linear bilevel optimization problems can be solved by optimizing the upper level objective function over the set of Pareto-optimal extremal points of a corresponding multiple objective linear program. We extend this result to more general upper level functions and discuss improvements resulting from a more direct approach based on polyhedral projection. It is shown how solver software for both multiple objective linear programming and polyhedral projection can be used to solve bilevel optimization problems being polyhedral on the lower level. By slight modifications of these solvers we can implement efficiently branch-and-bound techniques known from global optimization. Numerical examples are given.

2 - A nonsmooth Newton method for disjunctive optimization problems
Stephan Buetikofer, Diethard Klatte

In previous works of the authors [1,2] a nonsmooth Newton method was developed in an abstract framework and applied to certain finite dimensional optimization problems with C1,1 data. Such problems arise e.g. from general semi-infinite optimization problems (GSIP) under suitable assumptions. We will explain how we apply this method to disjunctive optimization problems. For this we reformulate stationary points of a disjunctive optimization problem [3] as a zero of a suitable nonsmooth function F. We will work out in detail the concrete Newton schemes from [1,2] for disjunctive optimization problems and discuss the (local) convergence properties of the Newton scheme.

References

3 - Problems being equivalent to multiple objective linear programming
Andreas Löhne

The problem to project a polyhedral convex set into a subspace is equivalent to a multiple objective linear program. This result is used to show that the following problem classes can be solved via multiple objective linear programming: parametric linear programming, parametric multiple objective linear programming, multiple objective linear programming with arbitrary polyhedral convex ordering cone (vector linear programming), vertex enumeration, calculus for polyhedral convex functions. Corresponding modeling techniques are discussed and numerical examples are presented.
1 - Scheduling of complex dismantling projects in nuclear facilities
Felix Huebner, Rebekka Volk, Frank Schultmann
The International Energy Agency (IEA) expects that until 2040 about 200 nuclear reactors in various nuclear facilities worldwide have to be decommissioned and dismantled. Dismantling of nuclear facilities is a large-scale project with high requirements for safety and security, an expected make-span about 15 to 20 years and budget with about 0.5 to 1 billion Euros per facility. Project planning is based on very few experience values and thus various uncertainties exist. The scheduling of dismantling activities for nuclear facilities imposes high requirements and has to incorporate uncertainties. Therefore, we develop a decision making model that provides a calculation of a reliable dismantling plan with minimal total project costs. The model includes three steps: 1. simulation of different scenarios, 2. calculation of a cost-optimal schedule (MRCPSP with precedence constraints) for every simulated scenario, 3. identification of robust solutions. In the simulation of scenarios we consider different execution sequences and different durations of activities. The calculation of a cost-optimal schedule is based on a relaxation-based enumeration approach. First, we solve the optimization problem without resource restrictions. Then, we examine the resulting schedule for renewable or cumulative resource conflicts. If such a conflict exists, we introduce further appropriate precedence relations. The created enumeration tree represents every feasible schedule. To find the optimal schedule we use a branch-and-bound algorithm which eliminates certain parts of the enumeration tree by using upper and lower bounds (total costs). All calculated schedules are evaluated via robustness criteria to find a robust schedule.

2 - An application of Microsoft Excel’s Evolutionary Solver to the RCPSP
Norbert Trautmann, Mario Gnägi
The Solver Add-In of Microsoft Excel is widely used in courses on Operations Research and in industrial applications. Since the 2010 version of Microsoft Excel, in addition to the Simplex algorithm for linear programming, the GRG algorithm for nonlinear programming, and a Branch-and-Bound algorithm for mixed-integer programming, the Solver Add-in comprises a so-called evolutionary solver. We analyze how this metaheuristic can be applied to the resource-constrained project scheduling problem RCPSP. We present an implementation of a schedule-generation scheme in a spreadsheet, which we combine with the evolutionary solver for devising feasible schedules. Our computational results indicate that this approach performs surprisingly well for 360 non-trivial instances of the J30 PSPLIB set.

Simulation in Health Care
Stream: Health Care Management
Chair: Sebastian Rachuba

1 - Reallocation of operating hours in an operating theatre
Lisa Koppka, Matthias Schacht, Lara Wiesche, Khaireen Bapumia, Brigitte Weimers
Operating room planning is highly restricted by a variety of conditions. Regardless of the planning method, adjustments in those conditions result in major consequences. Due to budget and personnel restrictions, expansion of the limiting factors is often difficult to realize. Therefore, we address shifting instead of resizing of capacities. In particular, we aim at allocating the total operating room time over the available operating rooms. While the total amount of available time in the operating theatre remains the same, we modify the individual opening hours taking the specialization of rooms into account. To depict the planning procedure authentically, we consider realistic patient data and analyze them with regard to treatment duration, type of surgery and frequency of occurrence. Different configuration alternatives are included in an optimization instead of generating schedules, which are analyzed using a simulation model. Uncertainty in treatment duration is embedded in the simulation model through distributions fitting realistic data. The results indicate impacts on objectives such as overtime hours, short-term rescheduling of patients and the operating room utilization and provide support for decision makers.

2 - An Integrated Operating Room Scheduling and Patient Pick-up and Drop-off Problem
Lars Moench, Hanna Ewen
This research is motivated by a real-world operating room (OR) scheduling problem found in a private German Eye Hospital. An integrated appointment scheduling and vehicle routing problem is studied since minibuses are operated by the eye hospital to pick-up the patients at their home and bring them to the hospital and transport them after their surgeries to their homes. A Non-dominated Sorting Genetic Algorithm (NSGA-II) scheme based on the random key representation is proposed to compute appointment and transportation. Based on these times, the patients are assigned according to different criteria to groups that are routed together. Since each patient can be either a linehaul or a backhaul customer, a series of vehicle routing problems with mixed linehaul and backhaul (VRPMBs) is considered where the hospital serves as the depot. The resulting VRPMB instances are solved using the record-to-record travel heuristic from the VRPHe library. We are interested in reducing the waiting time of the patients, increasing the utilization of the operating rooms, and reducing the cost for the pick-up and drop-off service of the hospital, respectively. Discrete-event simulation is used to calculate the fitness function values in the NSGA-II approach taking into account the availability of the staff and the transport capacity. Several computational experimental results are presented to demonstrate that the proposed heuristic works well.

3 - A generic simulation based DSS to evaluate patient transfer decisions strategies in hospital ward clusters
Thomas Stoeck, Taieb Mellouli
Today 30% off all German hospitals are unprofitable. In order to lower costs and to handle the estimated increase of patient admissions, all hospitals have to increase their efficiency. Managing inpatient beds, which are one of the most expensive resources in hospitals, is crucial. Without idle beds available waiting times occur, operations have to be cancelled or patients have to be rejected. Simulation studies show that increasing the flexible use of beds by creating ward cluster can reduce shortages up to 95% within a year. A cluster is defined as a class of wards where patients can be admitted if the proper ward has occupied all its bed capacities. To prevent disadvantages like long travel distance for staff or creating new bottlenecks on other wards good transfer decision strategies are needed. Based on a classification of possible transfers regarding range and dimensionality deterministic and stochastic criteria for these strategies are analyzed by simulating given cluster scenarios. Technical compliance and physical distance of the wards are examples of deterministic criteria while the estimated amount of patients and their length of stay are examples for stochastic criteria. It is expected that these criteria will affect the rating of the cluster scenarios. In order to evaluate transfer decision strategies based on these criteria we discuss a possible enhancement of our generic simulation model facing the complexity of hospital-wide relocation processes on four approximation methods based on a combination of discrete event simulation and optimization techniques like stochastic programming or linear programming. By using standardized real world data of a hospital we are able to receive practical relevant results and furthermore our approach can easily be reused in other hospitals.

4 - Simulating pathway redesign at an NHS walk-in centre
Sebastian Rachuba, Martin Pitt
Walk-in centres across the UK provide a wide range of services for patients arriving without an appointment. According to patient conditions, an assessment of medical history is required and tests may need to be performed before a decision on treatment and further management of the patient is made. As individually required care is often not known in advance, a well-balanced skill set across members of clinical staff is essential to provide care both effectively and efficiently. In our study, we focus on a genitourinary medicine clinic in the South West of England as an example for an NHS walk-in centre. The clinic offers both appointment and walk-in sessions and sees approximately 18,000 patients per year. In general, long wait times due to high patient numbers are compounded by bottlenecks accessing appropriately skilled staff and properly equipped rooms. Many patients require multiple services which often remain unknown until a patient is triaged or a clinical assessment takes place. Due to a high level of discretion, effective streamlining of symptomatic and asymptomatic patients is difficult. In order to improve waiting times for patients and to manage staff workload, changes to the existing pathways have been proposed, such as fast-tracking non-symptomatic patients and integrating existing services. A discrete event simulation model captures the current flow of
patients at the clinic taking into account available resources. We implement re-configurations in terms of different what-if scenarios and evaluate how the proposed changes impact key performance measures at the clinic. Based on these findings, we discuss how implementing these changes can be facilitated.

**WB-17**

**Demand Fulfillment in Hierarchies**

**Stream:** Supply Chain Management  
**Chair:** Herbert Meyr

1. **A deterministic approach for multi-period hierarchical demand fulfillment**
   **Jaime Cano Belmán, Herbert Meyr**

   In Make-to-Stock environments with a hierarchical sales organization and heterogeneous customers (i.e. profit-based segmented customers) the optimal matching of available resources (in form of Available-to-Promise - ATP) with demand is a challenging task if resources are scarce. Demand Fulfillment in a first step allocates these scarce resources as quotas to forecasted demand. In a second step, these reserved quotas are consumed (promised) when actual customer orders arrive. In a multi-stage sales hierarchy, this allocation process often has to be executed level by level, on basis of central, aggregate information only. Decentral, deterministic linear and non-linear programming models are proposed approximating the first-best benchmark of a central, multi-period allocation planning with full information. Additionally, a model for real-time order promising will be described. A roll over simulation has been performed to obtain first insights into the model’s behaviour.

2. **Service-level based allocation planning in customer hierarchies**
   **Konstantin Kloos**

   Meeting the explicit or implicit service level requirements of their customers is an important, but also very challenging, task for many companies. If some customer segments require higher service levels, allocated ATP approaches can help to reach the service requirements when supply is scarce. The determination of such allocations is crucial to the performance of the overall demand fulfillment system and determines the service level of all customers. No research has yet addressed the determination of these allocations under hierarchically structured customer groups. Our model tackles this allocation problem in a multi-period setting where we measure service levels independently for each period. Based on this, we derive elementary properties of an optimal allocation and then extend the model to a setting, where service levels are not measured period-wise but - more realistically - over a sequence of periods. This allows adjusting period-wise service level targets based on actual demand realizations.

3. **Decentralized allocation planning in customer hierarchies with stochastic demand**
   **Maryam Nouri Roozbahan, Moritz Fleischmann**

   To maximize profits, given limited resources, companies commonly divide their overall customer base in different segments, based on their respective profitability. In many cases, these customer segments have a multi-level hierarchical structure, which reflects the structure of the sales organization. Demand fulfillment allocates available supply to these hierarchical segments. In this setting, transmitting all detailed information regarding base customer segments is not feasible in general. Therefore, decision makers on higher levels of the hierarchy need to make their allocation decisions based on aggregated information. This presentation reports on a research project that addresses demand fulfillment, given such hierarchically structured customer segments. The focus is on identifying critical information for good decentralized allocation decisions. To this end, Revenue Management concepts are applied.

**WB-18**

**Location Routing**

**Stream:** Logistics, Routing and Location Planning  
**Chair:** Michael Schneider

1. **A new approach for a location routing problem with pick-up and delivery including home delivery services for food products**
   **Christian Franz, Rainer Leisten**

   Customers in western countries still mostly continue to shop their daily life products by going to supermarkets and other stores. In Germany, the online grocery sales market comprises just 0.2 percent of total grocery sales. However, there are two systems for food delivery services in Germany: pure players (who operate exclusively online, i.e. with no offline stores) vs. store-based home delivery services of traditional large retailers. None of these systems has become widely successful so far. The reasons for this are diverse. A low confidence in food online services is one main reason. A more customer motivating approach might be combining the two concepts as follows. Customers order online and have the opportunity to determine from which store the products shall come from. To address this issue, we model the problem as a location routing problem (LRP) with pick-up and delivery. LRP takes into account vehicle routing aspects. In this case, the locations represent the parking positions for the cars of the delivery service company. The different stores and the customers are interpreted as pick-up and delivery points. Furthermore, our model includes aspects of time-windows as well as multi-product problems and we try to formulate this problem as a multi-criteria decision problem to consider the costs of the system and also the service level, including the freshness of food products. We present this model as a mixed-integer linear model and use CPLEX 12.6 to solve small-scale instances. Computational results show that instances with up to 30 points (parking positions, pick-up and delivery points) can be solved in reasonable computation time.

2. **Strategic Planning of Electric Logistic Fleet Networks: A Robust Location Routing Approach**
   **Maximilian Schiffer, Grit Walther**

   Climate change and increasing environmental awareness call for a change towards sustainable transportation networks. Within this context, electric commercial vehicles (ECVs) contribute significantly to lower greenhouse gas as well as noxious and noise emissions. However, recharging options on routes have to be provided to keep vehicles operational, since the driving range of ECVs is still limited. Thus, it is necessary to design optimal transportation networks for ECVs considering vehicle routing decisions as well as siting decisions for recharging stations simultaneously. Additionally, many uncertainties exist in this strategic decision, e.g. regarding future developments of customer locations, delivery requirements, and demand. Against this background, we derive the Robust Electric Location Routing Problem with Time Windows and Partial Recharging considering uncertainties in customer demand, time windows and customer locations. We present an adjustable robust counterpart (ARC) with a non-adjustable decision component (siting charging stations) and an adjustable decision component (routing of ECVs). Since even the underlying deterministic planning problem is np-hard, the ARC is no longer computationally tractable for large instances, even if robust reformulation techniques are used. Thus, we present a hybrid of adaptive large neighborhood search, dynamic programming, and solving the ARC for large instances using an adversarial approach. The proposed solution method provides high quality results for the underlying problem. To highlight the benefit of the proposed modeling approach, results are compared to results of deterministic models regarding overall costs, vehicle fleet and number of charging stations.

3. **A model to locate and supply biorefineries in large-scale multi-biomass supply chains**
   **Nasim Zandi Atasibar, Nacima Labadie, Christian Prins**

   Increasing concerns about the effect of greenhouse gas emissions from fossil fuels and ever-growing energy demand have raised a strong interest in sustainable and renewable energies. Biofuels derived from biomass can play a crucial role as one of the main sources of renewable energies. As logistics may represent 50% of the biomass cost, it is necessary to design efficient biomass supply chains to provide biofuels with adequate quantities of biomass at reasonable prices and appropriate times. The task is challenging since, contrary to industrial
logistics, the raw materials (oilseed and lignocellulosic crops) are produced slowly, seasonally, and with a limited yield, over vast territories. In particular, a refinery must use successive crops during the year, e.g., miscanthus (a kind of cane) in Spring, rape in July, cereal straws in August, camellina in October and short rotation trees like willows in Winter. The paper proposes a Mixed Integer Linear Program (MILP) to optimize a multi-period and multi-biomass supply chain for several bio-refineries, at the tactical decision level. The locations of refineries can be fixed by the user or determined by the model. The aim is to minimize the total cost of the supply chain, including biomass production, pretreatments (e.g., pelletization), storage, handling, bio-refineries setup and transportation, while satisfying given refinery demands in each period. The model determines the amount of biomass produced, shipped and stored during each period as well as the number, the size and the locations of bio-refineries. The resulting MILP is tested and validated on small instances, before solving a large-scale real case covering two regions of France (Champagne-Ardenne and Picardie) with 273 territorial units and 8 biomass types.

**WB-19**

**Wednesday, 11:00-12:30 - Seminarraum 403**

**Algorithm Engineering for Route Planning (I)**

**Stream: Traffic and Passenger Transportation**

**Chair: Matthias Müller-Hannemann**

1 - **Customizable Contraction Hierarchies**

**Ben Strasser, Julian Dibbelt, Dorothea Wagner**

We consider the problem of quickly computing shortest paths in weighted graphs. Often, this is achieved in two phases: 1) derive auxiliary data in an expensive preprocessing phase, 2) use this auxiliary data to speedup the query phase. By adding a fast weight-customization phase, we extend Contraction Hierarchies to support a three-phase workflow: The expensive preprocessing is split into a phase exploiting solely the unweighted topology of the graph, as well as a lightweight phase that adapts the auxiliary data to a specific weight. We achieve this by basing our Customizable Contraction Hierarchies on nested dissection orders.

2 - **How Far You Can Drive: Fast Exact Computation of Isocontours in Road Networks**

**Moritz Baum, Thomas Bläsius, Valentin Buchhold, Julian Dibbelt, Andreas Gemsa, Ignaz Rutter, Dorothea Wagner, Franziska Wegner**

Electric vehicles play an increasingly important role in sustainable mobility. One of the main obstacles to a widespread adoption is range anxiety, that is, the fear of running out of power. Displaying the cruising range of an electric vehicle may alleviate range anxiety.

Driven by this application, we study the problem of computing isocontours in static and dynamic road networks, where the objective is to identify and visualize the boundary of the region that is reachable from a given source within a certain amount of time, or alternatively, with a certain battery charge. Although this problem has a wide range of other practical applications (e.g., urban planning, geomarketing), there has been little research on fast algorithms for large, realistic inputs. There has been some work on this problem, which is driven by2D VORs and road networks. We consider this problem for the road networks of France and Germany with 273 territorial units and 8 biomass types.

3 - **Recent Advances in Public Transport Timetable Information Systems**

**Matthias Müller-Hannemann**

We survey the state-of-the-art in efficient algorithms for timetable information systems. Thereby, we discuss several problem settings, including versions of multi-criteria, robust, and real-time information. Recent years have shown significant progress in the field, but a number of challenges still remain from a practical point of view.

**WB-20**

**Wednesday, 11:00-12:30 - Seminarraum 404**

**Business and Industrial Analytics**

**Stream: Business Analytics and Forecasting**

**Chair: Arnd Huchzermeier**

1 - **Demand volatility and skill-oriented workforce scheduling**

**Matthias Schüniger, Peter Letmathe**

Multiple research studies have shown that learning of shop-floor employees can significantly reduce production costs and also lead to improvements of product quality. The antipode of learning is forgetting referring to degrading competencies if the respective skills are not utilized over a longer period of time. Conventional scheduling methods often neglect competency development (degradation) and the consequences of task assignments to employees on long-term firm performance. We analyze learning-oriented task assignments to employees and different training strategies and their impacts on costs and skill levels of employees. Taking demand volatility into account, we present an MIP workforce scheduling model that considers learning and forgetting of employees. Furthermore, the model incorporates skill development, knowledge depreciation, training measures and short-term costs. As a result we show how to generate learning and qualification strategies under different demand volatility scenarios and analyze the specific properties of our solutions.

2 - **Judgmental Demand Forecasting for Direct Sales: Segmenting by Type or Age**

**Arnd Huchzermeier**

Manufacturers and retailers often face the challenge that they have to commit supply orders well ahead of the selling season. We consider the case of a German manufacturer selling premium mountain and road bikes online. All components are ordered ahead of the selling season, mostly from Asia. Moreover, more than half of the product collection is newly introduced each year. While most competitors have filed for bankruptcy, the company has exhibited an annual growth rate of 40% and is considered as technology, quality and cost leader in its industry. This case study shows how Sales & Operations Planning (S&OP) can be effectively optimized to improve supply chain performance.

3 - **Spare parts dispatch fraud detection analysis**

**Shivangi Verma**

Along with warranty service abuse, dispatch frauds are a huge concern area for major IT hardware companies. A spare part dispatch by a service provider to the customer is ideally complimented by a faulty part being returned back by the customer. Hence, every part that the service provider sends to a customer is followed by the customer replacing the non-functional part and sending it back. Unfortunately, the service providers lose over millions of dollars globally to non-returned parts and system exchanges. Neither are the companies tracking whether the parts or systems are being returned or not, nor are there processes in place to predict if a particular dispatch is fraudulent. A deep understanding of the dispatch process, with inputs from various stakeholders like technical support, logistics provider and customer is required. The objective of the paper is to analyze dispatch frauds and develop a methodology that helps in avoiding and catching a fraudulent dispatch before it takes place, and hence, save millions of dollars in parts intake and sent. The steps followed to build this methodology are: 1. Recognizing and defining the metrics that help in identifying a machine on which a fraudulent dispatch has taken place 2. Carrying out primary analysis to gain a deeper understanding of the data and the fraud process as a whole 3. Performing cluster analysis to group and characterize the features of such a machine and hence draw inference about possible machines on which fraud dispatch would have happened or can happen. The propensity of a machine to commit fraud is used to flag the machine and to serve as an alert when the service provider is contacted for another dispatch. Subsequently, very high risk machines can be blocked for no future dispatches.
Stochastic and Exact Vehicle Routing

Stream: Logistics, Routing and Location Planning
Chair: Philipp E.H. Salzmann

1 - Routing under uncertainty: a new approach to the stochastic VRP with dependent demands
Alexandre Florio, Stefan Minner, Richard Hartl

We present advances on the research on vehicle routing with stochastic demands under the a priori routing approach. The variant of the problem we study admits positively correlated (and thus dependent) demands, a behavior likely to be found in some practical scenarios, but rarely considered in the scientific literature. First we propose a demand model where all the demands are simultaneously affected by an external factor. Given the sequential nature of routing problems, we can update the knowledge over this factor each time a customer is visited and its true demand observed. This is accomplished by applying Bayesian learning methods. Based on the demand model we propose a stochastic dynamic programming algorithm to compute an optimal restocking policy. Such technique is common in a priori routing problems. In our case we augment the state set to incorporate the information about the external factor. We also generalize the traditional approach by considering unbounded demands. We formalize the finite-horizon Markov decision process behind the restocking decisions and the dynamic programming algorithm, and transform this model into an equivalent linear program. We add routing constraints to this linear program, and formulate the problem of finding the optimal a priori route considering the optimal restocking policy. Finally, we present some results and discuss the validity of our approach to obtain the best possible combination of one a priori route and one restocking policy.

2 - A stochastic vehicle routing problem with ordered customers and stochastic preferences and demands
Epaminondas Kyriakidis, Theodosis Dimitrakos, Constantinos Karamatsoukis

We develop and analyze a mathematical model for a specific vehicle routing problem that has many realistic applications. Specifically, we assume that a vehicle starts its route from a depot loaded with items of two similar but not identical products, which we name product 1 and product 2. The vehicle must deliver the products to n customers according to a predefined sequence. This means that first customer 1 must be serviced, then customer 2 must be serviced, then customer 3 must be serviced and so on. The vehicle has finite capacity and after servicing all customers it returns to the depot. It is assumed that each customer prefers either product 1 or product 2 with known probabilities. The actual preference of each customer becomes known when the vehicle visits the customer. It is also assumed that the number of items that each customer demands is a discrete random variable with known distribution. The actual demand is revealed upon the vehicle’s arrival at customer’s site. The demand of each customer cannot exceed the vehicle capacity and the vehicle is allowed during its route to return to the depot to restock with items of both products. The travel costs between consecutive customers and the travel costs between the customers and the depot are known. If there is shortage for the desired product it is permitted to deliver the other product at a reduced price. The objective is to find the optimal routing strategy, i.e. the routing strategy that minimizes the total expected cost among all possible strategies. It is possible to find the optimal routing strategy using a suitable stochastic dynamic programming algorithm. It is also possible to prove that the optimal routing strategy has a specific threshold-type structure.

3 - Exact Approaches for the Multi Depot Travelling Salesman Problem with Pickup and Delivery
Philipp E.H. Salzmann, Margaretha Gansterer, Richard Hartl

The Multi Depot Travelling Salesman Problem (MDTSPPD) is a special case of the Pickup and Delivery Problem (PDP) and the Collaborative Carrier Routing Problem (CCRP). For the CCRP, the solution of the MDTSPPD is the optimal solution assuming full collaboration. We aim at the generation of optimal solutions for the MDTSPPD, since they are valuable benchmarks for decentralized collaborative scenarios. To the best of our knowledge, there are no exact approaches applicable to the MDTSPPD available in the literature. Exact approaches proposed for PDPs commonly take a lot of advantage from time window and capacity constraints, which are not part of the MDTSPPD. We analyse the applicability of (i) Branch and Cut, (ii) Benders Decomposition and (iii) Column Generation for the proposed problem. We then solve MDTSPPD instances by Benders Decomposition based approach as well as a Branch and Cut approach based on valid (in-)equalities. The strengths and weaknesses of these approaches depending on the problem formulation are discussed.
Wednesday, 13:30-15:00

■ WC-02

Wednesday, 13:30-15:00 - Hörsaal 1
Recent Advances in Mixed-Integer Linear and Non-linear Programming (i)
Stream: Discrete and Integer Optimization
Chair: Dennis Michaels

1 - Maximum semidefinite extension complexity for families of polytopes
Gennadiy Averkov, Volker Kaibel, Stefan Weltge
We present a result that provides bounds on the maximum extension complexity (both linear and semidefinite one) for general families of polytopes. Various bounds on the maximum extension complexity of 0/1-polytopes and polygons can be derived by a straightforward application of this result.

2 - Valid linear inequalities and nonlinear cutting planes for MINLP
Stinke Behrends, Anita Schöbel
We consider the problem of minimizing a polynomial objective subject to polynomial and integrity constraints. Instead of solving the problem directly we investigate promising geometric properties of closely related sets: The set of all feasible solutions, its continuous relaxation and the set of all optimal solutions. Specifically, we search for half-spaces, seminorm balls and ellipsoids that encompass the aforementioned sets. As these objects correspond to linear and nonlinear valid inequalities, this can be reformulated into means of auxiliary programs. We give tractable relaxations for these auxiliary programs in terms of a hierarchy of sos programs. Also, we give necessary and sufficient conditions for the convergence of the optimal values of the hierarchies towards the optimal values of the auxiliary programs. In the case of nonlinear valid inequalities we may use arguments from (elementary) number theory that allow to tighten the inequalities further. This potentially cuts off points from the continuous relaxation, thus yielding a nonlinear cutting plane. Computational experiments show that this concept improves on earlier ideas and that the integrality arguments work in practice.

3 - Solving Mixed-Integer Nonlinear Programs with hierarchical Mixed-Integer Linear Programming relaxations
Lars Schewe, Robert Burlacu, Alexander Martin
We show how to use a hierarchy of MILP relaxations to solve MINLP, for this we solve coarse MILP relaxations of the MINLP and refine these adaptively. For the MILP on each level of the hierarchy we can give tight bounds on the relaxation error we are making. The main problem with approaches of this type was the lack of theoretical results for nonlinearities of higher dimensions. We extend prior work to give convergence results for different variants of the method and give a priori bounds on the required size of the MILP relaxations. To show the applicability of our method we present computational results on MINLP from gas network optimization.

■ WC-03

Wednesday, 13:30-15:00 - Hörsaal 2
Applied Mixed Integer Programming (i)
Stream: Discrete and Integer Optimization
Chair: Matthias Walter
Chair: Anja Fischer

1 - Solving an On-line Capacitated Vehicle Routing Problem with Time Windows
Christian Trudene, Philipp Hungerländer, Andrea Rendl, Kerstin Maier, Jörg Pöchert
The capacitated vehicle routing problem with time windows (cVRPTW) is concerned with finding minimal tours for vehicles to deliver goods to customers within a specific time window, respecting the maximal capacity of each vehicle. In this work, we consider an on-line variant of the cVRPTW that arises in the online shopping service of an international supermarket chain: customers choose a delivery time window for their order online, and the fleet’s tours are updated accordingly in real time. This means that the vehicles’ tours are incrementally filled with orders.

This leads to two challenges. First, the new orders need to be inserted at a suitable place in one of the existing tours. Second, the new orders have to be inserted in real time due to high customer demand. This is why we apply a computationally cheap, two-step approach consisting of an insertion step and an optimization step.

For the insertion step we first try a simple insertion heuristic. If unsuccessful, our heuristic is preceded by a mixed integer linear program (MILP) that is solved as a feasibility problem. The MILP models a single time window across all tours. Thus it exploits the special structure of the time windows in our application: each time window contains many orders, and all have the same length.

For the optimization step, we iteratively apply two exact approaches to different tours and time windows: the time window based MILP from above augmented by an objective function in order to minimize the sum of the travel time of all tours. And a MILP for the traveling salesman problem with time windows that optimizes single tours.

In an experimental evaluation, we demonstrate the efficiency of our approaches on a variety of benchmark sets.

2 - Solving the Timetabling Problem of University College London
Paul Alexandru Bucur, Philipp Hungerländer, Markus Aschinger, Kerstin Maier, Sam Applebee, Harry Edmonds

Course timetabling deals with scheduling lectures of a set of university courses into a given number of rooms and time periods, taking into account various hard and soft constraints. Since timetabling problems come in various forms, it is impossible to write a formulation that suits all cases, as every institution has its own features and conditions. However, the goal of the International Timetabling Competitions ITC2002 and ITC2007 was to establish models for comparison that cover the most frequently used cases. Our model, motivated by a project with University College London (UCL), is building on the standard model from track 3 of ITC2007. This has the advantage that we have lots of information on potential approaches and many benchmarking instances for checking the performance of our implementations against current state-of-the-art methods. Compared to the standard model from the literature, we cover several new constraints and extra features. For example, we distinguish between under- and postgraduate students and prioritize usage of the own department rooms. Furthermore, we also introduce new metrics such Timetable Regularity, which deals with maximizing the consistency of time and room for a course throughout the term, assuming that each week of the term has slightly different courses and rooms. We consider three solution approaches: a Mixed Integer Linear Programming model, a Boolean Satisfiability solver, and a genetic algorithm hybridized with a Tabu Search heuristic.

In our computational experiments we first benchmark our solvers against the traditional literature instances. Then we suggest benchmarking instances for the expanded problem. Finally we compare our solvers on this new set of benchmarks with respect to solving time and solution quality.

3 - Approaches for Virtual Network Embeddings Problems with Time Windows
Frank Fischer, Andreas Bley

The Virtual Network Embedding Problem (VNEP) aims at embedding virtual network services in physical substrate networks. A service consists of virtual computing nodes connected by virtual links. The virtual nodes are embedded in physical nodes, virtual links are embedded to paths on the substrate network. Each service has certain demands on the available physical resources as computing time or transmission bandwidth, and multiple services may be embedded onto the same physical infrastructure as long as the capacities are not exceeded.

In the classical VNEP typically all services are embedded at the same time and the goal is to reject as less services as possible. In practice, however, services are only embedded for a certain amount of time. We consider the VNEP with time windows, where each service has additional release and due times and has to be embedded for a certain amount of time. Thus, the aim is to find feasible embeddings and a feasible schedule of the services at the same time.
We present and compare different solution approaches based on time discretised models. The most successful approach is based on a Ben- der’s decomposition, where the master problem determines a feasible schedule and the subproblems ensure the existence of feasible simultaneous embeddings of services scheduled at the same time. With our approach we have been able to solve medium sized test instances from the literature to optimality for the first time within very short running times.

**WC-04**

**Wednesday, 13:30-15:00 - Hörsaal 3**

**Electric Mobility: Battery Technologies**

**Stream: Energy and Environment**

**Chair: Grit Walther**

1. **Stochastic Valuation of Battery Storage Systems in Second Life Applications**
   **Andreas Dietrich, Benjamin Böcker, Christoph Weber**

   Battery storage systems are seen as a promising, but costly technology for balancing electricity demand and supply in future energy systems with high shares of fluctuating renewables. Likewise electric cars are entering automotive markets in increasing numbers. Typically, batteries in automobile applications are replaced if their capacity has reduced to 70 - 80 % of nominal capacity. The remaining capacity could be used for other purposes, hence extending the utilization period and creating additional value. However, for investors it is hard to determine the economic value associated with the battery’s second life since future revenues are highly uncertain.

   This presentation focuses on stochastic valuation of battery storage systems in second life applications. The developed model is based on the Least Square Monte Carlo method, considering uncertainty in future cash flows. It allows for an economic assessment and comparison of different application cases. Deterioration of the battery over time is taken into account by modeling calendrical as well as cyclical aging effects. Compared to conventional approaches based on linear programming, the implementation of nonlinear technical relations is an additional advantage of the model. The results are shown for a selected storage system configuration in a typical application.

2. **Location Planning of Charging Stations for Electric City Buses Considering Battery Aging Effects**
   **Brita Rohrbeck, Kilian Berthold, Felix Hettich**

   Fuel prices on the rise and ambitious goals in environment protection make it increasingly necessary to change for modern and more sustainable technologies. This trend also affects the public transport sector. Electric city buses with stationary charging technology fit this development perfectly since they unburden cities from greenhouse gases and noise emissions. However, their technology and charging infrastructure is still costly, and a cost-optimal solution strongly depends on the batteries’ capacities as well as on the number and locations of charging stations. The usable capacity of a battery is again greatly influenced by aging effects due to time and usage.

   In our talk we discuss the parameters influencing the battery performance and deduce a capacity decrease function to incorporate the impact of battery aging. We revise shortly a basic mixed integer model that gives an optimal solution concerning the investment costs for a bus route with several buses and one time period. This model is then extended by multiple periods and battery technologies, and enhanced by a battery aging function.

   We give an overview of our results obtained from real world data of the bus network of Mannheim. Technology as well as costs for batteries and charging infrastructure underlie the technical progress and are supposed to improve significantly within the next years and decades. We therefore considered different scenarios for prices, capacities and battery aging factors.

3. **Integrated Planning of Charging Infrastructure for Battery Electric Vehicles considering Interdependencies with the Electrical Grid**
   **Barbara Scheiper, Maximilian Schiffer, Grit Walther**

   Battery electric vehicles as well as renewable energies contribute to sustainable development as they lead to clean and sustainable road transportation and energy supply. However, the introduction of both technologies results in new challenges within the energy and the transportation sector, and interdependencies between both sectors have to be considered. Thus, an integrated modeling approach regarding both sectors simultaneously is necessary to take advantage of possible synergies. So far, location models for charging stations and charging models for battery electric vehicles of the transportation sector do not sufficiently consider interdependencies with capacity planning and load management models of the energy sector. Against this background, we derive an integrated planning approach for charging infrastructure of battery electric vehicles considering interdependencies with the electrical grid. Our modelling approach, the Flow Refueling Location Problem with Load Flow Control, combines a charging station location model and a power flow model with integrated energy storages. We aim at determining a network configuration that satisfies the charging demand of battery electric vehicles, thereby simultaneously aiming at maximizing the usage of renewable energies in charging processes as well as at minimizing the additional load flow within the electrical grid. To highlight the impact of our modelling approach, we present results for novel benchmark instances focusing on the parameter variation of charging stations and different generation profiles of renewable energies.

**WC-05**

**Wednesday, 13:30-15:00 - Hörsaal 4**

**Behavioral Taxation (i)**

**Stream: Game Theory and Experimental Economics**

**Chair: Martin Fochmann**

1. **Tax Incidence in the Presence of Tax Evasion**
   **Philipp Dörrenberg, Denvil Duncan**

   This paper studies the economic incidence of sales taxes in the presence of tax evasion opportunities. We design a laboratory experiment in which buyers and sellers trade a fictitious good in double auction markets. A per-unit tax is imposed on sellers, and sellers in the treatment group are provided the opportunity to evade the tax whereas sellers in the control group are not. We find that the market equilibrium price in the treatment group is lower than in the control group. This difference is economically and statistically significant, and implies that sellers with access to evasion shift a smaller share of the statutory tax burden onto buyers relative to sellers without tax evasion opportunities. Interestingly, we find that sellers with evasion opportunities shift the full amount of their effective tax rate onto buyers. Additional experimental treatments show that the full shifting of the effective tax burden is due to the evasion opportunity itself rather than the evasion-induced lower effective tax rate.

2. **Does Legality Matter? The Case of Tax Avoidance and Evasion**
   **Jochen Hundsdorfer, Kay Blautius, Martin Jacob, Matthias Sünwoldt**

   Previous research argues that the law expresses social values and could, therefore, influence individual behavior independently of enforcement and penalization. Using three laboratory experiments on tax avoidance and evasion, we study how legality affects individuals’ decisions. We find that, without any risk of negative financial consequences, the qualification of tax minimization as illegal versus legal reduces tax minimization considerably. Legislators can thus, in principle, affect subjects’ decisions by defining the line between legality and illegality. However, once we introduce potential negative financial consequences, we observe no difference between legal and illegal tax minimization behavior. Only if we use moral priming to increase subjects’ moral cost do we again find a legality effect on tax minimization. Overall, this demonstrates the limitations of the expressive function of the law. Legality might be an important determinant of behavior only if we consider activities with little or no risk of negative financial consequences or if subjects are morally primed.

3. **Mental Accounting in Tax Evasion Decisions - An Experiment on Underreporting and Overdeducting**
   **Martin Fochmann, Nadja Wolf**
Although tax evasion costs governments worldwide trillions of US dollars, revenue bodies are increasingly confronted with reduced audit capacities. The decisions on whom to audit and what to audit therefore become essential to ensure tax evasion is combated effectively. Using different controlled experiments, we analyze whether taxpayers are more willing to evade taxes by underreporting income (i.e., declaring less than their actual income) than by overdeducting expenses (i.e., declaring more than their actual expenses) if the benefits and costs of evasion are kept constant. We robustly observe an asymmetric tax evasion behavior and find that tax authorities are advised to pay more attention to income reporting than to expense deduction. We show that this result can be explained by mental accounting and an asymmetric evaluation of tax payments and tax refunds in accordance with prospect theory. In an experimental environment in which we expect that mental accounting has no influence on behavior, however, the effect vanishes. This provides strong evidence that mental accounting plays an important role in tax evasion decisions.

Due to ongoing growth of traffic airports are constantly struggling to provide a sufficient service level for passengers. This primarily boils down to having an efficient strategy of sharing the given resources at an airport. Among these resources we find ‘gates’, ‘stands’, ‘check-in desks’, ‘baggage belts’, ‘security lanes’, ‘busses’, ‘towing trucks’ and ‘runways’. In this talk we will give a brief overview of how BEONTRA tackles these different resource-allocation-problems. We focus on two of those problems, the allocation of airplanes to gates and stands and the allocation of airlines to check-in desks. For both problems a short outline of a ‘Column Generation Approach’ will be given.

- **Price Optimization: From prediction to decision with Gurobi**
  Hannes Siebling

  In prescriptive analytics, optimization is a key part to turn decisions into decisions. At Blue Yonder, we are using Gurobi to deliver a large number of daily pricing decisions to our customers based on our price elasticity and demand models. In this talk, we will discuss the variety of high dimensional optimization problems that emerge in price optimization and give examples on how they can be solved using Gurobi. Furthermore we will address the question of balancing computational precision against computation time. This is a significant part of the optimization problem for us, as our problems are large and pricing decisions need to be done almost in real time.

- **Extension of Bouygues Telecom’s ADSL network**
  Julien Darlay, Frédéric Gardi

  Bouygues Telecom is a leading Internet service provider in France. Its broadband clients are connected by optical fiber or via an ADSL service by the telephone line. This line has one end at the subscriber and one end in a subscribers connecting nodes (NRAs). The customer is then connected either to Bouygues Telecom’s equipment or a third party’s equipment. In the first case, Bouygues Telecom must invest to install its equipment in the impact of an incident. This resulting problem is NP-hard, while instances to solve in practice have a large scale: 15,000 nodes, 180,000 edges. Then, we present a heuristic solution approach based on LocalSolver.

  The software was used by Bouygues Telecom to plan and optimize unbundling campaigns. Since our optimization software was delivered in July 2014, Bouygues Telecom has unbundled 500 new NRAs in addition to the 700 ones they already operated. This unbundling strategy allows Bouygues Telecom to offer low-cost ADSL to a much larger customer base, contributing to gain 500,000 new clients over the last year and then to reach a total number of 2.5 million ADSL clients.

- **Airport Resource Management using the ‘BEONTRA Scenario Planning Suite’**
  Daniel Binkle-Raible

  Production decisions are distributed throughout a supply chain. In order to minimize the total cost of a supply chain, multiple agents have to coordinate their decisions. In this setting, our focus is on a distributed capacitated multi-level lot-sizing problem which has to be jointly solved by multiple agents. To solve this problem, we developed a negotiation scheme. Agents negotiate a contract which consists of delivery dates for each item. Rotationally, agents propose contract modifications. Based upon a given contract proposal, an agent identifies an item with a high potential for cost savings within her schedule. She proposes a corresponding modification of the contract; the other agents re-evaluate the modified contract and indicate their preferences for it via voting. Concurrently, each agent reveals changes in her local costs. Based on these, payments are collected which can be used to compensate some agents for deviating from their local optimum. In order to calculate the actual side payments, a technique from cooperative game theory is used to calculate the actual side payments.

- **A Collaborative Filtering Approach to Fit Prediction**
  Josef Feigl

  OTTO.de is one of the largest online retailer for fashion in Germany. The fashion segment suffers from high return rates, often caused by customers choosing an inappropriate size or by orders of the same product in different sizes. The decision process to find the correct size is often difficult and fuzzy. Typical instruments to help customers, like conversion tables, are often complicated or simply not very helpful. The Otto Group’s Business Intelligence unit developed a service based on collaborative filtering techniques to help customers in this difficult decision process to find their correct size. This talk will give a walk through on the modelling, evaluation and deployment process of this service.
3 - Credible information sharing in supply chains - A behavioral assessment of review strategies

Guido Voigt, Stephan Schosser, Bodo Vogt

In laboratory experiments, we compare the ability of trigger strategies with that of (relatively complex) review strategies to coordinate capacity decisions in supply chains when demand forecasts are based on private information. While trigger strategies punish apparently uncooperative behavior (misstated demand forecasts) immediately, review strategies only punish when apparently misstated information culminates over several periods. We contribute to the existing literature on capacity coordination in supply chains by showing that repeated game strategies lead to a significant degree of forecast misrepresentation, although they theoretically support the truth-telling equilibrium. However, forecast misrepresentation is more pronounced in review strategies. This behavioral effect is diametrically opposed to the theoretically predicted benefit of review strategies.

■ WC-08

Wednesday, 13:30-15:00 - Seminarraum 101/103

Cross Docking and Stochastic Approaches

Stream: Logistics, Routing and Location Planning
Chair: Lars Eutinger

1 - Combining mathematical optimization with discrete-event simulation to improve cross docking operations

Daniel Diekmann, Uwe Clausen, Lars Eutinger, Gülgün Alpan, Anne-Laure Ladier

Cross docking is a logistic technique which seeks to reduce the inventory holding and transportation costs as well as delivery time. In order to successfully operate a cross docking terminal, different resources - such as vehicles and workers - need to be scheduled, allocated and synchronized in the best possible way. Several models have been developed which mainly use either mathematical optimization or (discrete-event) simulation. Simulation-based approaches allow a very realistic modelling of cross docking facilities. Complex processes can be implemented in detail including stochastic behaviour. However, finding the best system configuration is very difficult and time-consuming since there are usually many strategies and configurations that need to be evaluated. In contrast, approaches that are based on mathematical optimization have the ability to make complex decisions and find (near) optimal solutions. But to solve real world logistic problems they are usually implemented on a lower level of details and without stochastic behaviour. Joint optimization and simulation approaches have recently been proven promising and are therefore getting increasingly relevant to handle complex industrial planning and scheduling problems. This work discusses different methodological approaches to combine mathematical optimization and simulation in order to make use of their complementary advantages. Potential options for linking both modelling paradigms are presented. In addition to that, modelling issues and technical aspects are shown by different application examples.

2 - Two-Stage Stochastic Truck Assignment and Scheduling in Crossdocking Terminals using Hybrid Evolutionary Optimization

Lars Eutinger, Uwe Clausen

Cross docking is a warehouse management concept in which goods delivered to a warehouse by inbound trucks are immediately sorted out, reorganized based on customer demands and loaded into outbound trucks for delivery to customers, without requiring excessive inventory at the crossdocking terminal. Compared to traditional warehousing, the storage as well as the length of the stay of a product in the warehouse is limited, which requires an appropriate coordination of inbound and outbound trucks. Many uncertain factors influence the planning. Especially fluctuations in the arrival times of vehicles have great impact on the planning process. To handle the occurring uncertainties we use a two-stage stochastic mixed-integer program, which is handled by a stage-decomposition based hybrid algorithm. An evolutionary algorithm determines the first-stage decisions and mathematical programming determines the second-stage decisions. In the two-stage model for the truck assignment and scheduling problem, the assignments of the trucks to the gates are used as the first stage decision variables. All remaining variables, e.g. the assignment times of the trucks, are the second stage decision variables. Which means, in the first stage, a gate assignment is determined. The quality of the assignment is evaluated in the second stage, where the assignment times and the transports of the goods inside the facility are determined for the given scenarios.

■ WC-09

Wednesday, 13:30-15:00 - Seminarraum 105

Finance II

Stream: Finance
Chair: Marco Wilkens

1 - Applying a Novel Investment Evaluation Method with Focus on Risk - A Wind Energy Case Study

Jan-Hendrik Piel, Felix Humbert, Michael H. Breitner

Renewable energy investments are typically evaluated using traditional discounted cash flow methods, such as the net present value (NPV) or the internal rate of return (IRR). These methods utilize the discount rate as an aggregate proxy for risk and the time value of money, which leads to an inadequate modelling of risk. An alternative to these methods represents the decoupled net present value (DNPV): a novel and practical concept for decoupling the time value of money from the risk associated with investments. Instead of accounting for risk in the discount rate, the DNPV utilizes so-called synthetic risk premiums. These allow for individual and disaggregate pricing of risk and enhance the quality of investment decisions due to a more detailed and comprehensive representation of the underlying risk structure. After reviewing the main theory of the DNPV, we apply the method to a wind energy investment case in order to demonstrate its applicability and prospects. For this purpose, we use a cash flow model in the programming environment MATLAB. To illustrate the calculation of the synthetic risk premiums, selected risk factors are modelled with probability distributions via Monte Carlo simulation. Our results show that the DNPV’s seamless appropriation of risk assessment with investment evaluation is a very promising combination and warrants further research.
2 - Are Momentum Strategies Feasible in Intraday-Trading? Empirical Results from the German Stock Market
Matthias Horn, Tim Herberger, Andreas Oehler

Momentum trading strategies have been proved to be profitable in different asset classes and on various national capital markets in the past. However, there are some indications for eroding momentum profits. Based on the theory of gradual information distribution on capital markets and the technological progress of the last years, we suppose that the momentum effect transformed from a monthly basis to shorter time horizons. With regard to stocks that were listed in the German blue chip index DAX 30 between November 2013 and December 2014, this study is the first to examine, whether such strategies generate market adjusted excess returns on an intraday-trading basis. We analyze 16 momentum strategies, inspired by Jegadeesh/Titman (1993) and Jegadeesh/Titman (2001) original momentum strategy design (4x4), with ranking and holding periods of 15, 30, 45 or 60 minutes. For each stock, we analyze 27,219 price observations on a five minutes frequency. From the empirical results we conclude that momentum strategies do not provide positive excess returns. However, we find indications for price reversals in intraday stock market returns for past loser stocks. Our results are robust on portfolio size (winner- as well as loser-portfolio), on the duration of the lag between the ends of the formation ranking periods and the beginnings of the holding periods as well as on the influence of trading-time and on the market price trend.

3 - Quantification and Management of Carbon Risks of Stocks and Stock Portfolios
Marco Wilkens, Martin Nerlinger

Today there is no doubt about climate change mainly driven by carbon emissions and equivalents (IPCC Fifth Assessment Report, 2013). This leads to many new legislations and regulations worldwide aiming the 2°C target, agreed between 195 nations at the 21st Conference of the Parties in Paris (2015). The corresponding and already started transformation process towards a “Green Economy” affects nearly all parts of the society and the whole economic system including the financial systems. Our paper helps to identify and manage the risk for stocks and stock portfolios, related to this transformation process of the economy, the so called “carbon risk”. The relevance of carbon risks can already be seen in “stranded assets” and the “carbon bubble” (Carbon Tracker Initiative, 2011). Since carbon risk is a kind of systemic risk, it is highly relevant not only for single companies or investors, but for the whole financial system (ESRB, 2016). Based on the Fama and French’s three-factor model (1993) and Carhart’s four-factor model (1997), we introduce, estimate and verify a new factor model including a set of carbon risk factors, derived from carbon dioxide emissions and diverse other fundamental data of more than 2,000 companies worldwide. Applying this factor model we are able to quantify the carbon risk of potentially all stocks and stock portfolios worldwide. Using an out-of-sample hedging approach we further show that our model enables to hedge large parts of the carbon risk of stock portfolios. Over all our paper support investors and funds as well as regulators and politicians to comprehend and manage the risks for financial assets due to the worldwide started transformation process towards a “Green Economy” originating by climate change.

2 - A Method for Solving Multiple Integer Linear Programming Stochastic Problem
Meberek Fatma, Chaabane Djamal

In this paper we study the problem of optimizing an aggregate function over an integer efficient solution set of a Multiple Objective Integer Linear Programming Stochastic problem (MOILPS). Once the problem is converted into a deterministic one by adapting the two-levels recourse approach, a new pivoting technique is applied to generate all efficient solutions. The combination of both approaches, L-Shaped and the aggregation of objective method, enables us to produce the whole set of all non-dominated stochastic integer solutions.

3 - Solving Combinatorial Min-Max Regret Problems with Non-Interval Uncertainty Sets
Marc Goerigk, André Chassein

In min-max regret optimisation, the most widely used uncertainty sets are intervals (hyperboxes). They have the advantage that finding a worst-case scenario for a given solution is easy, and even allow compact reformulations as a mixed-integer programme if the original problem can be formulated as a linear programme.
In this talk we consider different uncertainty sets, which are relevant in practice, but so far have not been considered in min-max regret. We consider the problem complexity, present an approximation algorithm, and discuss exact solution approaches. Different approaches are compared in numerical experiments.

WC-10
Wednesday, 13:30-15:00 - Seminarraum 108
Robust algorithms
Stream: Optimization under Uncertainty
Chair: Marc Goerigk

1 - MIp-based approaches for robust storage loading problems with stacking constraints
Thanh Le Xuan, Sigrid Knust

We consider storage loading problems under uncertainty where the storage area is organized in fixed stacks with a limited height. Such problems appear in several practical applications, e.g., when loading container terminals, container ships or warehouses. Incoming items arriving at a partly filled storage area have to be assigned to stacks regarding that not every item may be stacked on top of every other item and taking into account that some items with uncertain data will arrive later. Following the robust optimization paradigm, we propose different MIP formulations for the strictly and adjustable robust counterparts of the uncertain problem. Furthermore, we show that in the case of interval uncertainties the computational effort to find adjustable robust solutions can be reduced. Computational results are presented for randomly generated instances with up to 480 items. The results show that instances of this size can be solved in reasonable time and that including robustness improves solutions where uncertainty is not taken into account.

WC-11
Wednesday, 13:30-15:00 - Seminarraum 110
Lot Sizing
Stream: Production and Operations Management
Chair: Florian Isenberg

1 - Integrated safety stock placement and lot-sizing in capacitated production networks
Tarik Aouam, Kunal Kumar

In capacitated production networks, strategic safety stock placement and tactical lot-sizing are typically treated as independent decisions when, in reality, they are linked through production cycle times (PCTs). On the one hand, PCT of a capacitated resource depends on lot-sizing and its congestion effects, on the other hand, the size and placement of safety stocks depend on the demand over a replenishment period that includes PCT. Therefore, treating safety stock placement and lot-sizing decisions as independent would erode the performance of production networks. In this study, we model and solve the integrated strategic safety stock placement and lot-sizing problem in the context of a capacitated production network facing uncertain demand of a single product. Each stage in the production network is modeled as a series of a raw-material inventory, a production workstations and a finished-goods inventory. We follow the guaranteed-service approach to model the safety stock placement problem, where stages are coordinated through quoted guaranteed service times. The finished goods inventory is assumed to operate under a periodic review base-stock policy, with a common review period between stages. The production station is modeled as a G/G/1 system with setup time and cost. An optimization problem that jointly determines the optimal lot-sizes and safety stock placement is formulated. Analysis of the problem allows us to establish bounds for lot-sizes, which are then used to develop an efficient dynamic program that solves the problem in polynomial time. Based on numerical experiments the efficiency of the algorithm and the value of integrating the two decisions are demonstrated and practical insights and recommendations are derived.
2 - Planned lead times, safety stocks, and lot sizing in capacitated production networks
Kunal Kumar, Tarik Aouam

The optimization of planning parameters in capacitated production networks facing supply and demand uncertainty is considered. Each stage includes a series of a raw-material inventory, an M/M/1 production workstation with batching and setup time, and a finished-goods inventory. The finished goods inventory operates under a periodic review base-stock policy, with a common review period between stages. Stages are coordinated through quoted guaranteed service times. In this setting, the size and placement of decoupling safety stocks depend on a replenishment period that includes random production cycle times. Batching or lot-sizing decisions have congestion effects, due to limited capacity, which affect mean and variance of production cycle times. To control the variability inherent in production cycle times, we use a production control policy with planned lead times and flexible capacity (overtime or subcontracting). Based on a planned lead time, the control policy sets the production rate proportional to the workload, and unlimited flexible capacity processes workload exceeding workstation capacity. In this way, the promised service time is guaranteed. While, higher planned lead-times reduce variability and increase inventory in the system, production flexibility incurs high costs. The problem of jointly setting safety stocks, lot-sizing and planned lead times to minimize the total operational cost subject to service time constraints is formulated and solved. We establish bounds for lot-sizes and planned lead-times and use these bounds to develop a dynamic program that solves the problem in polynomial time. Numerical experiments demonstrate the efficiency of the proposed algorithm and a sensitivity analysis on key parameters is carried out to provide practical insights.

3 - Lot sizing and scheduling for manufacturing with tooling machines
Florian Isenberg, Leena Suhl

Practically all manufacturing companies today face constant change. The growing globalization and the rapid technical development offer new opportunities and risks. Additional competitors and an intensified competition increase the pressure to act. Companies using tooling machines are no exception. The machines used by such companies to process metal are highly advanced but offer little potential for improvement. Batching or lot-sizing decisions have congestion effects, due to limited capacity, which affect mean and variance of production cycle times. To control the variability inherent in production cycle times, we use a production control policy with planned lead times and flexible capacity (overtime or subcontracting). Based on a planned lead time, the control policy sets the production rate proportional to the workload, and unlimited flexible capacity processes workload exceeding workstation capacity. In this way, the promised service time is guaranteed. While, higher planned lead-times reduce variability and increase inventory in the system, production flexibility incurs high costs. The problem of jointly setting safety stocks, lot-sizing and planned lead times to minimize the total operational cost subject to service time constraints is formulated and solved. We establish bounds for lot-sizes and planned lead-times and use these bounds to develop a dynamic program that solves the problem in polynomial time. Numerical experiments demonstrate the efficiency of the proposed algorithm and a sensitivity analysis on key parameters is carried out to provide practical insights.

2 - A VNS Approach for Solving the Maximum Dispersion Problem
Mahdi Moenei, Oliver Wendt

Consider a set of objects such that each of them has its individual (non-negative) weight. The objective of the Maximum Dispersion Problem (MDP) consists in finding a partition of this set into a predefined number of groups, such that the overall dispersion of elements assigned to the same group is maximized. Furthermore, each group has a target weight and the sum of the weights of all objects, assigned to the same group, needs to meet a specific interval around the target weight. The maximum dispersion problem can be formulated as an Integer Programming (IP) problem. However, the MDP is NP-hard and, consequently, difficult to solve by exact algorithms. In this work, we present Variable Neighborhood Search (VNS) heuristics for solving the maximum dispersion problem. In order to evaluate the efficiency of the proposed method, we test it on randomly generated instances and compare the results with the solutions of the standard IP solver Gurobi. According to the numerical results, for solving MDP, the VNS approach is more efficient than the Gurobi.

3 - Analyzing the order of neighborhood operators in an iterated Variable Neighborhood Search
Sandra Huber, Martin Josef Geiger

In an iterated Variable Neighborhood Search (VNS) decisions must e.g. be made about the number of neighborhood operators and what sequence should be applied. With the aim of determining a sequence for the Swap-Body Vehicle Routing Problem (SB-VRP), we propose an experimental setup to test and analyze the order of neighborhood operators in a VNS. The findings of the experiments show that the order matters. Without further adaption of the algorithm, and by only modifying the sequences of operators, best known solutions can be improved with a maximal improvement of 2.25% and an average improvement of 0.70%. These results are promising and recommend to spend some time on finding an encouraging sequence which enhances the solution quality. Experiments on benchmark instances are conducted and compared for the SB-VRP.
3 - Solving Disjunctive Optimization Problems by Generalized Semi-infinite Optimization Techniques
Oliver Stein, Peter Kirst

We describe a new possibility to model disjunctive optimization problems as generalized semi-infinite programs. In contrast to existing methods in disjunctive programming, our approach does not expect any special formulation of the underlying logical expression. Applying existing lower level reformulations for the corresponding semi-infinite program we derive conjunctive nonlinear problems without any logical expressions, which can be locally solved by standard nonlinear solvers. Our preliminary numerical results indicate that our reformulation procedure is reasonable.

**WC-14**

Wednesday, 13:30-15:00 - Seminarraum 206

Multiobjective Location and Routing Problems

Stream: Decision Theory and Multiple Criteria Decision Making
Chair: Kathrin Klamroth

1 - Modelling Outliers in Center Location Problems - A Multiobjective Perspective
Teresa Schnepper, Kathrin Klamroth, Michael Stiglmayr

Location models typically use the distances to all customer locations for the assessment of the service provided by a new facility. Particularly when locating central facilities, i.e. when using a center objective function, the optimal new location is sensitive to outliers among the customer locations that are located far away from the majority of customers.

We model the exclusion of very distant facilities in a center location problem by using k-max functions: Not the maximal, but the k-th largest distance should be minimized, with \( k = 1 \). The selection of a suitable value of \( k \) asks for a multiple objective analysis of the problem. We show that the complete non-dominated set of this biobjective optimization problem (number of outliers versus original objective function value) can be determined in polynomial time. We particularly focus on weighted problems, where customer locations are weighted according to their relative importance. We discuss strategies of incorporating weights in k-max location problems.

2 - Optimally solving the TSP on acyclic networks with soft due dates and multiple congestion scenarios
Stefan Bock

In this talk, an extension of the well-known Line-TSP is considered. In this extension, an optimal schedule is sought that services all customers by using an acyclic system of predetermined transportations. In order to deal with unreliable data, different congestion scenarios are integrated. These scenarios are determined by specific travel times. Moreover, each customer possesses a soft due date. Although a violation of due dates is possible, it is assumed that the cost effect of the resulting tardiness is significant. Therefore, the hierarchical objective function pursues the finding of a tour schedule that primarily minimizes the total tardiness over all scenarios. As a secondary objective, the makespan of the schedule is minimized. This talk analyzes the complexity status of different variants of the model. While the NP-hardness is proven for some variants, an efficient pseudo-polynomial solution approach is proposed for cases in which processing times at the delivery locations are negligible in comparison with the travel times and the numbers of scenarios and transportation paths are constant.

3 - Optimal placement of weather radars network as a multi-objectives problem
Redouane Boudjemaa

In this work we propose an approach to the optimal site locations for the installation of weather radars as a solution to a multi-objective optimization problem. By considering a finite number of weather radars and a restricted geographical region, different network architectures are produced by taking into account different objectives simultaneously such as the maximization of network coverage area, minimization of network general cost, and the reduction of environmental impact. Constraints on the solutions are considered such as topography obstacles, maximum radar beam elevation and distance from wind farms. Multiple geographical information system data sets are used in the analysis of different sites locations and as a result a more realistic network is generated. The search space is discretized into a grid system which allows a reduction in the number of possible combinations of radar networks and thus effectively making the optimal placement problem manageable in size and execution time. Evolutionary methods are utilized in solving the multi-objective optimization problem. The obtained results are analyzed using different performance metrics. Different combinations of different types of radars spread in different topographies are also considered in this work. By producing different set of Pareto optimal solutions, the proposed approach can serve as an analysis tool for meteorologist and climatologist in the selection of future prime sites for the installation of weather radars.

**WC-15**

Wednesday, 13:30-15:00 - Seminarraum 305

Scheduling Problems and Applications (I)

Stream: Project Management and Scheduling
Chair: Edhem Canakoglu

1 - ILP-based Modulo Scheduling for High-level Synthesis
Julian Oppermann, Andreas Koch, Melanie Reuter-Oppermann, Oliver Sinnen

A high-level synthesis system automatically compiles a sequential C program into a hardware accelerator to be realised on a field-programmable gate array (FPGA). In this context, loop pipelining is a technique to improve the throughput of these accelerators by starting new loop iterations after a fixed amount of time, called the iteration interval (II), allowing to overlap subsequent iterations. The problem is to find the smallest II and corresponding operation schedule that fulfills all data dependencies and resource constraints, both of which are usually found by modulo scheduling.

We present Moovac, an ILP formulation for the modulo scheduling problem based on overlap variables to model exact resource constraints and compare it to the state-of-the-art Modulo SDC heuristic. We examine kernels from the CHStone and MachSuite benchmarks, scheduling them for loop pipelining using both Moovac and Modulo SDC, and compare the results. Moovac has competitive performance in its time-limited mode, and delivers better results faster than the Modulo SDC scheduler for some loops. Using the Moovac-computed optimal solutions as a reference, we can confirm that the Modulo SDC heuristic is indeed capable of finding optimal or near-optimal solutions for the majority of small- to medium-sized loops. However, for larger loops the two algorithms begin to diverge, with Moovac often being significantly faster to prove the infeasibility of a candidate II. This can be exploited by running both schedulers synergistically, leading to a quicker convergence to the final II. We will also discuss possibilities to determine the minimal II together with the optimal schedule.

2 - Audit Scheduling in Banking Sector
Edhem Canakoglu, Ibrahim Muter, Onur Adanur

The scheduling of activities in an organisation has been an interesting topic in the literature. The problems include a set of tasks to be performed, resources used in performing the tasks, and some certain constraints (resource capacity, time limitations, etc.). One variation of these problems is the assignment and scheduling of the activities in an audit environment, which is called audit staff scheduling in general.

The firms in financial sector are required to carry on regular audit activities for the local branches. The audit plan is done semi-annually and the audit team visits are scheduled for the upcoming period. Usually, in this type of problem, there is a set of auditor with different capabilities, and a bunch of branches corresponding to the activities, and the time limitations as deadlines and flow times. The team assigned to the branch should have enough skill level for the branch. The objective of this problem is to assign the teams of staff to branches for a given time period in order to audit maximum number of branches. The problem size increases exponentially as the size of audit department, number of branches and length of the planning horizon increases. Therefore we propose different heuristic methods for the solution of problem and compare the results of these approaches.
Appointment Scheduling

1 - Strategies for Improving Block Appointment Schedules at Specialty Clinics
Rajesh Piplani, Eva Fancévy

Appointment scheduling is used by specialty care clinics to manage access to the most critical resources in the clinic. Many factors affect the performance of appointment scheduling systems, including arrival and service time variability, patient no-shows, walk-ins, and emergency cases. The goal of a well-designed appointment system is to deliver timely access to clinic’s services, while maximizing the utilization of clinic’s critical resources. Appointment management for specialty care clinics is made more challenging due to the fact that the clinic may have to reserve capacity for urgent cases, referred by general practitioners, while ensuring high utilization of more expensive specialists’ time. Most appointment systems follow a multiple block schedule where a fixed number of patients are given appointment in each block during the day, each day being divided into certain number of blocks. While this ensures that a certain number of patients are always waiting for the specialist, ensuring their high utilization, the service time variability and cancellation and walk-ins complicate the management of patients’ waiting times. In this research, we investigate strategies to improve traditional block appointment schedules by segregating different categories of patients and scheduling them on different days or at different times of the day. We study the operations of a specialty eye-care clinic, collect detailed data on patients processing over a week, and analyse improvements to segregated block schedules by means of a detailed simulation model of the clinic.

2 - Interday appointment scheduling and capacity allocation in primary care
Matthias Schacht

Patient occurrence per weekday varies significantly in primary care. This is due to the differing number of walk-in patients (walk-ins) during a week who seek for a same-day treatment. Such walk-ins join the practice of a primary care physician (PCP) especially at the beginning of the week. In addition to walk-ins there are patients who book their appointments in advance (preschedules). For preschedules who prefer a given appointment on a specific time and day, appointment slots are provided. By offering appointment slots on days with a small expected amount of walk-ins, capacity and demand for treatment can be matched leading to a more balanced utilization for the PCP and to lower waiting times for patients. First concepts of interday appointment schedules exist in literature and increase patient as well as PCP satisfaction to a limited extent. While the occurrence of preschedules can be assigned to appointment slots, walk-in patients join the clinic uncontrolled. Because of this the capacity for treatments should be matched with demand which cannot be completely scheduled. Thus, we extend current interday appointment scheduling models by integrating capacity adjustments in terms of varying clinic opening hours. We present a concept for an extended MILP whose optimal solutions on the tactical level are evaluated in an extensive simulation study on the operational level where uncertain patient occurrence, treatment times and emergencies are considered. It is shown that slightly adjusting opening hours with respect to treatment demand has an impact on patient as well as on PCP objectives, while overall capacity is kept constant.

3 - Scheduling appointments based on probabilities for patient’s presence
Manuel Glaser, Jens Brunner

Optimizing appointment schedules without considering the variability of service times leads to a valid but only in rare cases feasible solution. Treatment durations, which are shorter than expected, cause idle times of medical personal and resources. Longer than expected treatment durations shift the start time of subsequent treatments into the future and cause additional waiting times for patients. The introduced model uses the probabilities of patient’s attendance to optimize a complete appointment schedule. Therefore, treatment periods are partitioned in several time slots. For each slot, the probability for patient’s presence during a treatment period are calculated based on a treatment durations representing cumulative distribution functions. The optimization shifts the appointments to slots where the respective probabilities for patient’s presence is balanced concerning to the weighted idle and waiting times. We show first experimental results to demonstrate the approach.

Supplier Selection and Closed-Loop Supply Chains

Stream: CANCELED

Truck and Trailer Routing

Stream: Logistics, Routing and Location Planning
Chair: Joachim Kneis

1 - Solving a Rich Intra-facility Steel Slab Routing Problem
Biljana Roljic, Fabien Tricoire, Karl Doerner

We optimize the routing of steel slabs between locations in a steel producing facility during a one hour-long operational period. Steel slabs are heterogeneous items that appear at locations at different release times. Each slab should be delivered to another location before its specified due time. They are transported by fleets that include standard vehicles as well as truck-and-trailer type vehicles. Due to incompatibilities between slabs and vehicles, not every vehicle type can transport all types of slabs. The vehicles visit several locations multiple times. Also, it is feasible to simultaneously transport multiple slabs. The input is such that not all slabs can be delivered in time, therefore two objective functions are provided that are organized in a lexicographic fashion: First, we maximize the throughput. Second, we aim to minimize travel times. We provide a mathematical formulation for our routing problem. An exact solution can only be obtained for small problem settings. In order to solve larger instances, we developed a heuristic. The results show that the solutions obtained by the heuristic are competitive to real world solutions provided by our industrial partner.

2 - Branch-Price-and-Cut for the Truck and Trailer Routing Problem with Time Windows
Ann-Kathrin Rothenbächer, Michael Drexl, Stefan Irnich

We consider the truck-and-trailer routing problem with time windows (TTRPTW). The fleet consists of several lorries which may attach a trailer. As some customers are not accessible for a lorry with the trailer attached, the trailers can be parked at customer sites or additional transshipment locations. When a lorry returns to its trailer after a subtour, load can be transferred from the lorry to the trailer. We extend the TTRPTW planning horizon to two days and allow customers to be visited either on both days or on only one day (in which case twice the daily supply must be collected), and we consider that the time needed for a load transfer depends on the quantity of load transferred. We tackle the problem with an exact branch-and-price-and-cut algorithm and generate the columns with a label-setting algorithm. The pricing procedure uses many known acceleration techniques, e.g., a bidirectional labelling, the ng-neighbourhood, reduced networks and relaxed dominance. Moreover, we separate subset-row inequalities to strengthen the lower bounds. Computational studies show that our algorithm compares favourably with existing approaches on TTRP and TTRPTW benchmark instances known from literature.

3 - A Rich Truck and Trailer Problem arising in the Steel Industry
Joachim Kneis

In this talk, we introduce a rich Truck and Trailer problem that arises in the steel industry. Huge steel coils are repeatedly refined until they are ready for shipment. After each refinement step, the coils are loaded onto a waiting trailer. Once the trailer is full, it is moved by a special truck to next refinement point. There, the trailer is decoupled from the truck and remains stationary until unloaded while the truck can move
on to handle some other trailer. The truck itself can never be loaded directly.

In this setting, we need to compute not only tours for the trucks, but also have to decide how trailers are moved and which trailers are used for which coils. This is important as docking space for trailers is very limited and emptied trailers thus need to be moved out of the way quickly. Moreover, providing fresh empty trailers for loading and moving loaded trailers to the next positions quickly is required to avoid production bottlenecks. Finally, efficient usage of the trucks is paramount as these have large operational costs.

Although typical real life instances are rather small compared to other routing problems, this problem is of huge importance as the involved costs can reach several hundred million dollars per year. Here, we discuss an algorithm for this problem that is implemented in a real time optimization developed by INFORM and its application at one of our customers.

### WC-19
Wednesday, 13:30-15:00 - Seminarraum 403

**Delay Management and Re-Scheduling (i)**

**Stream:** Traffic and Passenger Transportation

**Chair:** Sander Van Aken

1. **Strategic Deconfliction in the European Air Traffic Flow Management Network with Column Generation**
   **Jan Berling, Alexander Lau, Volker Gollnick**

   In the European Air Traffic Flow Management, en-route conflicts between aircraft may be avoided strategically. One option for strategic deconfliction is the allocation of alternative departure-timeslots. To find the best slots for all flights, we solve a Binary Integer Problem. In this problem, each flight is associated with linear delay costs and a departure condition. Furthermore, flights have to satisfy sector and aerodrome capacity constraints. Since conflicts involve at least two flights, there is a coupling between variables. Each potential conflict is modelled by a linear constraint, which assigns conflict costs by setting a conflict variable. However, conflict constraints of Ip-relaxed variables do not trigger their conflict costs. Therefore, branch-and-bound nodes do not contain costs for relaxed conflicts, which weakens lower bounds. With a conventional solver, the deconfliction of a full-day of European air traffic takes approximately one hour. To reduce the computation times of the Network Flow Environment (NFE), we extend the pricing algorithm to perform deconfliction. This method of column generation is initiated with only a subset of possible departure-timeslots and includes more slot-options iteratively. Promising variables with reduced costs are discovered by pricing dual variables. Conflicts increase dual departure costs and thereby boost the search of alternative departure-timeslots for conflicted flights. The column generation method reduces computation times for the optimal solution of a problem with over twenty-five thousand flights by more than eighty percent.

2. **Computing alternative railway timetables to deal with infrastructure maintenance works**
   **Sander Van Aken, Nikola Besinovic, Rob Goverde**

   Increasing supply in railway networks comes at the cost of an increased need for infrastructure maintenance. Up until now, not much research has been devoted to adjusting the timetable due to long maintenance or construction’s possessions. In this article, we introduce the Train Timetable Adjustment Problem (TTAP), which for given station and open track closures, finds an alternative timetable that minimizes the deviation from the original timetable. We propose a mixed integer linear programming (MILP) model for solving TTAP, and apply retimeing, reordering, short-turning and cancellation to generate alternative timetables. The model represents an extended periodic event scheduling problem (PESP) formulation and introduces new constraints for cancelling and retiming train lines, while short-turning is being applied in a preprocessing step. In order to solve larger and more complex instances, we use a row generation approach to add station capacity constraints. The model solves real-life instances for a large area of the Dutch railway network in reasonable time, and could be up-scaled to the complete Dutch network. Operators and infrastructure managers could use it to automatically generate optimal alternative timetables on the macroscopic level in case of maintenance or construction works and thus coordinating traffic for the complete network.

### WC-20
Wednesday, 13:30-15:00 - Seminarraum 404

**Smart Services and Internet of Things**

**Stream:** Business Analytics and Forecasting

**Chair:** Johannes Kunze von Bischoffshausen

**Chair:** Maria Maleshkova

1. **Realising Smart Services Through Intelligent Interfaces**
   **Maria Maleshkova**

   Current developments in the context of the lifecycle of services are strongly influenced by new technology developments and the need for ensuring market competitiveness. Technology trends that shape the market are the proliferation of sensor technologies, and the availability of mobile devices and wearables, which enable the direct integration of their data as part of client applications. These, in combination with the overall data digitalization, lay the foundation for offering new smart services. However, despite the existing potential, currently, the actual technical implementations are usually isolated custom solutions for particular use cases, which cannot be integrated and used together, and do not support further scenarios. To this end the vision of the Web of Things (WoT) aims to leverage Web standards in order to interconnect all types of devices and real-world objects, and thus to make them part of the World Wide Web. We take this approach one step further and introduce the concept of intelligent programmable interfaces that do not only provide remote access to resources and functionalities, but also encapsulate ‘intelligence’. Smartness features can include, for instance, context-based adaptation, cognition, inference and rules that implement autonomous decision logic in order to realize services that automatically perform tasks on behalf of the users. This intelligence is implemented directly as part of the interface, instead of relying on the client or on the server to provide it. As a result, the intelligent interfaces can be used as building blocks for developing adaptive, flexible, and customizable systems. We describe in detail the key characteristics of the intelligent interfaces, and introduce a reference implementation framework.

2. **Towards Smart Services based on Distributed Architectures**
   **Felix Leit Keppmann**

   Current technological developments have a twofold impact on the development of Smart Services. On the one hand, a large and increasing amount of services, in particular Smart Services, depends on and, subsequently, is not realizable without integrated support of computer and Internet-based technologies. On the other hand, software applications and hardware systems become smaller, more modularized, and distributed (e.g., heterogeneous sensors, smart devices). While this trend lays the foundation for the development of a multitude of new Smart Services, it also introduces additional complexity - individual components have to be composed to form distributed applications. This situation is aggravated by the fact that currently, while developing distributed solutions, only interfaces and interactions covering common use cases, are supported, while requirements of specific use cases (e.g., enabling particular Smart Service) are difficult to realize. Our goal...
is to reduce this complexity and to enable the adaptability of systems to specific use cases. We introduce an architecture for Smart Web Services, which enables the adaptation of service-based applications to the requirements of specific use cases at runtime. In addition, we present a reference implementation of this architecture, based on a combination of widely accepted Web standards and Semantic Web technologies. Our approach introduces a layer between the local functionality/data of an application and the interface, it exposes. This layer is capable to process declarative rule-based programs that can dynamically adjust the interface and interaction during deployment or runtime, based on the requirements of the herewith implemented Smart Service.

3 - Business analytics for managing uncertainties in industrial service contracts

Michael Vössing, Björn Schmitz

The industrial sector is experiencing a service transformation. Equipment providers strengthen their service business and move from product-centric spot transactions towards long-term service contracts and relational business models. While services promise continuous revenue streams, higher profitability and tighter customer relationships, many manufacturing companies still refrain from servicing their business. Recent studies suggest that the increasing exposure to uncertainties is a major reason why providers hesitate to engage into longer-term service contracts. In such contracts, providers take over responsibilities and uncertainties from their clients. For instance, in full service maintenance contracts, providers bear the cost for maintaining or repairing their clients’ equipment regardless of the number or severity of failures occurring. From a research perspective, contributions to uncertainty management in service contracting are scarce. There is a lack of methods which allow to evaluate uncertainties and to quantitatively assess their impact on business. However, business analytics provides ample opportunities for reducing uncertainty - by supporting its quantitative measurement and by assisting to identify cause-effect relationships among influencing factors. Based on the use-case of maintenance services, we investigate how analytics can contribute to a quantitative assessment of uncertainty. Subsequently, we develop strategies to improve the design of service contracts in order to reduce providers’ exposure to uncertainty or to mitigate its business impact. Linking capabilities in data analytics to decision sciences, our research contributes to improving contract design and to promote service-based value propositions in the industrial sector.

4 - Field Technician Scheduling 4.0

Johannes Kunze von Bischoffshausen, Michael Vössing

Technician scheduling problems have been studied in operations research for decades. Classical modeling of field technician scheduling problems includes different types of jobs (repair, maintenance, installation) and different technician skills. Furthermore, classical optimization models take different time windows where jobs have to be started, different locations of jobs, as well as prioritization into account. With the rise of the Industrial Internet of Things and Industry 4.0, more and more sensor data is captured from assets which need to be repaired, maintained or installed by field service technicians. Predictive maintenance, using sensor data for forecasting required maintenance of assets, is becoming one of the major fields of application in Industry 4.0. However, little research has been conducted on how to leverage predictive maintenance for field technician scheduling. We propose a research agenda towards leveraging the potential of Industry 4.0 for field service technician scheduling. This requires implementing an analytics IT-infrastructure for integrating and analyzing high-frequency sensor data, predictive analytics for forecasting required maintenance actions, and prescriptive analytics for determining maintenance schedules. This will enable industrial firms to increase the availability of their assets, decrease maintenance costs, and implement new business models such as full-service contracts.

Christian Tilk

Many governments worldwide have imposed hours of service regulations for truck drivers to avoid fatigue-related accidents. These regulations ensure that break and rest periods are regularly taken, i.e. they define a minimum amount of break and rest times for truck drivers as well as a maximum driving time between two break or rest periods. Transport companies have to take this into account and plan the routes and schedules of their truck drivers simultaneously. This problem is called vehicle routing and truck driver scheduling problem (VRTDSP).

Recently, Goel and Irnich (2014) presented the first exact approach for the VRTDSP. They include hours of service regulations in a vehicle routing problem with time windows and use a branch-and-price algorithm to solve it. Here, we present a sophisticated branch-and-price-and-cut algorithm for the VRTDSP that is based on the parameter-free auxiliary network and the resource extension functions (REFs) defined by Goel and Irnich (2014). We will extend their labeling algorithm by means of defining backward REFs in order to build a bidirectional labeling. To obtain feasible routes a non-trivial merge procedure is presented. The concept of using a dynamic halfway point and the ng-route relaxation (Baldacci et al., 2011) is used to speed up the solution process. In addition, different families of known valid inequalities are used to further strengthen the LP-relaxation of the master program. We will present a detailed computational study to analyze the impact of different techniques.

2 - A regulatory impact analysis of hours of service regulations in Europe

Asvin Goel

This contribution studies how different hours of service regulations impact road freight transport in the European Union. In Europe, hours of service of truck drivers must comply with Regulation (EC) No 561/2006 and the respective national implementations of Directive 2002/15/EC. Throughout the European Union, the night work provisions of the directive are differently implemented into national law. This contribution presents an adjustable model and solution approach that can be used to generate routes and schedules complying with these differing implementations. The approach is evaluated within an exact approach for the vehicle routing and truck driver scheduling problem. A regulatory impact analysis is conducted comparing the impact on costs and road safety of the routes and schedules generated by the proposed approach considering the different regulations in Europe.

3 - Truck Driver Shift Scheduling in Vehicle Routing with Time-Dependent Service Costs

Alexander Kleiff, Tobias Pröger

Our research is motivated by a real-life problem which shares the characteristics of three enhancements of the classical vehicle routing problem. The first enhancement is to expect a time-dependent service cost function for every delivery order as input, instead of hard or (still less general) soft time windows. Such a function reflects how inefficient the delivery is at a certain point in time. Vehicle routing with time-dependent service costs was first introduced as the vehicle routing problem with general time windows. While goods can be delivered anytime in any case, drivers cannot work an arbitrarily long time. Hence drivers alternate in shifts, i.e., every vehicle can be used multiple times per day. For a planning horizon of one day, usually three shifts and thus three trips are planned. This is the second enhancement, usually called the vehicle routing problem with multiple trips. As the third enhancement, we are given a maximum shift duration as input. So each trip must not exceed this duration. Also, drivers have to respect break and rest rules. For instance, the regulation 561/2006 of the European Union states that after driving for at most 4.5 hours, drivers have to take a break of at least 45 minutes. This constitutes (a variant of) the vehicle routing and truck driver scheduling problem. The combination of these three enhancements has not been studied before. In our talk, we will focus on the truck driver scheduling part of the problem.
Wednesday, 15:30-16:15

**WD-02**

**Semi-Plenary Miettinen**

Stream: Semi-Plenaries  
Chair: Kathrin Klamroth

**1 - Advantages of Interactive Multiobjective Optimization Methods Demonstrated with NAUTILUS Navigator enabling Navigation without Trading-Off**

Kaisa Miettinen

Multiobjective optimization is needed because most real-life optimization problems contain more than one objective function. The goal in multiobjective optimization is to find the best possible solution in the presence of several, conflicting objective functions. Using mathematical tools we can define a set of Pareto optimal solutions where none of the objective function values can be improved without impairing at least one of the others. However, we need additional preference information from a domain expert, a decision maker, to find the most preferred Pareto optimal solution as the final solution to be implemented. Multiobjective optimization methods can be classified according to the role of the decision maker in the solution process. We concentrate on interactive methods, where the decision maker takes actively part in the solution process and directs the search for the final solution according to her/his desires and hopes. This enables the decision maker to gain insight about the interdependencies of the conflicting objectives and learn about one’s own preferences. Typically, interactive methods deal with Pareto optimal solutions only and the decision maker must trade-off to be able to move from one Pareto optimal solution to another. To avoid this need of trading-off, a family of NAUTILUS methods has been proposed. In NAUTILUS, the interactive solution process begins from an inferior solution and the decision maker can gain improvement in all objective functions and direct the solution process until (s)he reaches the set of Pareto optimal solutions. In this way, (s)he can move more freely without anchoring around any solution. We introduce a new method called NAUTILUS Navigator which incorporates the NAUTILUS philosophy with elements of the Pareto Navigator method. With NAUTILUS Navigator, the decision maker can navigate in real time towards the set of Pareto optimal solutions and continuously see how the region of objective function values that are reachable without trading-off shrinks. The distance to the set of Pareto optimal solutions is also shown. Thanks to the graphical user interface, the information is available in an understandable form. The decision maker can provide preference information to direct the movement as desirable aspiration levels and bounds that are not to be exceeded. The decision maker can change the navigation direction at any time and even go backwards if needed. The NAUTILUS Navigator method is also applicable to computationally expensive problems where function evaluations are time-consuming. We demonstrate how the method can be applied with a three-objective optimization problem for identifying the improvements that can be carried out in the auxiliary services of a power plant in order to enhance its efficiency, taking into account energy savings and economic criteria.

**WD-03**

**Semi-Plenary Woeginger**

Stream: Semi-Plenaries  
Chair: Michael Juenger

**1 - New answers to old questions on the TSP**

Gerhard J. Woeginger

k-OPT is one of the most popular local search heuristics for the Travelling Salesman Problem (TSP). k-OPT tries to improve a suboptimal tour by removing k of the edges and by reconnecting the resulting tour pieces into a new tour by inserting k new edges. In the talk, I will mainly concentrate on the question whether a given tour is a local optimum for k-OPT (where k is some fixed, small number), and I will present a fine-grained complexity analysis of this problem.

**WD-04**

**Semi-Plenary Marklund**

Stream: Semi-Plenaries  
Chair: Stefan Minner

**1 - Sustainable Supply Chain Inventory Control**

Johan Marklund

The increasing environmental awareness drives a growing interest among companies for more sustainable supply chain operations. One important challenge is to reduce transportation emissions while minimizing total inventory and transportation costs for multi-stage systems. In this talk different aspects of this challenge are considered for distribution systems where a central warehouse replenishes a number of local warehouses or retailers. Particularly, we present a multi-echelon inventory control model incorporating volume dependent freight costs and emissions, shipment consolidation, and intermodal transport options. To emphasize the importance of a multi-stage perspective, we also present results from a simulation study of a Scandinavian spare parts provider with frequent use of emergency deliveries. It illustrates that applying a multi-echelon inventory control method can significantly reduce total inventories and transport emissions while improving fulfillment of target fill-rates.

**WD-06**

**Semi-Plenary GOR Unternehmenspreis**

Stream: Semi-Plenaries  
Chair: Alf Kimms
Chair: Matthias Walter

WE-02 Wednesday, 16:30-18:00 - Hörsaal 1

Polyhedral Combinatorics (i)
Stream: Discrete and Integer Optimization
Chair: Matthias Walter
Chair: Anja Fischer

1 - Dantzig-Wolfe Reformulations for the Stable Set Problem
Jonas Witt, Marco Lübbecke

Dantzig-Wolfe reformulation of an integer program convexifies a sub-
set of the constraints, which yields an extended formulation with a
potentially stronger linear programming (LP) relaxation than the orig-
inal formulation. This paper is part of an endeavor to understand the
strength of such a reformulation in general.

We investigate the strength of Dantzig-Wolfe reformulations of the
classical edge formulation for the maximum weighted stable set prob-
lem. Since every constraint in this model corresponds to an edge of the
underlying graph, a Dantzig-Wolfe reformulation consists of choosing a
subgraph and convexifying all constraints corresponding to edges of this
subgraph. We characterize Dantzig-Wolfe reformulations not yielding a
stronger LP relaxation (than the edge formulation) as reformula-
ations where this subgraph is bipartite. Furthermore, we analyze the
structure of (critical) facet-graphs (i.e., graphs that define facets) of the
stable set polytope and present a characterization of Dantzig-Wolfe
reformulations with the strongest possible LP relaxation as reformula-
tions where this subgraph contains all odd holes (and 3-cliques).

These results motivate the investigation of Dantzig-Wolfe reformula-
tions obtained by (heuristically) searching for edges that are contained in
an odd hole (or a 3-clique) and convexifying the corresponding con-
straints. We discuss algorithms to calculate such reformulations and
present computational results using the generic branch-price-and-cut
solver GCG. In particular, we examine the reformulations in relation to
other reformulations computed by GCG and draw a comparison to
solving the initial integer programming formulation with the branch-
and-cut solver SCIP.

2 - A New Hierarchy for Solving Polynomial Matroid Op-
timisation Problems
Anja Fischer, Frank Fischer, Thomas S. McCormick

In this talk we consider polynomial matroid optimisation problems. We
present a new hierarchy for solving these problems. This approach is
based on polyhedral results for special polynomial matroid optimi-
sation problems with some non-linear monomials that satisfy certain
up- and downward completeness conditions. The monomials are lin-
earised by introducing new variables. Extending results of Edmonds
we present a complete description for the linearised polytope. Indeed,
our algorithm and convexifying the corresponding con-
straints. We discuss algorithms to calculate such reformulations and
present computational results using the generic branch-price-and-cut
solver GCG. In particular, we examine the reformulations in relation to
other reformulations computed by GCG and draw a comparison to
solving the initial integer programming formulation with the branch-
and-cut solver SCIP.

3 - Investigating Polyhedra by Oracles
Matthias Walter, Volker Kaibel

The software framework IPO (Investigating Polyhedra by Oracles) is
presented which allows to analyze polyhedra that are given only im-
licitly by an optimization oracle. The motivation comes from poly-
hedral combinatorics, where the oracle can easily be provided by a mixed-
integer-programming solver. IPO detects a full system of equa-
tions and some facets of the implicitly given polyhedron with exact
arithmetic. The facets are produced in such a way that they are helpful in
optimizing a given objective function. This is in contrast to usual
convex-hull algorithms which produce the entire description of a poly-
hedron, but run out of resources for small dimensions already. Thus,
IPO can typically handle larger dimensions.

In the talk we will briefly discuss how IPO actually works, followed by
a demonstration of its capabilities. For this we consider short com-
putational studies, namely dimension analysis of MIPLIB 2.0, facet-
detection for matching polytopes with one quadratic objective term and
adjacency statistics for TSP polytopes.

WE-03 Wednesday, 16:30-18:00 - Hörsaal 2

Combinatorial Optimization II
Stream: Discrete and Integer Optimization
Chair: John Martinovic

1 - Two-Stage Cutting Stock Problem with Due Dates
Zeynep Sezer, Ibrahim Muter

In this study, we consider a scheduling extension for the two-stage cut-
ting stock problem with the integration of order due dates. The two-
stage cutting stock problem arises when technical restrictions inhibit
demanded items to be cut from stock rolls directly and hence require the
cutting process to be done in two subsequent stages. The mathe-
matical model proposed for the due date extension aims to determine a
scheduling plan which minimizes the number of stock rolls used but
also reduces tardiness and earliness costs incurred. Preliminary re-
sults have shown that the modeling approach used is capable of over-
coming difficulties caused by the dependencies between stages.

2 - On-line Algorithms for Controlling Palletizers
Frank Gurski, Jochen Rethmann, Egon Wanke

We consider the FIFO Stack-Up problem which arises in delivery in-
dustry, where bins have to be stacked-up from conveyor belts on pal-
et. Given are k sequences of labeled bins and a positive integer p. The
objective is to stack-up the bins by iteratively removing the first bin of
one of the k sequences and put it onto a pallet located at one of p stack-
up places. Each of these pallets has to contain bins of only one label, bins
of different labels have to be placed on different pallets. After all bins of
one label have been removed from the given sequences, the corre-
sponding stack-up place becomes available for a pallet of bins of an-
other label. The FIFO Stack-Up problem is computationally intractable
(Gurski, Rethmann, Wanke, MMOR 2016). In this paper we consider
on-line algorithms for instances where we only know the first c bins of
every sequence instead of the complete sequences. We implemented our
algorithms and could show that for randomly generated instances
we could approximate the optimal solution with an arbitrary factor
which shows the potential of our approach.

3 - On the Solution of Generalized Spectrum Allocation
Problems
John Martinovic, Eduard Jorswieck, Guntram Scheithauer

We consider a spectrum aggregation based spectrum allocation prob-
lem (SAP) for wireless communications: find the maximum number
of secondary users whose bandwidth requirements can be satisfied by
aggregating (parts of) given spectrum holes. In the classical form, this
optimization problem turns out to share a common structure with the
one-dimensional skiving stock problem (SSP). However, in practice, the
spectrum aggregation is usually restricted by hardware limitations,
such as filter technologies, and the capability of controlling interfer-
ence. These additional constraints separate the considered problem
from an ordinary SSP, and represent a new challenge in the field of
discrete optimization. This presentation provides a general introduc-
tion to the relations between the SSP and the SAP. Furthermore, we
will discuss how practical meaningful extensions of the classical SAP
can be tackled from a mathematical point of view. As a main contribu-
tion, we exploit some important problem-specific properties to derive
tailored solution techniques.

WE-04 Wednesday, 16:30-18:00 - Hörsaal 3

Energy Management in the Steel Industry
Stream: Energy and Environment
Chair: Magnus Fröhling

IPO is available at http://polyhedra-oracles.bitbucket.org/
1 - A real world application for the „Balanced Blocks Relocation Problem“ in the steel industry
Jan Necil, Felix Brandt, Eric Ebermann, Stefan Nickel

In these days the price of steel has come under pressure due to Asian low-cost providers. For that reason producing best quality particularly efficient is more important than ever for steel producers in high-cost countries like Germany. In our contribution we provide a short insight into our long-term cooperation with DILLINGER, one of the biggest heavy plate producers in the world. We set a special focus on the well-known Blocks Relocation-Problem and its application in the steel industry. The basic problem deals with the removal of blocks out of storage in a given sequence. In the storage the blocks are stored in stacks. The objective is to minimize the amount of restacking. This problem also occurs for example at sea container terminals. Additionally we show how we expand the basic formulation to a Balanced-Blocks Relocation-Problem. In our case the model is applied to a heavy plate store of the Heavy Fabrication Division at DILLINGER. Here several plates are buffered in stacks before they are processed at the customer’s request. The primary objective is to maximize (balance) the utilization of the downstream production with as little restacking operations as possible. For this purpose, we developed an efficient solution method for the Balanced-Blocks Relocation-Problem, which is currently evaluated in the operations at DILLINGER. The system’s task is on the one hand to support the crane operators, who execute the restacking operations. On the other hand, it provides the opportunity to simulate future situations at the heavy plate store for several weeks to gain planning insights. In our contribution we motivate the problem and provide an efficient solution method.

2 - Operations-Research in integrated steel industry: Use cases from DILLINGER
Eric Ebermann, Heike Busch, Jan Necil, Stefan Nickel

Nowadays European steel makers face high competitive pressure. High quality is demanded at a low price. The strong competition leads to continuous increasing cost pressure, especially due to overproduction at the global market, price dumping or the current plans of the EU regarding CO2-emissions trading. This situation makes the application of Operations Research in the steel production indispensable. The company DILLINGER, one of the biggest heavy plate producers in the world, takes a leading role in this field of innovation. For this purpose a team of experts with the task of applying optimization methods to production was created. It focuses on the development, implementation and transfer of problem-oriented solution methods to operations. In our contribution we provide a broad review of the use cases at DILLINGER that where tackled with OR techniques such as mixed integer optimization, genetic algorithms or local search methods. Additionally we explain fundamental challenges and best practices. Furthermore we describe problems of the future and potential solutions.

3 - Estimating greenhouse gas emissions of European steel suppliers
Andreas Schiessl, Patrick Breun, Konrad Zimmer, Frank Schultmann

In times of fast growing stakeholder interest in sustainability, the ecological and social performance of industrial companies and its products is gaining increasing importance. In particular, the emission of greenhouse gases (GHG) in the automotive industry has come to the forefront of public and governmental attention. This changeover represents a major challenge especially for the purchasing section, as up to 75% of the value adding process of a car takes place in the upstream supply chain. Faced by the regulatory factors of the use phase of a car the thirst for innovation, OEMs are constantly developing new technological solutions. Looking at a selected product of a German car manufacturer, a hybrid design of steel, aluminum and CFRP has been applied with the aim of reducing weight and CO2 emissions. From a life-cycle perspective, steel - 40-45% of the overall car weight - remains to be the leading critical material in terms of GHG emissions in the upstream supply chain. In order to integrate CO2 as decision criteria - along with quality and cost - in a supplier selection process in the long run, this research develops a combined-LCA model which is suitable for a supplier specific assessment of the environmental performance of steel manufacturers without the need for confidential internal data. By using a technology-driven bottom-up approach, the internal material and energy flows corresponding to the on-site production facilities are at first calculated by means of a carbon balance. The site-specific reported CO2 emissions are then allocated to the relevant facilities via a top-down approach, while traded intermediate products are explicitly incorporated in order to adjust the system boundaries. The model is applied to 22 case studies in the European steel industry.

WE-05
Wednesday, 16:30-18:00 - Hörsaal 4
Coordination Games
Stream: Game Theory and Experimental Economics
Chair: Thomas Neumann

1 - An experimental investigation of supplier-retailer contracts
Claudia Kesper, Giuseppe Paleologo, Emmanuel Petéré

We examine individual decisions of supply-chain partners in a newsvendor setting. We conduct a laboratory experiment to compare the performance of the standard wholesale price contract to the theoretically efficient buyback contract. Findings indicate that introducing a buyback component to supply-chain contracts does not significantly increase efficiency. This is principally due to the fact that suppliers set relatively low buyback prices. Consistent with theoretical predictions, we find that retailers’ ordering decisions are negatively related to the wholesale price and positively related to the buyback price. This suggests that buyback contracts could potentially lead to an increase in the supply-chain efficiency, provided that the incentives associated to such contracts are well-understood and correctly implemented by the suppliers.

2 - Vasopressin increases human risky cooperative behavior
Bodo Vogt, Claudia Brunntlib

The history of mankind is an epic of cooperation, which is ubiquitous across societies and increasing in scale. Much human cooperation occurs where it is risky to cooperate for mutual benefit, because successful cooperation depends on sufficient level of cooperation by others. Here we show that subjects make the risky stag choice, A VP down-regulates the BOLD-signal in the left dorsolateral prefrontal cortex (dLPFC), a risk-integration region, and increases the left dLPFC functional connectivity with the ventral pallidum, an AVP receptor-rich region previously associated with AVP-mediated social reward processing in mammals. These findings show a novel causal role for AVP in social approach behavior in humans, as established by animal research.

WE-06
Wednesday, 16:30-18:00 - Hörsaal 5
GOR Dissertation Prize
Stream: Prize Awards
1 - Solving Network Design Problems - with an Application to the Optimal Expansion of Railway Infrastructure
Andreas Bärmann

In this work, we develop solution approaches for large-scale network design problems, focussing on both theoretical and algorithmic aspects. Our motivation is a task set by our industry partner Deutsche Bahn AG, which is to study an optimal capacity expansion for the lines in the German railway network until 2030. We develop a specialized decomposition approach for this multi-period network design problem that works by splitting up the problem along the timescale. The approach allows both for a quick heuristic with high-quality results and for an exact method via a suitable embedding into a Benders decomposition framework. To treat the huge size of the networks under consideration, we develop an exact spacial decomposition based on graph aggregation. The idea is to solve the problem over a coarse network representation obtained via a clustering of the nodes to components and to refine it iteratively where needed. The result is a cutting-plane method whose cutting-planes dominate the Benders feasibility cuts. Both ideas are not only transferred to a more general network design context. We conduct a comprehensive computational case study for the German railway network showing the excellent performance of the approaches in terms of solution time and quality compared to standard methods.

2 - On- and Offline Scheduling of Bidirectional Traffic
Elisabeth Lübbecke

The thesis provides theoretical and practical insights related to bidirectional traffic on a stretch containing bottleneck segments. On a bottleneck segment, concurrent traveling of vehicles in opposite direction is restricted. Single tracks in railway planning are a typical example. This work is motivated by and considers in particular the ship traffic at the Kiel Canal which connects the North and Baltic Seas and is operated bidirectionally. Since ships register their travel requests only on short notice, the planning of the Canal’s ships traffic additionally features the requirement that decisions must be adapted online.

Characteristic for bidirectional traffic is that vehicles moving in the same direction can enter a tight lane sequentially with relatively little headway while vehicles in opposite direction must wait until the whole lane is empty again. With a compact scheduling model that accurately accounts for this specialty, a detailed analysis of the problem’s off- and online complexity is accomplished. To deal with open gaps between upper and lower bounds on optimal competitive ratios in the online setting, a new concept for its approximation is presented. Finally, combining the scheduling perspective with a dynamic routing approach yields a performant heuristic to tackle complex ship traffic control instances.

3 - Integrated Segmentation of Supply and Demand with Service Differentiation
Benedikt Schulte

The presented research addresses the integrated segmentation of supply and demand with service differentiation by means of service-level menus. To this end, it establishes a joint perspective on the market side – that is, prices and service levels – and the operations side – that is, inventory management policy and the corresponding parameters. This joint perspective comprises analyzing when the introduction of a service-level menu increases profits over those of a single undifferentiated offering and how to design optimal service-level menus. Surprisingly, in many cases service differentiation does not increase profits significantly. One way to interpret this finding is that differentiating customers based on service levels alone is a weak differentiation lever only, that is, the price differences between offerings with differing service levels need to be small in order to prevent customers from switching to offerings with lower prices and service levels. Therefore, successful price differentiation requires service differentiation’s being supported by presence of additional options or measures (e.g., pricing restrictions or further differentiation levers). Indeed, it is possible to show that service differentiation can significantly increase profits if the company experiences pricing restrictions.

1 - Sourcing Innovation: Public and Private Feedback in Contests
Jochen Schlapp

Contests, in which contestants compete for a prize offered by a contest holder, have become a popular way to source innovation. Despite great interest from the academic community, many important managerial aspects of contests have received very little formal inquiry. The most important of these is feedback from the contest holder to the contestants while the contest unfolds. This paper sets out to establish a comprehensive understanding of how to give feedback in a contest by answering the questions of when to give feedback and when not to give feedback and which type of feedback to give, public (which all solvers can observe) or private (which only the concerned party can observe). We find that feedback will not affect the behavior of competing problem solvers unless the contest holder credibly pre-commits to a truthful feedback policy. We then set up a framework that reduces the feedback decision to a pair of conceptual questions: First: Is the contest’s ultimate objective to increase average quality or to find the best solution? Second: How uncertain are outcomes for the solvers? We show that no feedback or public feedback generally dominate private feedback. However, if the host is interested exclusively in the best performance and if the contest displays large uncertainties, private feedback is optimal.

2 - A Dynamic Game Theory Model for Dispute Resolution between Public and Private sector Partners in PPPs
Mohammad Rajabi, Jamal Ouenniche

Public-Private Partnerships (PPPs) is a widely used modality that provides many benefits for the public sector in the delivery of public services. Negotiation is one of the most important business activities in the whole life cycle of PPP projects. The long-term nature of the projects and the rapid changes in the market lead to numerous conflicts between the public sector representative and the private sector partner during the execution stages. In this research, we consider the negotiation process after awarding the contract to the selected private sector partner as a non-cooperative dynamic game of complete information and propose an analytical model to assist with decision making. Our analysis is concerned with resolving economic disputes and provides an appropriate strategy for overcoming financial problems and preventing delays in project’s implementation. Managerial guidelines and solutions to prevent conflicts and improve the administrative process are proposed.

3 - Designing Inspector Rosters with Optimal Strategies
Stephan Schwartz, Thomas Schlechte, Elmar Swarat

We consider a network security game where the aim is to allocate limited inspection resources to defend a network against potential attackers. This is typically modeled in a game theoretic framework where the inspectors commit to a control strategy while the attackers strike accordingly. Indeed, these optimal inspectors’ strategies are widely regarded as superior to standard scheduling strategies, such as uniform random inspections. A crucial step towards practical use however, is to transform the control strategy into feasible inspectors’ duty rosters, which are subject to various legal constraints. Due to the complexity of the game theoretic problem an integrated game theoretic duty rostering approach is impracticable.

In this work, we examine how key aspects of the rostering problem can be introduced to the game theoretic model and how the optimal control strategy can be converted into feasible duty rosters for the inspectors. While the game theoretic optimization is formulated as a flow problem in a control graph, we impose several constraints regarding the working hours as arc capacities. We present a clustering approach to identify pairs of duty types and operation days with a similar traffic load. This leads to a reduced game theoretic model formulation as well as to an increase of the degree of freedom for the subsequent rostering problem. Furthermore, we present a randomized rounding algorithm to transform the mixed control strategy into a set of duties for the planning horizon.
The research is motivated by a cooperation with the Federal Office for Goods Transport which is responsible for enforcing a truck toll on German motorways. We apply the presented methods to real world scenarios to demonstrate the potential of the proposed approaches.

### WE-08

**Wednesday, 16:30-18:00 - Seminarraum 101/103**

**Network Design for Distribution Logistics**

**Stream:** Logistics, Routing and Location Planning  
**Chair:** Tobias Buer  
**Chair:** Michaela Thuikle

1. **Competitive Service Network Design when Demand is Sensitive to Congestion**  
*Pratibha Pratibha, Cornelia Schoen*

In this paper we present a market-oriented service network design model where the seller’s problem is to determine the number of facilities, their locations, their service capacity, and their service level such that overall profit is maximized. Our model explicitly takes into account customer choice of a facility as a function of typical choice determinants, such as travel distance and congestion delays (endogenously impacted by the seller’s decision), as well as other exogenous factors such as price level and product variety. We relax the assumption of many related works that the service provider has discretion about the assignment of customers to facilities; rather, we allow customers to self-select based on their preference for facility attributes according to an attraction-based choice model. Furthermore, we do not only capture the effect that congestion has on demand but also the reciprocal impact of demand on congestion and service level, respectively, by modeling each facility as an M/G/1 queue where service capacity is a decision variable. The resulting model is a nonlinear mixed-integer problem; however, we show that problem can be linearized and solved exactly by introducing several new continuous variables and “big M” constraints. We test the performance of our approach in an extensive computational experiment. A case study of locating new convenience stores in Heidelberg, Germany illustrates real-world applicability of the model using empirical market research data. The problem arises in a number of other applications, in particular in service shop industries such as restaurants, retailers, etc. but surprisingly, profit maximization under customer choice behavior has been hardly considered as an objective in the literature.

2. **Planning of mobile deconsolidation points in grocery retail logistics**  
*Micahela Thuikle, Thomas Volling*

Mobile deconsolidation points are an innovative approach towards re-organized structures in distribution logistics. The underlying principle is the following: goods are consolidated to full truck loads in central warehouses to be shipped to strategically placed deconsolidation points. From these points the goods are transshipped to their final destination. As opposed to traditional transshipment concepts, mobile deconsolidation points have minimal infrastructure requirements and can be dynamically (re-)located to match transportation demands. Mobile deconsolidation points therefore combine the efficiency of hub-and-spoke networks with the flexibility of direct shipments. This makes them a particularly interesting candidate solution to tackle the challenges in grocery retail logistics: high cost pressure, pronounced demand variability and rigid traffic and delivery constraints.

We identify the potential of mobile deconsolidation points in grocery retail logistics under different operating conditions and specify implications for distribution planning. We discuss the interdependencies between locating deconsolidation points and vehicle routing, and develop an integrated planning approach. The approach is illustrated based on the case of a German grocery retailer. To conclude, we point out issues for future research.

3. **Optimization Based Network Design in UPS Turkey**  
*Gozde Merve Demirci, Aylin Baykan, Yaprak Dolgun, Fatime Üney-Yüksektepe*

United Parcel Service (UPS) was established as a package delivery company in 1907 by Jim Casey, which provides specialized transporta- tion and logistics services expanded to Turkey in 1988. UPS Turkey has 23 hubs and more than 260 branch offices and authorized service suppliers.

In order to satisfy customers’ requirements, company needs to arrange their network design and planning thereby, massive demands, coming from customers, can be easily transported. Since UPS Turkey has not changed its network design since 2008, it becomes hard to fulfill the increasing demand and to manage the distribution efficiently. Thus, in this project network redesign problem of UPS Turkey is studied by analyzing the current network and customer demands.

In this study, a mathematical programming model is developed to solve the proposed problem efficiently. By using the data obtained from the company, the network is reorganized while satisfying limitations and optimizing its objectives. The developed model is solved by using GAMS software and CPLEX solver. The results are compared with the current situation and different scenario analysis are performed.

### WE-09

**Wednesday, 16:30-18:00 - Seminarraum 105**

**Finance III**

**Stream:** Finance  
**Chair:** Michal Fendek

1. **Long-run UIP Holds even in the Short Run**  
*Fabian Ackermann, Karl Schmiedders, Walter Pohl*

Understanding the relationship between interest rates and exchange rates has proven to be surprisingly difficult. One of the oldest theories in finance, uncovered interest parity, provides an attractive explanation for the behavior of exchange rates. Exchange rates should adjust to equalize returns on loans across countries. This means that high interest-rate currencies will depreciate relative to low interest-rate currencies. Unfortunately, empirical research has not been kind to this hypothesis. Not only do exchange rates not adjust in the direction predicted by the theory, but in some samples they move in the wrong direction.

Long-run UIP, like any long-run financial hypothesis, is difficult to test. To get sufficient statistical power to resolve the question would require many non-overlapping intervals, and financial time series are generally not long enough to provide a clear test for longer maturities. Estimates for the effect of interest rates and exchange rates have proven to be rather unstable. Evidence suggests that interest rates themselves have a unit root, which makes statistical inference difficult.

In this paper we introduce a short-run test of long-run UIP. This test sidesteps the econometric difficulties mentioned above, and provides unambiguous evidence in favor of long-run UIP. UIP can be reinterpreted as a contemporaneous relationship between returns. This relationship can be tested at a monthly frequency, which sidesteps the non-overlapping intervals problem. Returns do not suffer from a unit root, and the estimates have the same sign as predicted by UIP in most subperiods. Interestingly, the support for UIP is stronger after the financial crisis than before.

2. **Bond Mutual Funds and Complex Investments**  
*Markus Natter, Martin Rohleder, Dominik Schulte, Marco Wilkens*

We are the first to analyze bond mutual funds’ permission and use of complex investment practices such as derivatives, restricted securities and securities lending. Based on unique regulatory information from the SEC’s N-SAR filings, we show that most complex investments do not affect fund performance or risk. However, interest rate futures and securities lending. Based on unique regulatory information from the SEC’s N-SAR filings, we show that most complex investments do not affect fund performance or risk. However, interest rate futures (IRF) are harmful to bond funds. Bond funds engaging in IRF (45.8% of all bond funds) underperform nonusers by economically meaningful 51 basis point p.a. (alpha). Further results reveal that bond funds employ IRF for speculation as they increase funds’ exposure towards interest rate risk.

3. **Quantitative analysis the degree of concentration in the Slovak banking sector**  
*Eleonora Fendekova, Michal Fendek*

A competitive environment is an attribute of virtually every aspect of economic relations. A characteristic feature of the market environment is dynamism, a constant change which is induced by an effort to reach maximum competitiveness. Functioning of a market mechanism is conditioned by the existence of a good market conditions for which respecting the conditions of economic competition is necessary. An effective functioning of the economy in a developed and globalized market environment requires many system measures which relate
Chair: Tobias Kreiter
Stream: Production and Operations Management

1 - Solving job-shop problems with blocking constraints by simulated annealing
Julia Lange, Frank Werner

Solving job-shop scheduling problems with blocking constraints constitutes a theoretical foundation of new applications in production planning and logistics. In order to decrease inventory costs, just-in-time production systems aim to use no storage capacities and in railway transportation a no-station restriction is directly implied. In both cases a product or a train blocks the machine or the track it is assigned to until the next machine or track is idle. These planning situations can be interpreted as job-shop scheduling problems, where a certain set of jobs with given release and due dates has to visit machines in a predefined order without storage capacity in between. Since customer satisfaction is one of the main goals in many industries, a schedule (i.e. the starting times of the jobs on the machines), which minimizes the total tardiness of all jobs, is to be determined. A job-shop scheduling problem with a total tardiness objective is NP-hard even without blocking constraints. Computational experiments on MIP formulations of the given optimization problem documented high computation times for very small instances. This implies a necessity to develop heuristic approaches to generate near-optimal feasible solutions. Blocking constraints cause an additional difficulty in defining a feasible schedule based on a given solution encoding. A procedure how to always generate a feasible schedule is developed. With this, a simulated annealing approach is implemented using different priority rules to determine initial solutions and applying several neighborhood structures and cooling schemes. The results obtained with different settings of the algorithm are presented and compared by means of total tardiness values and computation time.

2 - Optimization models for vehicle planning in the pre-production phase
Tilak Raj Singh

Pre-production vehicles are used to facilitate extensive testing of new components and their interfaces. Despite the success of simulation model based testing, physical prototypes are still a necessary step in automobile development. Full vehicle tests are required to capture overall system performance (e.g. cabin noise, mileage) and technical feasibility among different individual systems. Contrary to current automobile series production process, the degree of automation during pre-production stage is minimal, thus, manual and specialized process incurs significant cost and time on every vehicle produced. Total number of vehicle required during pre-production is mainly governed by the predefined set of tests, test schedule and components configuration rules. Task is to find minimal number of vehicle configurations such that each test is executed in pre-specified time frame. The problem turnsouts to be a large scale optimization problem as number of possible vehicle configurations are huge. We use column generation method to solve this optimization model. First results are demonstrated from industrial size problem instance.

3 - Sequencing mixed-model multi-level assembly lines
Tobias Kreiter, Ulrich Pferschy

In a wide range of industries product variety increased drastically over the last decade. Manufacturers face the challenge of providing a growing variety at a low cost. The traditional production schemes with large batch sizes are transformed by decreasing lot sizes and mixed-model assembly lines. The extreme point of this development will be a one-piece flow model where the production plan considers each single product individually. However, different products (variants) differ in their configuration and thus may also differ significantly in the induced workload. To reach a production plan where the work intensity of all products lies within a limited range, manufacturers with a heterogeneous portfolio have to outsource some assembly steps to pre-levels. In this way, a constant speed on the main assembly line should be reached by shifting variances in work intensity to pre-production lines. These can be organized in one or several levels. As for lean manufacturing systems only very small intermediate buffers exist (if any), the temporal distribution of workload in these pre-levels is strongly affected by the production sequence of the main line. Therefore smoothing pre-level workload needs to be respected in sequencing the main assembly line. Considering the real-world application of assembling engines and gearboxes in a large Austrian manufacturer, a MILP-model for optimizing sequences in a mixed-model multi-level assembly line production system is presented. Taking additional constraints from the real-world situation into account requires non-trivial extensions of the main MILP-model. Our modelling approach and obtained results compare favorably to those of the advanced planning system that is currently in use by the company.

Chair: Tobias Kreiter
Stream: Production and Operations Management

1 - Anticipation for Stochastic Inventory Routing in Bike Sharing Systems
Jan Brinkmann, Marlin Wolf Ulmer, Dirk Christian Mattfeld

Bike Sharing Systems (BSS) allow individual and sustainable urban mobility. They have been implemented in a considerable number of cities around the globe. In BSS, customers can rent and return bikes ad hoc at stations and at each end of the day. To allocate a reliable number of bikes, system operators have to realize sufficient fill levels, i.e., numbers of bikes and free bike racks, at each station. Decisions regarding inventory management and vehicle routing, we model these processes as a stochastic Inventory Routing Problem (IRP). To solve the IRP, we introduce a Rollout algorithm (RO) that simulates the near future to anticipate future requests and reveals stations’ urgencies for relocations. Decisions regarding inventory management are made by simulating the consequences of possible decisions. Decisions regarding routing are made by approximating the number of failed requests in the near future for each station. We evaluate the RO in computational studies on real world data based on Vienna’s BSS “CityBike Wien”. A myopic Short-term Relocation strategy (STR) serves as benchmark heuristic. It does not anticipate future requests and makes use of static safety buffers to balance bikes and free bike racks. Results point out that for the RO a suitable time span for simulating the near future needs to be determined to reveal decisions’ consequences and stations’ urgencies. If a suitable time span is chosen, RO outperforms STR by far.

2 - Multi-Period Technician Scheduling with Experience-based Service Times and Stochastic Customers
Barrett Thomas, Xi Chen, Mike Hewitt

This talk introduces the multi-period technician scheduling problem with experience-based service times and stochastic customers. In the problem, a manager must assign tasks of different types that are revealed at the start of each day to technicians who must complete the tasks that same day. As a technician gains experience with a type of task, the time that it takes to serve future tasks of that type is reduced (often referred to as experiential learning). As such, while the problem could be modeled as a single-period problem (i.e. focusing solely...
on the current day's tasks), we instead choose to model it as a multi-period problem and thus capture that daily decisions should recognize the long-term effects of learning. Specifically, we model the problem as a Markov decision process and introduce an approximate dynamic programming-based solution approach. The model can be adapted to handle cases of worker attrition and new task types. The solution approach relies on an approximation of the cost-to-go that uses forecasts of the next day's assignments for each technician and the resulting estimated time it will take to service those assignments given current period decisions. We also introduce a value-function approximation that uses each worker's experience on each task as a basis function. Using an extensive computational study, we demonstrate the value of our approaches versus a myopic solution approach that views the problem as a single-period problem.

3 - Risk-Averse Approximate Dynamic Programming for Dynamic Vehicle Routing

Marlin Wolf Ulmer, Stefan Voss

In the field of dynamic vehicle routing, the importance to integrate stochastic information about possible future events in current decision making increases. Integration is achieved by anticipatory solution approaches, often based on approximate dynamic programming (ADP). ADP aims at estimating the expected future value associated with a particular decision. In many cases, decision makers are risk-averse, meaning that they avoid "risky" decisions with highly volatile outcomes. Current ADP methods in the field of dynamic vehicle routing are not able to integrate risk-averse decisions explicitly considering risk-aversion to a dynamic vehicle routing problem with stochastic requests. We analyze how risk-aversion impacts solutions' quality and variance. We show that a mild risk-aversion may even improve the risk-neutral objective.

WE-13

Optimal Control for Supply Chain and Operations Management I

Stream: Control Theory and Continuous Optimization
Chair: Dmitry Ivanov

1 - Serious Strategy for the Video Games Industry: Pay-to-Play vs. Free-to-Play
Andrea Seidl, Jonathan Caulkins, Richard Hartl, Peter M. Kort

The paper analyzes two business models commonly used in the video games industry. We consider the situation when the game producer starts out with a subscription-based model but then considers when, if ever, to switch to a free-to-play business model which price discriminates between typical users, who play free, and heavy users who pay for acquiring extra features.

We find that over time, the qualitative behavior of prices and associated number of users is the same, while advertising behaves oppositely. Switching from subscription to free-to-play induces a considerable increase in advertising efforts. If the costs of switching business models are considerable and/or the "addictiveness" of the game is low, a history-dependent solution emerges, where different outcomes result in different long-run business strategies. On the other hand, an intermediate level of game addictiveness can lead to thresholds in which the firm can be indifferent between two distinct initial business strategies, even though both converge to the same strategy in the long run and produce the same overall profit.

2 - Ripple Effect in the Supply Chain: Control Perspective
Dmitry Ivanov

In light of low-frequency-high-impact disruptions, ripple effect has been long-term effects of learning, literary, we model the problem as a Markov decision process and introduce an approximate dynamic programming-based solution approach. The model can be adapted to handle cases of worker attrition and new task types. The solution approach relies on an approximation of the cost-to-go that uses forecasts of the next day’s assignments for each technician and the resulting estimated time it will take to service those assignments given current period decisions. We also introduce a value-function approximation that uses each worker’s experience on each task as a basis function. Using an extensive computational study, we demonstrate the value of our approaches versus a myopic solution approach that views the problem as a single-period problem.

First, recent literature on both optimization and control theoretic modelling is analysed. Second, a control theoretic model for multi-stage supply chain design with consideration of capacity disruptions and experimental results are presented. Based on both literature analysis and modelling example, managerial insights and future research areas are derived in regard to optimal control theory application to ripple effect analysis in the supply chain. The paper is concluded by summarizing the most important insights and outlining future research agenda.

3 - Optimal Control of Stochastic Hybrid Systems under Regime Switches, Impulsiveness and Delay, in Finance, Economics and Nature
Gerhard-Wilhelm Weber, Emel Savku, Nadi Serhan Aydin, Busra Temocin, A. Sevtap Selcuk Kestel

We contribute to modern OR by hybrid, e.g., mixed continuous-discrete dynamics of stochastic differential equations with jumps and to its optimal control. These hybrid systems allow for the representation of random regime switches or paradigm shifts, and are of growing importance in economics, finance, science and engineering. We introduce some new approaches to this area of stochastic optimal control and present results. One is analytical and bases on the finding of optimality conditions and, in certain cases, closed-form solutions. We further discuss aspects of differences in information, given by delay or insider information. The presentation ends with a conclusion and an outlook to future studies.

WE-14

Wednesday, 16:30-18:00 - Seminarraum 206

MCDM Applications and Case Studies
Stream: Decision Theory and Multiple Criteria Decision Making
Chair: Erdem Aksakal

1 - The older, the better..!? - Benchmarking Quality Efficiency of time-consuming Whisky Production using DEA
Magnus Richter

According to experts, production/distillation of scotch single malt whisky has reached sufficiently high levels of technical efficiency within the last years, especially concerning the most cost-intensive factors such as, e.g., labor. Because of the low/zero prices of the remaining factors as e.g. barley, water and air, (partial) inefficiencies concerning their input will hardly decrease distilleries' profits as well. Thus enhancing quality of single malt whisky nowadays seems more important. In the paper a quality adjusted, two-model DEA approach, invented by Sherman and Zhu (2006) and modified by Shimshak and Lenard (2007), is applied on empirical data of scotch whisky to identify quality leaders. Quality is incorporated in the model by considering distilleries as quality producing DMUs whose outputs are qualitatively captured via the rating scheme of MURRAYS Whisky Bible. Its categories Nose, Taste, Finish and Balance, each of them ranging from 0-25 Points, serve as output criteria so the distillation technology can be checked for quality-benchmarks. An input-oriented envelope model with constant returns to scale (CCR) is run using the software MaxDEABasic404. The results, inter alia, show that exceeding the legal minimum of storage time of 3 years considerably decreases quality efficiency of whisky production, that is, the contribution of time to whisky quality has been systematically overestimated within theory and practice. Hence, an appropriate reduction of storage time seems advisable; this insight, by the way, seems to be a persuasive explanation for the use of so-called non-age-statements, which are increasingly used by many distilleries as a replacement for explicit age declarations which are traditionally printed on whisky bottles (e.g. “12 years old”).

2 - Multi Criteria Decision Making Methods for Ranking the Countries with respect to the Logistic Performance Index
Nimet Yapıcı Pehlivan, Aynur Şahin

Logistics and transportation play an important role in international trade relations. The international trade is one of the complicated interactions between people, firms, and organizations, whereas supply chains cross countries and regions. Competitiveness of the countries on a global scale is affected by unsatisfactory systems of transportation, logistics and trade-related infrastructure. The Logistics Performance Index is an interactive benchmarking tool and it measures
logistics performance of countries according to six indicators which are customs, infrastructure, international shipments, logistics quality and competitiveness. The LPI was last published by World Bank in 2007 and then repeated in 2010, 2012, 2014. The LPI is performed a worldwide online survey on responsibilities of companies based on 5-point numerical scale to evaluate logistics performance of countries around the world. The LPI consists of two parts: International LPI and Domestic LPI. The World Bank’ LPI and its indicators help to understand and identify the challenges and opportunities of the countries that they face in their performance on trade logistics and what they can do to improve their performance. The LPI allows leaders in government, business, and civil society to better evaluate the competitive advantage created by good logistics and to understand the relative importance of different interventions. The aim of this study is to propose multiple criteria decision making (MCDM) methods for ranking the countries with respect to the logistic performance index regarding six indicators. Furthermore, we will analyze and compare the ranking results with respect to the considered MCDM methods and Principal Component Analysis (PCA) prepared by World Bank.

3 - Building decision making models through Conceptual-Constraints: multi-scale process model implementations
Canan Donibayci, Antonio Espuña
The integration of decision-making procedures typically assigned to different hierarchical levels in a production system (strategic, tactical, and operational) requires the use of complex multi-scale mathematical models and high computational efforts, in addition to the need of an extensive management of data and knowledge within the production system. The aim of the study is to propose a comprehensive solution for this integration problem through the use of Conceptual-Constraints. This study presents a methodology based on a model in a domain ontology and proposes the use of generalized concepts to develop tailor-made decision making models, created according to the introduced data. Different decision making formulations are reviewed accordingly, Conceptual-Constraints for material balances are determined. This work shows how the Conceptual-Constraints can be used when the quality of information is changed, enables multi-scale implementations.

Financial support from the Spanish Ministry of Economy and Competitiveness and the European Regional Development Fund, both funding the Project ECOCIS (DPI2013-48243-C2-1-R), from the ‘AGAUR’, and from the Generalitat de Catalunya (2014-SGR-1092-CEPfEiMA) is fully appreciated.

4 - Marina destination selection under Analytic Network Process: A Case from Turkey
Erdem Aksakal
As being a part of the tourism activity, marine tourism getting much more popular in nowadays. On the other hand, as a part of it, marinas play a significant role in marine tourism. With the dictionary meaning, marina is a dock or basin for yachts and small boat. From this point, if you have yacht or a boat you need some facilities in marinas as refueling, washing and repair facilities, stores, restaurants and etc. According to the definition and significant part of marine tourism, marinas can be described as destinations. In recent years, as considering the dimensions of the tourism activities, multi criteria decision making methods have been applied in evaluation studies. This study aims to is to propose an approach for the selection of a marina destination with using Analytic Network Process. Criteria were taken as Transport, Service, Accessibility, Facilities, Local Culture, Entertainment. The weights of the evaluation criteria were determined by pair-wise comparison and Analytic Network Process is used to make a prioritization among six different destinations over Turkey.

WE-15
Wednesday, 16:30-18:00 - Seminarraum 305
Complex scheduling problems (I)
Stream: Project Management and Scheduling
Chair: Sigrid Knust

1 - Decomposition algorithms for synchronous flow shop problems with additional resources and setup times
Sigrid Knust, Stefan Waldherr
We present decomposition algorithms for synchronous flow shop problems with additional resources and setup times. In such an environment, jobs are moved from one machine to the next by vehicles in a synchronized transportation system, which implies that the processing is organized in synchronized cycles. This means that in each cycle the current jobs start at the same time on the corresponding machines and after processing have to wait until the last job is finished. Afterwards, all jobs are moved to the next machine simultaneously. During processing, each job needs an additional resource and setup times have to be taken into account when changing from one resource to another. The goal is to find a production sequence of the jobs as well as a feasible assignment of resources to the jobs such that the total production time (makespan) is minimized. We propose two decomposition approaches dealing with the two subproblems of job scheduling and resource assignment hierarchically. Both approaches are computation-ally evaluated and compared.

WE-16
Wednesday, 16:30-18:00 - Seminarraum 308
Data Analytics
Stream: Health Care Management
Chair: Sebastian Kohl

1 - Towards a Process Analysis Tool: Goodness-of-Fit Tests on clinical processes
Tobias Weller, Maria Maleshkova, Martin Wagner, Lena-Marie Ternes, Hannes Kenngott
Everyday work in clinics and hospitals generates a lot of data such as the runtime of tasks, diagnosis, and the occurrence of complications during the treatment of patients. Due to the increased use of sensors and the continuous digitalization, the volume of electronic health records is estimated to grow worldwide from 500 petabytes in 2012 to 25,000 petabytes by 2020. This growing data volume cannot be handled without the help of computers. Commonly, clustering algorithms are used to group similar data elements according to specific characteristics. However, they do not provide information about the distribution of the data. To this end, we use Goodness-of-Fit Tests to determine the distribution of health records. This allows for making more precise statements over health data, which cannot be done just by using clustering. This information can help to plan processes and make statements over the frequency of observations. As a case study, we have 1,690 process instances from the Heidelberg University Hospital. The process instances describe the perioperative process (e.g., what tasks are performed before, during, and after surgery). Data points such as the duration of each task, blood loss, and complications are given. We refined the process instances and uploaded them into a Semantic MediaWiki. Based on this data, for the purpose of determining the distribution among health records, we perform Chi-Square Goodness-of-Fit Tests, which is a widely used statistical test to assess the distribution for certain observations. We use the correlation coefficient to evaluate the fitness of the distribution to the observed data. To perform the Chi-Square Goodness-of-Fit Tests, we implemented an extension to Semantic MediaWiki that performs the tests and presents the results.

2 - Pitfalls in Hypothesis Testing: Sensitization and Solution to Multiple Testing Problems
Christina Bartenschlager, Jens Brunner

Deciding on more than one null hypothesis based upon the same data set can lead to an inflation of the type I error rate. Therefore, statisticians have developed an abundance of methods for multiple testing problems over the last century. Our study on current publications in Management Science emphasizes that multiple testing methods are relatively rarely applied, despite the significant relevance for empirical research. The multitude of available multiple testing methods may deter researchers from employing them altogether. Hence, we provide guidance to researchers by means of a user-oriented systematization. As the identified ranges of application are suitable with different multiple comparisons simulations are meant to show the adequate multiple test within each profile.

3 - Exploring the Accuracy of Data Envelopment Models models using Monte Carlo Simulated Production Data
Sebastian Kohl, Jens Brunner

Data Envelopment Analysis (DEA) is one of the most popular benchmarking techniques to assess the efficiency of companies or organizations. It identifies "best practices" and compares the performance of all companies to the resulting best practice frontier. Areas of application are among others, banking, healthcare, education, transportation or agriculture. Since its invention in 1978, lots of different model developments have emerged. Yet it is unclear, which of those models delivers the most accurate results and should therefore be the first choice for the computation of efficiency. To overcome this gap, we try to develop a benchmark based on generated data that combines multiple performance indicators and delivers robust results on the performance of different DEA models.

WE-18
Wednesday, 16:30-18:00 - Seminarraum 401/402

Collaborative Transportation Planning II (I)

Stream: Logistics, Routing and Location Planning
Chair: Mario Ziebuhr
Chair: Kristian Schopka

1 - Bundle generation in combinatorial transportation auctions
Margaretha Gansterer, Richard Hartl

In combinatorial transportation auctions, auctioneers have to decide on the bundling of requests such that attractive packages can be offered to the carriers. From a practical point of view, offering all possible bundles is not manageable, since the number of bundles grows exponentially with the number of requests that is traded. Thus, the auctioneer has to limit the number of bundles to a reasonable amount. The offered bundles should be attractive to the carriers in order to yield profitable allocations of requests. Furthermore, carriers are typically not willing to reveal sensitive information like their available capacities. Thus, the auctioneer has to deal with feasibility of offered bundles under incomplete information. We present a combinatorial auction framework, with a bundling strategy that guarantees to achieve feasible assignments of bundles to bidders without having them to reveal their capacity restrictions. We use two heuristic methods to generate attractive bundles: (i) k-means and (ii) an genetic algorithms-based approach. We compare the performance to the results that we achieve if all possible bundles are offered to the carriers. We demonstrate that by using appropriate heuristics, the number of offered bundles can be significantly reduced, while the solution quality shows only little deviation from the benchmark results.

2 - Non-cooperative pricing decisions in Site-Dependent Vehicle Routing Problems
Silvia Schwarze

We consider the situation of independent, heterogeneous carriers within a transport system and apply the Vehicle Pricing Game (VPG), a non-cooperative game approach that reflects the competition among the actors. In this setting, each vehicle chooses a price for carrying out transport services and receives a payoff dependent on the assigned tasks. In order to determine an optimal price, the respective payoffs, a Vehicle Routing Problem (VRP) including vehicle-dependent routing costs is solved. Heterogeneity is given by varying vehicle characteristics, like vehicle equipment or driver qualification. These characteristics may in turn restrict a vehicle's ability to carry out a particular service, which leads to site-dependencies in the corresponding VRP and affects a vehicle's competitiveness. Given the competition among vehicles, it is investigated which price a vehicle should choose to maximize its own profit and to which extend heterogeneity of vehicles influences this decision. For the case of a two-player ring network game, the existence of pure-strategy equilibria is discussed and the full set of pure-strategy equilibria is identified. To that end, the competition ratio and the acceptance ratio are introduced that provide bounds on prices such that competitiveness is maintained. It is shown that the uniqueness of the higher-skilled vehicle's payoff is guaranteed in a two-player ring network even for multiple equilibria. Experimental results are provided for general networks including the option for penalizing long tours.

3 - Transportation Planning with different Forwarding Limitations
Mario Ziebuhr, Herbert Kopfer

In competitive transportation markets, freight forwarders are confronted with thin margins and high demand fluctuations. In these markets, forwarders try to improve their planning situation by using external resources besides their own resources. These external resources might belong to closely related long-term carriers, common carriers or cooperating forwarders within horizontal coalitions. In recent publications, it is assumed that there are requests which have to be fulfilled by certain resources due to contractual obligations. These requests are denoted as compulsory requests. The contribution of this publication is to identify the increase in transportation costs caused by considering different kinds of compulsory request simultaneously. To analyze the impact of compulsory requests, an existing column generation-based heuristic with two solution strategies for handling compulsory requests is applied.

WE-19
Wednesday, 16:30-18:00 - Seminarraum 403

Resource Scheduling in Public Transportation (I)

Stream: Traffic and Passenger Transportation
Chair: Natalia Kliwer
1 - The Electric Vehicle Scheduling Problem - A study on modelling approaches for charging a vehicle's battery
Nils Olsen, Natalia Kliewer

The Electric Vehicle Scheduling Problem (E-VSP) extends the traditional Vehicle Scheduling Problem by restricting the range of the deployed vehicles and considering the possibility to recharge a vehicle’s battery at some charging stations. One fundamental aspect of electric mobility which hasn’t attracted much attention within existing solution approaches for the E-VSP is the manner and functionality of recharging the electric vehicles’ batteries.

In practice, the majority of deployed electric vehicles hold a lithium ion battery to store energy to power their engines. One crucial property of this battery type due to the internal processes which occur during a charging process is the aspect that a lithium ion accumulator can be recharged in a short time frame to a specific energy charge smaller than the maximum battery capacity (e.g. 60%) but the time needed to fully recharge a lithium ion accumulator is a multiple of that timeframe. Within existing solution methods for the E-VSP these nonlinearities haven’t been considered sufficiently yet.

We present different modelling approaches for the charging process of electric vehicles to consider the nonlinearities constituted previously and propose methods for computing resulting charging times. Following this, we analyse the impact of the different modelling approaches on the resulting vehicle schedules using heuristic solution methods. For that purpose, we solve different real-world instances of the E-VSP.

2 - A Sequential Approach for Vehicle and Crew Scheduling Problem in Public Bus Transportation
Hande Oztop, Uğur Eliiyi, Deniz Türsel Eliiyi, Levent Kandiller

In this study, we consider a real life vehicle and crew scheduling problem of a public bus transportation authority. The objective is to determine the optimal number of different types of vehicles and crew members (drivers) with a minimum cost, to cover a given set of trips and corresponding deadheads regarding working and spread time limitations of drivers. There are sequence-dependent setup times between trips corresponding to deadheads, and sequence-dependent setup times between tasks. Each trip must be covered by a single vehicle and at least one driver, and the trips can be divided into smaller trip segments. Each task, containing of a trip segment or a deadhead resulting from vehicle-trip assignments, must be performed by a single vehicle and single driver. The trips can require different types of vehicles requiring different crew capabilities. Therefore, several vehicle and crew classes exist in the problem. As the problem cannot be solved within reasonable time limits, a sequential approach is proposed where the vehicle and crew scheduling problems are solved successively. We formulate binary programming models for each subproblem. In crew scheduling, we consider only the processing times of tasks in the working term. We analyse the impact of the different modelling approaches on the resulting vehicle schedules using heuristic solution methods. For that purpose, we solve different real-world instances of the E-VSP.

3 - A framework for agent based simulation of demand responsive transport systems.
Joschka Bischoff, Ninja Stoettker, Michal Maciejewski

Demand responsive transport (DRT), such as shared mini busses, have become a viable form of public transport mainly in rural areas in recent years. In contrast to ordinary schedule-based services, DRT systems come in many different shapes and forms and are usually customised to the environment they operate in. E.g., they might be restricted to certain user groups or only operate in specific areas or with a specific fixed terminus. With advances in ICT and the possibility of driverless operations in the future, DRT systems may become an attractive additional mode also in urban and inter-urban transport. This brings the necessity to test and evaluate DRT services and possible business models, with transport simulations being one possible way. This study introduces a framework for an extensible, open source shared minibus service simulation. Based on the agent based transport simulation package MATSim, we develop an iterative valid inequality generation scheme for eliminating task sequences that exceed the total working time when setup times are included. The performance of the developed solution methodology is investigated through an experimentation and the numerical results are reported. The results show that our solution procedure is quite efficient for instances with up to 120 trips.

4 - Column generation for Airline Crew Rostering: Practical considerations in a production system
Hamid Kharrazita, Andreas Westerland

Jeppesen’s crew rostering optimizer is today used by around 40 airlines to produce monthly schedules for their flight crew. The optimizer allows the user to configure various kinds of business logic and it solves monthly schedules for problem instances with above 20k crew members and 100k activities. In this presentation we will start by defining the rostering problem in general. Then we will describe the column generation framework that is used to deal with it. Finally we will look at the specific problem of having an efficient fixing process in the presence of high degree of symmetry.

WE-20

Forecasting

Stream: Business Analytics and Forecasting
Chair: Sven F. Crone

1 - Modelling of water use patterns in the Rajasthan Province of India
Shankar Venkatagiri, Shashank Garg, Krishna Sundar Diatha

The Government of India frequently conducts surveys of its minor irrigation schemes, each of which covers a cultivable command area (CCA) of up to 2000 hectares. This paper examines the data from a pilot water census of Rajasthan, which is India’s largest province by area; a large part of the province experiences extreme heat. The pilot study conducted in 2013 was a landmark exercise: it was executed with the help of handheld devices, completed within two months, and generated over 1 million records across 10 districts within the province. One of the primary objectives of this pilot study was to demonstrate the feasibility of using low-cost mobile devices for a future census of minor irrigation schemes. We use analytical techniques to make inferences on water availability patterns, and the capacity of different villages to sustain multiple crop cycles within the region. By combining information from multiple sources, we show how the demographic composition of the villages is influenced by the availability of water.

2 - Statistics instead of stopover - Range predictions for electric vehicles
Christian Kluge, Stefan Schuster, Diana Sellner

Electric vehicles can play a central role in today’s efforts to reduce CO2 emission and slow down the climate change. However, despite various technological advancements and public support, consumers react cautiously to current offers of the electrical market. As surveys show, two of the most important reasons against the purchase or use of an electric vehicle are its short range and long charging times. In the project "E-WALD - Elektromobilität Bayerischer Wald", we develop mathematical models to predict the range of electric vehicles by estimating the electrical power consumption (EPC) along possible routes. Based on the EPC forecasts the range is calculated and visualized by a range polygon on navigation map which is represented on a tablet computer in the car. The models are based on data that is constantly collected by cars that operate within a commercial car fleet. The collected data are prepared in two different ways, an energy-based and a distance-based way. Both datasets are modeled with same methods, a linear model, an additive model and a fully nonparametric model. To fit the different models, ordinary least squares regression as well as linear median regression are applied. The other models are fitted by modern machine learning algorithms: the additive model is fitted by a boosting algorithm and the fully nonparametric model is fitted by support vector regression. The models are compared by the mean absolute error. Our research findings show that data preparation is more influential than...
3 - Don't Correct and Combine Judgmental Forecast
Sebastian Blanc

Corporate decision making and planning usually rely on the quality of forecasts. Since expert knowledge is considered relevant in many predictive tasks, many forecasts are generated - although often supported by a forecast support system - by human experts. In the literature, it is regularly found that forecast correction or combination can improve the accuracy of judgmental forecasts. Forecast correction techniques such as Theil’s method are motivated by the fact that judgmental forecasts are regularly biased. Systematic biases are identified using past forecasts and corresponding errors and are then removed from future forecasts. In contrast, forecast combination aims at reducing error by combining a judgmental forecast with an alternative forecast, for instance a model-based prediction. Since both techniques have been shown to improve accuracy, an obvious extension might be to include a corrected forecast instead of the original judgmental forecast in a combination. In this work, we study the theoretical properties of this approach. We show that applying both techniques can be expected to result in asymptotical accuracy improvements only under very narrow conditions. Consequently, we recommend applying only one of the two techniques since potential advantages in terms of bias-reduction will be easily negated by increased error variance resulting from the complexity of the approach.

4 - Improving the forecasting accuracy of two-step segmentation models
Friederike Paetz

The estimation of consumer preferences with conjoint-choice models is well-established. In particular, the use of Hierarchical Bayesian (HB) models, which estimate consumers’ individual preferences is nowadays state-of-the-art in theory and practice. However, the knowledge of consumer preferences on a less disaggregated level, like segment-level, is crucial especially for demand predictions of products, that could not be customized individually. Clustering individual HB data to achieve segment-level preferences is known to be inappropriate, since two-step segmentation approaches generally lead to worse forecasting accuracy in comparison to one-step segmentation approaches, e.g., Latent Class models. But, may the inclusion of different concomitant variables into the cluster process of individual conjoint-choice data relax the disadvantage of two-step approaches w.r.t. forecasting accuracy? To answer this question, we used an empirical data set and estimated a Latent Class Multinomial Logit (MNL) model as well as an HB model. Subsequently, we clustered the HB data with and without the consideration of different concomitant variables, e.g., demographic and psychographic variables. Finally, we compared the forecasting accuracy of all model types. While demographic variables, e.g., age or gender, showed only tiny effects, psychographic variables turned out to be very important in improving forecasting accuracy of two-step segmentation models. In particular, two-step approaches, that consider psychographic variables within the clustering process, showed a forecasting accuracy just as well as the one of one-step approaches.

WE-21
Wednesday, 16:30-18:00 - Seminarraum 405/406

Storage Systems Optimization

Chair: Achim Koberstein

1 - Loading and unloading strategies for a stacking problem with item families
Sven Boge

In this work, we consider the process of loading and unloading items in a warehouse. The items are stored in stacks and moved by a crane. Each item is associated with a family indicating the main attribute (type) of the item. For a given subsequence of these item families it has to be decided which item of each requested family shall be unloaded from the warehouse using the least number of moves to save time and cost. Related to this, incoming items shall be stored best possible for future retrievals. Algorithms for these problems have to decide which items of a family should be used at which point in the retrieval sequence and where incoming and blocking items should be located. Heuristics and metaheuristics for the loading and the unloading problem are proposed and compared to strategies which are currently used in the warehouse of a German company producing work plates. Computational results are presented for a large data set of randomly generated instances according to the setting in the warehouse and two smaller real-world data sets.

2 - Window Fill Rate in a Two-echelon Exchangeable-Item Repair-System
Michael Dreyfuss, Yahel Giat

The fill rate service measure describes the proportion of customers who commence service immediately upon arrival to an inventory system. Since, however, customers will usually tolerate a certain wait time, managers should consider the window fill rate in lieu of the fill rate. That is, they should maximize the probability that a customer is served within the tolerable wait time. In this paper, we develop approximation formulas for the window fill rate in a two-echelon, exchangeable-item repair system in which the top echelon is a central depot and the bottom echelon comprises multiple locations. To estimate the accuracy of the formulas, we compare the formula-derived window fill rate values with simulation-derived window fill rate values.

3 - Extension of the A*-Algorithm for Puzzle-Based Storage Systems Problems
Altan Yalcin, Achim Koberstein, Kai-Oliver Schocke

A Puzzle-Based Storage Systems (PBS) consists of a grid with an initial occupancy of densely stored unit-loads. Each item represents an obstacle that is movable. Escort locations (empty slots) are used to enable movement. System performance depends upon suitable use of escort locations. Previous work has focused on analytical studies of single-load systems with and one or two escort locations. An optimal solution method for systems with more than two escort locations has not been provided yet. We present a single-load motion planning algorithm with multiple escort locations that provides optimal solutions with a minimum number of moves. The algorithm is based on the A* algorithm that is a best-first search and uses heuristics to guide its search. We consider only a fraction of available escort locations and show the admissibility of this approach. Within that framework, we developed three heuristics by problem relaxation and solution criticism. Computational experiments compare the heuristics’ performance on randomly generated problem instances and show how well the algorithm performs for different configurations. Our contribution provides an algorithm that enables further research in the field of PBS such as retrieval time analysis studies of PBS with multiple escort locations or PBS with multiple I/O points.

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Thursday, 9:00-10:30

**TA-02**

*Thursday, 9:00-10:30 - Hörsaal 1*

**Mixed Integer and Linear Programming Software (i)**

Stream: Discrete and Integer Optimization  
Chair: Sven Wiese

1. **Parallelization of the FICO Xpress Optimizer**  
   **Timo Berthold**

   We will present some of the recent MIP advances in the FICO Xpress Optimizer, with an emphasis on its new parallelization concept. To achieve reasonable speedups from parallelization, a high workload of the available computational resources is a natural precondition. At the same time, reproducibility and reliability are key requirements for mathematical optimization software. Thus, parallel LP-based branch-and-bound algorithms are expected to be fully deterministic. The resulting synchronization latencies render the goal of a satisfying workload about partial information approach and separating the concepts of simultaneous tasks and independent threads from each other. Our computational results indicate that this leads to a much higher CPU workload and thereby to an improved scaling on modern high-performance CPUs. As an added value, the solution path that the Optimizer takes is not only deterministic in a fixed environment, but on top of that platform- and, to a certain extent, thread-independent.

2. **Recent improvements in the CPLEX LP solver**  
   **Bo Jensen, Roland Wunderling**

   Being able to efficiently solve Linear Programs has been taken for granted in the past decade, prompting practitioners to build larger and larger problem instances. In recognition of this fact, the CPLEX LP solver has been enhanced. We will discuss these developments and provide a detailed performance evaluation of their effect.

3. **Gurobi - Performance Improvements and New Features**  
   **Michael Winkler**

   We will give an overview on performance improvements for different problem classes and introduces new features of the current Gurobi release. In detail, we focus on some special tricks and ideas that are the foundation for these improvements.

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**TA-04**

*Thursday, 9:00-10:30 - Hörsaal 3*

**Applications in energy modelling**

Stream: Energy and Environment  
Chair: Michael Zipf

1. **BEAM-ME: Acceleration Strategies for Energy System Models**  
   **Frederik Fiand, Michael Bussieck**

   BEAM-ME is a project funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) and addresses the need for new and improved solution approaches for energy system models. The project unites various partners with complementary expertise from the fields of algorithms, computing and application development. The considered problems result in large-scale LPs that are computationally tractable for state-of-the-art solvers. Hence, new solution approaches combining decomposition methods, algorithm development and high performance computing are developed. We provide an overview on the large variety of challenges we are facing within this project, present current solutions approaches and provide first results.
2 - Linear reformulations of the unit commitment problem
Kerstin Daechert, Christoph Weber

The well-known unit commitment problem determines the cost-optimal commitment of power plants to meet an exogenously given demand while taking certain constraints like maximum capacity, minimum stable operation limit, minimum operation time, minimum down-time etc. into account. The problem is classically formulated as a mixed-integer linear program. However, when applying this MIP model to real-world instances like the German or European electricity market with a one-year optimization horizon some sort of simplification is required to obtain reasonable computational times. Moreover, the units are typically aggregated in this context. Therefore, a linear reformulation of the model seems appropriate. In this talk we compare different linear formulations of the unit commitment problem and discuss which formulation is best suited for our application. We present solutions for a large real-world electricity market model using these reformulations.

3 - Cooperation of TSO and DSO to provide re-dispatch capacities
Michael Zipf, Dominik Möst

Overview Today, ancillary services, such as congestion management, are mainly provided by large power plants which are located in the transmission grid. Due to the energy transition in Germany generation capacities will shift from the transmission to the distribution level. Thereby in the future the role of transmission and distribution system operators will change especially with regard to the provision of ancillary services. Thus the question is to which extent distribution system operators can actively contribute to system stability in the transmission system and how total system responsibility should be assumed by distribution system operators.

Methods A model based analysis is conducted to measure the impact of different cooperation regimes between the transmission and the distribution system operator (DSO). This problem leads to a Generalized Nash Equilibrium (GNE) and most likely no unique solution of the problem exists. A convenient approach for solving a GNE is presented and used in this analysis. Furthermore a detailed data set of the German electricity grid, including the transmission and distribution level, is used which forms a large scale optimization model. This paper gives first insights about economic implications of changing roles and examines the impact of a higher degree of coordination between distribution and transmission level to provide ancillary services.

Results Results indicate that a stronger cooperation of system operators yields positive effects for both players and substantial cost savings can be achieved. System responsibility of DSOs has to be extended in order to get access to all re-dispatch capacities located in the distribution grid. This gets important with a high share of renewables in the electricity system.

**TA-05**

**Thursday, 9:00-10:30 - Hörsaal 4**

**Behavioral Project Management (i)**

**Stream: Game Theory and Experimental Economics**

Chair: Sebastian Schiffels

1 - The effect of power on cost planning in project management
Andreas Fügener, Sebastian Schiffels

Managers routinely decide on deadlines, budgets, and quality levels, often facing a trade-off between increased costs by planning overly optimistic, e.g. too much time, or paying penalty costs by planning overly pessimistic, e.g. too little time. Current views from psychological research suggest that a managers’ sense of power will bias this kind of decision, but it is unclear if it leads to greater pessimism or optimism in planning under uncertainty. We used an episodic recall task to manipulate the sense of power and a newsvendor paradigm with penalty costs in two online experiments with different penalty cost settings to test the predictions. The results indicate that in cost scenarios with relatively high penalties (i.e., pessimistic plans would be rather favorable) high power led participants to plan more pessimistically and low power led participants to plan more optimistically. In cost scenarios with relatively low penalties (i.e., optimistic plans would be rather favorable) high power led participants to plan more optimistically and low power led participants to plan more pessimistically. The present research makes important contributions to both the behavioral operations literature and the management science literature by identifying a predictor of optimistic planning behavior and sensitivity to different cost types, respectively. It also yields interesting insights for the emerging stream of research on low-power individuals.

2 - Delegated Testing of Design Alternatives: Selectionism vs. Trial-and-Error

Gerrit Schumacher

During the development of a new product, firms are constantly confronted with challenging design choices. Typically, a variety of potential design alternatives exists and the firm aims to choose the one that promises the highest value. Upfront, however, the value of each alternative is unknown to the firm and therefore, it has to rely on design testing to gain (imperfect) information on a product’s true value. In reality, these testing activities are carried out by project teams with interests not necessarily perfectly aligned with the firm’s objectives. As a result, the firm has to design appropriate incentive schemes to motivate these teams to thoroughly test their designs and to truthfully reveal their acquired information. In this study, we derive the optimal incentive schemes for the two most wide-spread testing approaches - selectionism and trial-and-error learning - and compare their effectiveness.

3 - Does Strategic Behavior Mitigate Parkinson’s Law?

Sebastian Schiffels, Andreas Fügener

Projects running late is a widely-known problem while the source of this problem, e.g. poor planning of the project managers, poor execution of the project workers, or a mixture of both, is often unknown. Buffer time might prevent that projects are running late at the cost of additional resource usage. However, buffers are even more costly if the planning and execution of a project is conducted by different actors (planner and worker) as Parkinson’s Law comes into play. As a consequence a project almost never end before the time available for its completion. Determining the time available for a project the project planner is confronted with a challenging trade-off decision: insufficient time results in overtime or contractual penalties, too much time wastes limited resources like labor hours. In a setting with a project manager planning the time available and a project worker fulfilling the project the question arises how both influence each other, e.g. whether the time available to fulfill the project is influenced by Parkinson’s Law. We develop a theoretical framework considering an interactive project setting with a planner and a worker demonstrating that the optimal decision of the worker is in line with Parkinson’s Law in a single decision task. However, in many business situations planner and worker interact in several projects. Therefore, we also consider repeated interactions. Based on our theoretical framework we setup an experimental study and find support that work does not necessarily expand so as to fill the time available for its completion if planner and worker interact more than once.

**TA-06**

**Thursday, 9:00-10:30 - Hörsaal 5**

**Advanced Analytics in Revenue Management**

Stream: Pricing and Revenue Management
Chair: Catherine Cleophas

1 - Nonparametric Demand Estimation in Revenue Management
Johannes Ferdinand Jörg, Catherine Cleophas

Revenue management employs methods of demand forecasting and optimization to offer the right price at the right time to the right customer. Newer technology enables firms to store and access increasingly big data sets. This brings the challenge to incorporate the information contained in those data sets in revenue management. For example, current revenue management rarely exploits panel data. Our contribution proposes to estimate demand structures of a market from panel data using machine learning techniques to model booking events in different time frames and draw conclusions on the underlying structure. Synthetic data allows us to validate
the performance of the estimators in a controlled environment and then apply the procedure to a real data example from an international airline carrier. We discuss the results with respect to the underlying demand structure of the synthetic data set.

2 - Forecasting Price Elasticity with Generalized Additive Models assuming a Poisson Process with an Application to Dynamic Pricing
Jan Felix Meyer, Goeran Kauermann, Catherine Cleophas
Forecasting demand is a central question in airlines’ revenue management. As the capacity of a flight is a perishable asset typically two different cost-types are evaluated. In order to achieve the objective of revenue maximization the airlines’ control mechanism uses the cost-factors as input values to a control-scheme that defines the available price. This is done to guarantee that incoming bookings give a positive contribution to the objective. As sold seats cannot be offered again opportunity costs arise by the risk of spoilage if high yield customers are rejected due to overselling at discounted rates. Simultaneously the passengers’ willingness-to-pay is estimated to control for price-elasticity-costs. These may occur if a seat is sold at a rate which is below the individuals willingness-to-pay. This paper will focus on the latter and discuss how statistical modeling is used to exploit the demand-price-relationship to control for price-elasticity-costs. In particular we will present how the shape constrained additive model framework is capable of discovering complex dependencies that impact price-elasticity. Subsequently it is shown how these estimates are utilized by a dynamic-pricing-scheme that sets the optimal-price equal to the marginal-revenue plus an additional cost factor. It is demonstrated by application of the proposed method to several real data examples how this setup greatly simplifies the airlines’ pricing. Further benchmarking the forecasting-performance for the purpose of dynamic-pricing the proposed model outperforms other techniques that recently appeared within the revenue-management literature.

3 - Exogenous Capacity Changes in Airline Revenue Management: Quantifying the Value of Information
Catherine Cleophas, Daniel Kadatz, Natalia Kliewer
Frequently, airlines cannot operate flights with the initially scheduled aircrafts as technical defects, crew planning, weather conditions, etc. cause unexpected changes. These aircraft changes can alter the number of salable seats - the aircraft’s capacity - and thus affect revenue management results. Capacity changes that are intentionally driven by revenue managers to better match volatile demand have been addressed by existing research. However, current research and practice rarely consider unexpected exogenous changes, although these cause uncertainty of unquantified magnitude. This presentation proposes an approach for systematically considering exogenous as well as exogenously changing aircraft capacity and its effect on revenue management. Multiple solution methods are tested in a simulation environment calibrated on empirical data. We compare solutions with regard to revenue performance and the required information on the timing, magnitude, and probability of changes. Thus, we quantify the value of information when accounting for exogenous capacity changes in airline revenue management.

2 - Efficiency of two-part tariffs in supply chains: The role of bargaining power and demand uncertainty
Abdolkarim Sadrieh, Guido Voigt
Using laboratory experiments, we study behavior in supply chains with two-part tariffs and price-sensitive demand. We vary the degree of bargaining power between the supply chain partners by varying their outside options. In addition, we examine the role of demand uncertainty by comparing treatments with stochastic demand to treatments with deterministic demand. In theory, the efficiency of supply chains with two-part tariffs is independent of all of our treatment variations, but the distribution of payoffs is not. However, while the normative benchmark (with rational and expected profit-maximizing players) predicts an efficient outcome in all treatments, we observe substantially better supply chain performance when buyers have the high outside option (i.e. high bargaining power) but do not face demand uncertainty. Surprisingly, the effect is reversed when buyers face demand uncertainty. With demand uncertainty, supply chains perform better when buyers have low bargaining power. We discuss these results taking behavioral motives (e.g. loss aversion and fairness concerns) of buyers and suppliers into consideration.

3 - The effect of communication media on forecast information sharing in supply chains
Lennart Johnsen, Guido Voigt, Joachim Weimann
We consider the pricing decision of a supplier delivering to its retailer. The retailer has an incentive to understate her private information about end-customer demand in order to negotiate a lower retail price. This harms the overall supply chain performance. Game theory predicts that communication cannot resolve this incentive conflict. We examine in laboratory experiments the impact of unilateral and bilateral communication forms on retailer’s trustworthiness, supplier’s trust and the supply chain performance.

TA-08
Thursday, 9:00-10.30 - Seminarraum 101/103

Container and Terminal Operations I (i)
Stream: Logistics, Routing and Location Planning
Chair: Julia Funke

1 - Berth Allocation - Do we have it all wrong?
Stefan Voss
The Berth Allocation Problem (BAP) aims at assigning and scheduling incoming vessels to berthing positions along the quay of a container terminal. This problem relates to well-known optimization problems within maritime shipping. During the last decades many terminal operators and many academics have developed algorithms and decision support systems for optimizing berth planning including the BAP at container terminals. Moreover, we have seen quite a few extensions of the problem settings to incorporate, e.g., integrated problems or time-dependent limitations (tidal changes) and many more. Despite a wealth of existing systems as well as various recent surveys from literature there are still quite a few realistic issues that seem to be neglected including the consideration of berth error as well as disturbances in the daily operation. That is, in this paper we set up a research agenda pointing out that we need to consider and model disturbances and stochastic influences to make the problem more realistic.

2 - A Mixed Integer Programming Model for Integrated Operations in Container Terminals
Danaa Kizilay, Deniz Türel Eliyli
In this study, operations in sea port container terminals, namely the quay crane assignment and scheduling, yard crane assignment and scheduling, yard location assignment and yard vehicle dispatching are examined simultaneously. The operations of quay cranes, yard trucks, and yard cranes should be well coordinated in order to decrease vessel turnover times, which is the principle target of container terminals. We concentrate on minimizing the vessel turnover time by integrating the optimization of all examined operations. While a majority of the existing studies consider individual operations thoroughly, only some integrate up to three or four problems, without taking into account some important restrictions of container terminals in practice. Realistic restrictions such as blocking constraints for the handling equipment, precedence constraints for the containers are respected in our study.

TA-07
Thursday, 9:00-10:30 - Hörsaal 6

Behavioral Contracting (i)
Stream: Game Theory and Experimental Economics
Chair: Karina Held

1 - Sticky Wages and Effort Inertia - Experimental Evidence on Productivity and Distribution Effects under Inflation
Karina Held
In a controlled laboratory experiment, we study the impact of inflation and deflation on work relationships with incomplete contracts. With inflation, we observe that effort is only partially adjusted to the decreasing real wages. This is in line with money illusion and results in a lower cost of labor, but it also leads to lower total earnings than in an economy with stable prices. With deflation, the cost of labor is greater than with stable prices, but total earnings are not. While overall productivity is greater under stable prices, the employer's share of total earnings is highest with inflation and lowest with deflation.

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Chair: Werner Helm
Stream: Software and Modelling Systems
- Thursday, 9:00-10:30

■ TA-09
Thursday, 9:00-10:30 - Seminarraum 105
Modeling and Solver Performance
Stream: Software and Modelling Systems
Chair: Werner Helm

1 - Planarization of CityGML models using a linear program
Steffen Goebbels, Regina Pohle-Frohlich, Jochen Rethmann

CityGML is an XML based description standard for 3D city models that requires model buildings to have planar roof facets. Unfortunately, current tools that generate building models from airborne laser scanning point clouds violate this requirement to some extent. We propose a definition of approximate planarity and present a post-processing tool that establishes approximate planarity using linear optimization. It preserves the characteristic shape of roofs. In most cases, triangulation of non-planar facets is no longer needed. This not only reduces the number of facets and increases performance of applications that process city models, but also avoids disturbing lighting artifacts.

2 - Distributed solving of mixed-integer programs with GLPK and Thrift
Jochen Rethmann, Frank Gurski

Branch-and-Bound algorithms for Mixed-Integer Programs (MIP) are studied for over 40 years, see for example, Achterberg, Koch, and Martin (2005), Benichou et al. (1971), or Nygreen (1991). Object-oriented frameworks for parallel Branch-and-Bound algorithms like PICO (Eckstein, Phillips, Hart, 2001), MW (Goux, Linderoth, Yoder, 1999), ParaSCIP (Shinano, Achterberg, Berthold, Heinz, Koch, 2011), or ALPS (Xu et al., 2005) are well known, so why another paper about this topic? Our aim is to develop a powerful parallel MIP-solver by combining existing tools or frameworks that are platform independent and free of charge so that even small companies can contribute to the benefit of an optimization suite. First of all, the solver should be easy to use with or without special skills in decomposition techniques, branching rules or programming. Licences of commercial solvers like CPLEX or GUROBI are often not affordable for small companies. Our tool combines the GNU Linear Programming Kit (GLPK) and the remote procedure call framework Thrift. The GLPK-solvers are independently running processes to be independent of the further development of GLPK and algorithmic progress in future. We describe how to combine these two technologies to get an optimization suite for mixed problems and evaluate the power of our tool by solving some benchmark data from Chu and Beasley (1998), MIPLIB 2003 (Achterberg, Koch, and Martin, 2003), and MIPLIB 2010 (Puchinger et al., 2010). How good and powerful can be such a simple system?

■ TA-10
Thursday, 9:00-10:30 - Seminarraum 108
Advances in Stochastic Optimization
Stream: Optimization under Uncertainty
Chair: Marco Lau mann

1 - A maximum likelihood approach to optimization table balancing
Geoffrey Brent

Official statistical agencies often need to compile large tables of data from multiple sources. Errors in sources lead to inconsistent data, e.g. totals that should conceptually be identical do not match. To address this, tables must be “balanced” by adjusting entries to satisfy consistency constraints.

Some agencies approach this as an optimization problem, with a “level-preservation” weighted-least-squares (WLS) objective function that penalises adjustments. If variances for errors in individual sources are known, these can be used to set appropriate weights.

In practice, variances are often unknown. Weights may be set via models that estimate variance as a function of estimate magnitude, and type of source. Current implementations of this approach require setting model parameters subjectively, via expert judgement.

Level-preservation balancing can be interpreted as a maximum likelihood estimator (MLE) of the true data values, under a simple error model. I will show that this MLE interpretation offers a more objective method for setting model/weighting parameters.

Some balancing problems include time-series data where errors may be correlated over time. Previously this has been addressed by adding the level-preservation objective function to a “movement-preservation” objective based on Denton AFD/PFD metrics. This approach requires more subjectively-chosen parameters.

I show that although the movement- and level-preservation objectives are individually consistent with MLE estimates for simple error models, adding those two objectives together is not consistent with the corresponding MLE. By approaching balancing as a MLE problem we may be able to improve accuracy as well as reducing subjectivity of the optimization weighting.
2 - Scenario Aggregation using Binary Decision Diagrams for Stochastic Programs with Endogenous Uncertainty
Marco Lauermanns, Utz-Uwe Haus, Carla Michini

Modeling decision-dependent scenario probabilities in stochastic programs is difficult and typically leads to large and highly non-linear MINLPs that are very difficult to solve. In this paper, we propose a new approach to obtain a compact representation of the recourse function using a set of binary decision diagrams (BDDs) that encode a nested cover of the scenario set. The resulting BDDs can then be used to efficiently characterize the decision-dependent scenario probabilities by a set of linear inequalities, which essentially factorizes the probability distribution and thus allows to reformulate the entire problem as a small mixed-integer linear program. The approach is applicable to a large class of stochastic programs with multivariate binary scenario sets, such as stochastic network design, network reliability, or stochastic network interdiction problems. Computational results show that the BDD-based scenario representation reduces the problem size, and hence the computation time, significantly compared to previous approaches.

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2 - Flexible production scheduling with volatile energy rates
Christoph Johannes, Matthias Gerhard Wichmann, Thomas Spengler

The expansion of renewable energies is a global phenomenon on the way to a sustainable power generation. The accompanying strongly fluctuating power supply is usually complemented by classical power plants in order to meet the current power demand. This results in a power market with dynamic electricity rates. In these markets, energy suppliers offer manufacturing companies two types of electricity tariffs. These are tariffs with fixed electricity rates and tariffs with variable electricity rates. For manufacturing companies tariffs with variable electricity rates provide an opportunity as in the course of energy-oriented production planning the schedule and the machine states can be planned and therefore the resulting energy costs are reduced. Moreover, the use of battery storage allows manufacturing companies to store comparatively cheap energy and to use this during periods of increased electricity rates for production. In order to exploit the resulting potentials, their consideration in companies’ production planning is required. However, suitable approaches are missing so far. In the literature models for the flexible job-shop scheduling exist which take particular elements of an energy-oriented scheduling into account. But, a transfer of these elements on further planning tasks as the economic lot scheduling problem has not took place. In this contribution we will present an extension of an economic lot scheduling problem for energy-oriented production with time-dependent purchase of energy. The aim of the model formulation is to minimize production-related costs based on forecasts of electricity rates. On the basis of an illustrative example, the operational cost reduction potential through battery storage and variable electricity rates is indicated.

2 - Scheduling of uniform nonsimultaneous parallel machines
Liliana Grigoriu, Donald Friesen

We consider the problem of scheduling on uniform processors which may not start processing at the same time with the purpose of minimizing the maximum completion time. We give a variant of the MUL-TIP algorithm which generates schedules which end within 1.382 times the optimal maxmin completion time for the general problem, and within (square root of 6)/2 times the optimal maximum completion time for problem instances with two processors. Both developments represent improvements over previous results. We also comment on how a PTAS for scheduling on a constant number of uniform processors with fixed jobs can be used to obtain a PTAS for scheduling on a constant number of uniform nonsimultaneous parallel machines, and present experimental results about the performance of our algorithm LMULTIP.

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3 - Extension of the Quay Crane Scheduling Problem for scheduling of several rail-mounted robots and the development of a heuristic solver for fiber placement processes
Markus Schreiber, Rüdiger Ruwe

The automation of manufacturing large scale Carbon Fibre Reinforced Plastic (CFRP) components is still a relevant topic in research. It is necessary to speed up and improve production due to the increased demand for CFRP components. In the course of the project GroFi the German Aerospace Center (DLR) built a production plant for the fully automated manufacturing of large scale CFRP components for aerospace applications. It is located at the DLR Center for Lightweight-Production-Technology in Stade. One of the key features of the facility is the possibility of simultaneously producing CFRP components with multiple, mobile, rail-mounted robots. What is anticipated is that this concept will drastically increase the speed of the production process and, through the use of redundancies, reduce downtimes of the facility. In addition to the generation of numerical code for robots this introduces the need for scheduling their tasks. Scheduling on limited space with limited flexibility is prone to error when done manually. Therefore and according to the paradigm of current strategy Industry 4.0 an automated method is being developed. This presentation deals with the modelling of and a heuristic solution to this production process. In general both can be applied to processes of several robot units which are mobile on a single rail. The production process was formulated as a Mixed Integer Problem by using analogies to the Quay Crane Scheduling Problem. Furthermore, a genetic algorithm was developed and implemented as a heuristic solver.
as simplifications to make a problem tractable, and the user of the optimization system is able to identify them. In this case, the interaction should prevent unrealistic or infeasible solutions to be adopted.

Interactive optimization approaches range from rudimentary trial-and-error approaches to more sophisticated approaches such as interactive multiobjective optimization, human-guided search or long-term preference inference. Most of the optimization procedures implemented for these interactive approaches are heuristics and metaheuristics. In fact, interactive optimization is often used when optimization models or problem data need to be enriched by the user. In this context, an optimal solution with respect to the problem model may not be worth the computational time because the solution may not be optimal from a user’s perspective. Therefore, metaheuristics are particularly attractive for interactive optimization as they provide good solutions in reasonable time.

We recently proposed a classification to better understand the interaction mechanisms in interactive optimization. This classification considers four aspects of the interaction: the role of the user, the type of feedback integration (model-free or model-based), the lifetime of preference information (step-based, short or long-term), and the type of optimization procedure. In this presentation I detail this classification and illustrate it with interactive metaheuristics applied to network optimization problems.

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**TA-13**

**Thursday, 9:00-10:30 - Seminarraum 204**

**Error Bounds and Algorithms**

Stream: Control Theory and Continuous Optimization
Chair: Andreas Fischer

1 - Convergence of Newton-Type Methods for Degenerate Complementarity Systems

Andreas Fischer, Markus Herrich, Alexey Izmailov, Mikhail Solodov

We consider complementarity systems with nonsolved solutions which, for example, may come from Karush-Kuhn-Tucker (KKT) systems of nonlinear programs or generalized Nash equilibrium problems. The complementarity systems are reformulated as systems of piecewise continuously differentiable equations. Then, the local convergence of approximate Newton-type techniques applied to these nonsmooth systems is dealt with. It is shown that the only structural assumption needed for rapid local convergence of such methods is the piecewise error bound, i.e., a local error bound holding for the branches of the solution set resulting from partitions of the bi-active complementarity indices. The latter error bound is implied by various piecewise constraint qualifications, including relatively weak ones. We apply our results to KKT systems arising from generalized Nash equilibrium problems.


Markus Herrich, Andreas Fischer, Alexey Izmailov, Mikhail Solodov

The LP-Newton method has been recently proposed for the solution of constrained systems of equations. It turned out that this method has very strong local convergence properties. In fact, it converges locally quadratically under assumptions implying neither differentiability nor the local uniqueness of solutions.

However, the question concerning a suitable globalization was not satisfactorily answered yet. In this talk we discuss an algorithm based on the LP-Newton method which uses a linesearch technique for the natural merit function. The new algorithm keeps the strong local convergence properties but has, in addition, global convergence properties.

3 - Projected Levenberg-Marquardt methods under the constrained error bound condition

Klaus Schönefeld, Roger Behling, Andreas Fischer, Gabriel Haeser, Alberto Ramos

We consider a smooth system of nonlinear equations subject to a closed convex feasible set. The projected Levenberg-Marquardt method projects the result of a classical Levenberg-Marquardt step onto the feasible set. This method is known to be Q-superlinearly convergent to a (possibly nonisolated) solution of the constrained system of equations if an error bound condition holds locally both for feasible and infeasible points. It was proved recently that a combination of two weaker local error bound conditions guarantees at least R-linear convergence. In this contribution, we show that one of these conditions can be omitted without losing the linear convergence. What is still needed is the constrained error bound condition, i.e., a condition for feasible points only.

The derivation of this result led to the interesting fact that under the constrained error bound condition the solution set of the constrained system can be locally represented as an intersection of a differentiable manifold with the feasible set.

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**TA-14**

**Thursday, 9:00-10:30 - Seminarraum 206**

**Scalarizations, Bounds and Mathematical Programming Methods**

Stream: Decision Theory and Multiple Criteria Decision Making
Chair: Nikolai Krivulin

1 - Efficient Bound Computations in Multiobjective Optimization

Kathrin Klamroth, Kerstin Daechert, Renaud Lacour, Daniel Vanderpooten

Given some (partial) knowledge on the nondominated set of a multiobjective optimization problem, the search region corresponds to that part of the objective space that potentially contains additional nondominated points. We consider a representation of the search region by a set of tight local upper bounds (in the minimization case). While the search region can be easily determined in the bi-objective case, its computation in higher dimensions is considerably more difficult and gives rise to an interesting relation to computational geometry. We discuss the usefulness of local upper bounds in Branch and Bound type algorithms as well as in scalarization based solution methods, aiming at concise representations of the nondominated set.

2 - Methods of tropical optimization in rating alternatives based on pairwise comparisons

Nikolai Krivulin

We consider unconstrained and constrained optimization problems in the framework of the tropical (idempotent) mathematics, which focuses on the theory and applications of semirings with idempotent addition. The problems are to minimize or maximize functions defined on vectors over idempotent semifields (semirings with multiplicative inverses). We examine several problems of rating alternatives from pairwise comparisons, including problems with constraints on the final ranking. We represent the approximation problems as optimization problems in the tropical mathematics setting. To solve these problems, methods of tropical optimization are used to provide direct, complete solutions in a compact vector form. We discuss the applicability of the results to real-world problems, and provide numerical examples.

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**TA-15**

**Thursday, 9:00-10:30 - Seminarraum 305**

**Flows and Queues**

Stream: Project Management and Scheduling
Chair: Martin Josef Geiger
1 - Linking Queueing Theory and Scheduling Approaches
Kathrin Benkel, Rainer Leisten

Stochastic queueing theory on the one hand and static-deterministic scheduling on the other hand are both widely used approaches in their respective literature, but in most cases discussed separated from each other. Referring to queueing approaches it is known that each type of variability, and especially its increase, reduces the performance of manufacturing systems and has to be buffered by an efficient mix of time, inventory and/or capacity (Hopp/Spearman, 2008, Factory Physics). Variability can be divided into operations variability (variability in processing times) and flow variability which defines the way jobs arrive and leave a production system (arrival and departure variability) (Hopp/Spearman, 2008, Factory Physics). In static-deterministic scheduling, variability is often discussed as part of an objective function, e.g. minimization of completion time variance (CTV) or minimization of variability of completion time differences (CTDV2). While the CTV problem tends to finish all jobs at the same time (which is impossible), CTDV2 is aimed at smoothing the distance in completion times of two consecutively scheduled jobs. This can be interpreted as departure variability in queueing approaches and as a first link between queueing theory and scheduling (Leisten, Rajendran, 2015, Variability of completion time differences in permutation flowshop scheduling). In this presentation we continue with connecting both approaches by discussing arrival variability and operations variability in deterministic permutation flow shop systems.

2 - Analysis of integrated scheduling and intermediate transportation systems in production lines with variability-related measures
Miriam Zacharias, Rainer Leisten, Rajendran C

In 2015, Leisten and Rajendran introduced the variability-related objective function CTDV2 which aims at smoothness of a flowshop’s output by minimizing the difference of completion times of two consecutively scheduled jobs. In this presentation work, CTDV2 and modifications of CTDV2 are investigated in a serial assembly system. The influence of variability in one system on the overall performance of the combined system is evaluated via computational experiments. First, a single flow shop with transport unit is evaluated from a scheduling perspective. The makespan and flowtime values of the NEH-solution are taken as benchmarks for the performance of the new objective function from a scheduling perspective. Then, two flow shops in series with and without interflow logistics are analysed from a scheduling perspective. Variability keeping of jobs in the queue between the two flowshops (approximated by the Kingman equation) is considered. Looking at the overall performance from scheduling and queueing perspectives shall help to close the gap between static-deterministic scheduling and dynamic-stochastic queueing theory.

3 - Optimal Torpedo Scheduling in Steel Production
Martin Josef Geiger

The talk presents a solution approach for the torpedo scheduling problem, a planning problem arising in steel production. In this application, torpedoes carrying liquid iron must be routed through a system of production stages (cell steel mill). This implies the detailed scheduling of the torpedoes, as the production stages, such as desulfurization stations, buffer zones, oxygen converters, are of limited capacity and thus may only hold a finite number of torpedoes at each time step. We currently employ a Branch-and-Bound (B&B) algorithm for the problem at hand. Due to the complexity of the problem, and due to the size of the available problem instances, the search for optimal solutions sometimes must be restricted to a reasonable running time, resulting in a time-truncated BB algorithm which is especially designed for guiding the search process must therefore be integrated into the solution approach. We have developed some ideas for this. The solution algorithm is tested on benchmark instances from the literature. We currently are, together with two other teams, ranked first in the ongoing ACP Challenge on benchmark instances from the literature. We currently are, together with two other teams, ranked first in the ongoing ACP Challenge on benchmark instances from the literature.

3.1 - Analyzing economies of scale and scope in hospitals using non-linear optimization
Sebastian Hof, Jens Brunner

The case mix planning problem deals with choosing the ideal composition and volume of patients in a hospital. Major changes in hospital size, e.g., due to mergers or acquisitions, can lead to significant changes in operational efficiencies. We formulate a generic non-linear mixed integer program using non-linear production functions to model such operational efficiencies in case mix planning. Since the problem cannot be solved with standard solution methods for realistic problem instances, we develop an iterative linear approximation scheme that cannot be solved with standard solution methods for realistic problem instances.
functions adds significant value to case mix planning models if major changes in scale are planned as opposed to scenario analyses with minor adoptions of production scale.

### TA-18

**Thursday, 9:00-10:30 - Seminarraum 401/402**

**Collaboration In Logistics**

**Stream:** Logistics, Routing and Location Planning  
**Chair:** Margaretha Gansterer

1. **Transportation Planning in a Sharing Economy Setting**  
   **Moritz Behrend, Frank Meisel**

   The rise of the sharing economy fosters a shift from a purchase-based towards an access-based consumption. After all, the need of purchasing items that are used on rare or just temporal occasions dwindles when, as a member of a sharing community, one can access them need-based. Examples for such items are tools, children’s clothing, or leisure equipment. The matching of supplies and demands of such items within a community can be coordinated via online platforms. The actual forwarding poses a transportation challenge, as the peer-to-peer exchange needs to address the highly inefficient “last mile” twice. We model the resulting logistics-planning problem on a network of given supplies, demands, and planned trips of the community members. Mathematical optimization models are developed to assign supplies to demands in a first step and, in a second step, to modify the given trips so as to pick up and drop-off the items at acceptable effort for the travelling community members. The objective is the maximization of the net benefit a sharing community can gain from such an approach. For this purpose, we propose a first set of benchmark instances together with detailed computation results.

2. **The Political Campaigning Problem: A Selective and Periodic TSP Perspective on Electoral Campaigns**  
   **Deniz Aksen, Masoud Shahmanzari**

   The Political Campaigning Problem (PCP) deals with determining daily routes for a party leader who holds meetings in various cities during a campaign period of 30 days. On a graph with static edge costs and time-dependent vertex profits, PCP seeks a closed or an open tour for each day. The objective is the maximization of the net benefit defined as the sum of reward points collected from meetings in the visited cities minus the traveling costs normalized into a compatible unit. The leader is not required to visit all cities making the problem selective. Moreover, he can stay overnight in any city. This means there is no fixed departure node (no depot). We consider the provinces of Turkey in addition to the capital city Ankara which serves as the center of the campaign. Each city is associated with a specific base reward and a visit duration. The leader can travel from one city to another city either by bus or by flying through three hub cities. He can stay overnight in a city other than the capital Ankara. However, he cannot be outside Ankara for more than four days in a row. The total length of the talks and travel times between cities on the same day cannot exceed 14 hours. The proposed model utilizes a multifaceted reward function. It calculates the reward point of each city considering four factors: i) Population, ii) The vote rate in the previous election and the criticality of the votes, iii) The number of remaining days until the election, iv) The number of days passed since the previous meeting in that city. As we get closer to the election day, the reward points of crowded cities increase significantly. On the other hand, success settings in a city are severely depreciated. We propose a MILP formulation in which we capture many real-world aspects of the PCP.

3. **Solving the centralized problem for a two-clustered transport collaboration network**  
   **Adria Soriano, Margaretha Gansterer, Richard Hartl**

   We are dealing with centralized solutions in a complex collaborative transport network, where shipment services are interchanged between a network of carriers. Shipments are considered to be performed between two far away regions. We consider shipments of goods in a three-stage setting. Goods are collected via local trips and consolidated in a hub in one region, transported via long-haul to a hub in the other region, and delivered by local trips again. The problem is solved for sequential and reciprocal demand. In each instance, the tour is given and the carrier has to serve all demand within a tour. Each carrier is assumed to have at least one hub in each region. This problem setting represents on the one hand, a realistic scenario of the transportation industry. On the other hand, it is a well-known assignment problem. We propose a first set of benchmark instances together with detailed computation results. We present results for different classes of test instances.

### TA-19

**Thursday, 9:00-10:30 - Seminarraum 403**

**Integrated Public Transportation Planning (i)**

**Stream:** Traffic and Passenger Transportation  
**Chair:** Marie Schmidt

1. **Integrated Traffic Planning in Grid Graphs**  
   **Alexander Schiewe, Philine Gattermann, Anita Schönbel**

   Integrating the different steps in transportation planning (in our case line planning, timetabling and vehicle scheduling) is a problem considered in ongoing research. Until now, these problems are solved sequentially in fixed order. The main disadvantage of this procedure is that once the line plan is fixed, it cannot be changed anymore, therefore reducing the number of possible timetables and vehicle schedules and possibly impairing the quality of the overall solution drastically. In this talk we examine integrated traffic planning in grid graphs. Since the integrated problem stays NP-hard on grid graphs, we use a so-called Eigenmodel approach, optimizing the line plan, the timetable, and the vehicle schedule iteratively, always keeping two of the three variables fixed. We identify the resulting optimization problems, namely (1) finding a line plan when timetable and vehicle schedule are fixed, (2) finding a timetable when vehicle schedule and line plan are fixed, and (3) finding a vehicle schedule when line plan and timetable are fixed and give formulations for these. We analyze if these can be simplified in grid graphs. The different optimization problems are then solved sequentially in different orders to improve the quality of the given solution for the integrated problem.

   We will apply this algorithm to grid graphs of increasing size and discuss the performance in computation time and quality of the obtained solutions as well as convergence observations.

2. **A SAT-Formulation for Integrating Line Planning, Timetabling and Passenger Routing**  
   **Philine Gattermann, Peter Großmann, Karl Nachtigall, Anita Schönbel**

   In public transportation planning, line planning and (periodic) timetabling are well researched problems. They are mostly solved sequentially. However, the sequential approach potentially inhibits optimal solutions to the integrated problem, as a fixed line plan greatly restricts the number of feasible timetables. Thus, we are aiming to find a solution for both problems simultaneously. To this end, we propose an integrated model for line planning and timetabling, where the passengers are routed during the optimization process on shortest paths according to their respective travel time. As line planning and periodic timetabling are both NP-hard problems and especially timetabling is computationally difficult, the integrated problem will be even harder to handle. Therefore, we decided to extend the currently best performing formulation for periodic timetabling, which is a SAT-formulation proposed by Großmann et al. (2012). While feasibility of the integrated problem can be modeled by a satisfiability problem, we need an extension of SAT to model the objective function. We chose a partial weighted maxSAT problem, which allows to handle constraints which have to be fulfilled and to minimize the travel time as objective function. Furthermore, we compare this partial weighted maxSAT formulation to an IP-formulation of the integrated line planning, timetabling and passenger routing problem and discuss the advantages and disadvantages of each formulation.
3 - Line planning with user-optimal route choice
Marie Schmidt, Marc Goerigk

We consider the problem of designing lines in a public transport system, where we include user-optimal route choice. The model we develop ensures that there is enough capacity present for every passenger to travel on a shortest route. We present different integer programming formulations for this problem, and discuss exact solution approaches as well as a genetic solution algorithms.

TA-20
Thursday, 9:00-10:30 - Seminarraum 404

Forecasting with Artificial Neural Networks
Stream: Business Analytics and Forecasting
Chair: Sven F. Crone

1 - Forecasting Model Selection for Industry Data by Applying Meta-Learning with Feature Selection
Mirko Kück, Sven F. Crone, Michael Freitag

Demand planning is an important task for manufacturing companies since it is the main basis for all following steps of production planning. Typically, the future demand per stock-keeping-unit has to be forecasted based on time series of past customer orders. With several statistical methods created for different time series patterns, large scale applications on 10,000s of times series require a method selection, often done manually by human experts based on time series characteristics, or automatically using error metrics of past performance. However, the task of selecting adequate forecasting models can also be viewed as a supervised learning problem. For instance, a neural network can be trained as a meta-learner relating characteristic time series features to the ex post accuracy of forecasting models for each time series. Past research has proposed different sets of time series features for meta-learning, including simple statistical or information-theoretic as well as model-based features, and landmarks. This paper performs a feature selection on the different predefined sets of meta-features to provide a basis for a neural network meta-learner selecting between four statistical forecasting models. A large-scale empirical study on NN3 industry data shows promising results of the meta-learning approach for selecting appropriate forecasting models. The best model selection performance was achieved by the meta-learning approach with feature selection, leading to higher forecasting accuracy than approaches using the predefined feature sets as well as different benchmark methods for model selection, including the selection of the forecasting model with lowest error on the training set or the validation set, which is widely applied as best practice in industry.

2 - The Value of Visualization in Forecasting Applications
Dennis Eilers, Daniel Olivotti, Michael H. Breitner

The price of commodities is a critical success factor for a variety of companies. To identify the best possible price for a purchase in the future decision support systems based on forecasting models are used. Artificial Neuronal Networks (ANN) are a sophisticated method for non-linear time series forecasts. ANNs are trained with historical data to forecast future price paths. In most cases network ensembles are used. These ensembles consist of several thousand single networks. Due to random initialisation each network creates a different path. To visualize the information, several aggregation techniques can be applied. When using the simple arithmetic mean or the median the information of the ensemble gets pooled in a single path. For a decision maker this kind of presentation is easy to interpret. However, this may lead to misinterpretations if several bundles of paths with different implications emerge. With a heatmap visualization the information content can be significantly increased, as divergent assessments within the ensemble can be made visible. Our aim is to quantify the benefits of different types of visualizations. For this purpose, a design for a laboratory experiment is presented, in which the quality of the decisions of people based on various visualization techniques is examined. This results in recommendations for the implementation of visualizations in practical applications.

3 - Neural network initialisation for time series prediction - an empirical evaluation of different methodologies on Industry Data
Sven F. Crone

Artificial neural networks require multiple initialisations of their starting weights for training, and a number of methodologies have been proposed to set initial starting weights. In addition to the standard procedure, using starting values drawn at random from a uniform distribution around zero, e.g. [-1, 1], [0.5, 0.5] Sarle (2002), a number of alternative initialisation methodologies have been proposed by Nguyen and Widrow (1990), Drago and Ridella (1992), Wessels and Barnard (1992), Yam and Chow (2000) and LeCun et al. (1998), which promise enhanced accuracy, efficiency or robustness. Although their merit has recently received increasing attention for architectures of deep neural networks used in image recognition, no attention to these methodologies has been given in their application for multilayer perceptron in time series prediction and forecasting. This paper seeks to remedy this omission and assess the effect of different initialisation techniques in an empirical evaluation on real-world industry time series, using a representative experimental design of fixed-horizon forecasts across multiple rolling time-origins, and using robust error metrics. The results suggest that the selection of an adequate initialisation methodology has a significant impact on forecast accuracy, robustness and efficiency, which is larger than that of other meta-parameters in neural network modelling.

TA-21
Thursday, 9:00-10:30 - Seminarraum 405/406

Airspace Networks
Stream: Logistics, Routing and Location Planning
Chair: Adam Schienle

1 - A VRP Based Mathematical Model for Airspace Sectorization
Aydin Sipahioglu, Şaban Temizkan

Airspace is getting crowded day by day and to manage air traffic becomes much harder due to the fact that different types of aircrafts take place in the sky with having different purposes. Airspace sectorization or airspace sector design means partitioning of airspace so as to balancing workloads among the segments. In other words, it is determination of responsibility area for each controller team. Airspace sectorization is a special field of air traffic management problem and to obtain manageable sectors is important. All aircrafts in a sector are controlled by a team of controllers and it is demanded the variance of workload among sectors should be minimized. Airspace sectorization problem is also dynamic. Since conditions such as weather, national security and business connections are dynamic for a country, workloads are changeable. So, boundaries of sectors should be changed considering workloads. Because of this dynamic structure, an efficient sectorization method is required.

In this study, a vehicle routing problem (VRP) based mathematical model is proposed to obtain airspace sectors with balanced workloads. The model depends on discretization of the air space into quadrangles through geographical reference system. In order to calculate workload of each quadrangle, an Analytical Hierarchy Process (AHP) based method is also proposed. Airspace is described as a symmetric graph and it is shown on test problem that the model gives manageable and well balanced sectors.

2 - Preprocessing Techniques for the Shortest Path Problem on Airway Networks
Adam Schienle, Marco Blanco, Ralf Borndörfer, Nam Dung Hoang, Thomas Schlechte

We study a simplified version of the Flight Trajectory Optimisation Problem, which is the problem of finding a minimum travel time path between two airports on an airway network, a directed graph. We regard both wind speed and direction as functions of time, which allows us to model the problem as a time dependent shortest path problem with the FIFO property. While this problem has been extensively studied for road networks, airway networks have an essentially different structure: the average degree is higher, and shortest paths usually have only few arcs. We consider two well-known routing algorithms,
Thursday, 11:00-12:30

TB-02
Thursday, 11:00-12:30 - Hörsaal 1

Combinatorial Optimization (i)
Stream: Discrete and Integer Optimization
Chair: Dennis Michaels

1 - Robust Assignments with Vulnerable Nodes
Viktor Bindewald, David Adjiashvili, Dennis Michaels
Various real-life planning problems require making upfront decisions before all parameters of the problem have been disclosed. An important special case of such problem arises in scheduling and staff rostering problems, where a set of tasks needs to be assigned to the available set of personnel or machines (resources), in a way that all tasks have assigned resources, and no two tasks share the same resource. In its nominal form, the resulting computational problem becomes the assignment problem.

This talk deals with the Robust Assignment Problem (RAP) which models situations in which certain resources are vulnerable and may become unavailable after the solution has been chosen. Such unavailability can be caused e.g. by an employee’s sickness, or machine failure.

The goal is to choose a minimum-cost collection of resources (nodes in the corresponding bipartite graph) so that if any vulnerable node becomes unavailable, the remaining part of the solution still contains sufficient nodes to perform all tasks.

We develop algorithms and hardness results for RAP and establish several connections to well-known concepts from matching theory.

2 - On the stable set polytope of claw-free graphs: the class of icosahedral graphs
Claudio Gentile, Anna Galluccio
The problem of finding a complete linear description of the stable set polytope of claw-free graphs has been one of the major topics in combinatorial optimization since early Seventies. Indeed this problem was defined as a natural generalization of the Edmonds’ result on the matching polytope. Even if there has been many advances in the last 15 years, the stable set polytope of claw-free graphs is still not completely described.

While it is known that this linear description contains facet defining inequalities with arbitrary many and arbitrarily high coefficients, the set of claw-free graphs whose stable set polytope is described only by inequalities with 0,1,2-valued coefficients is considerably large. In fact, in 2014 Galluccio, Gentile and Ventura proved that this set contains almost all claw-free graphs with stability number greater than three plus some of the building blocks with stability number smaller than or equal to three, identified by Chudnovsky and Seymour in 2008.

In this talk we show that another important class of claw-free graphs with stability number three is described by 0,1,2-valued coefficients inequalities: the class of icosahedral graphs.

3 - Solution methods for the Quadratic TSP and its variations
Rostislav Staněk, Oswin Aichholzer, Anja Fischer, Frank Fischer, J. Fabian Meier, Ulrich Pferschy, Alexander Pilz
The traveling salesman problem (TSP) asks for a shortest tour through all vertices of a graph with respect to the weights of the edges. The symmetric quadratic traveling salesman problem (SQTSP) associates a weight with every three vertices traversed in succession. If these weights correspond to the turning angles of the tour, we speak of the angular-metric traveling salesman problem (Angle TSP). First, we consider the SQTSP from a computational point of view. In particular, we apply a rather basic algorithmic idea and perform the separation of the classical subtour elimination constraints on integral solutions only. It turns out that this approach is faster than the standard fractional separation procedure known from the literature. We also test the combination with strengthened subtour elimination constraints introduced by Fischer and Helmberg in 2013. Secondly, we provide a different, mathematically interesting MILP linearization for the Angle TSP that needs only a linear number of additional variables while the standard linearization requires a cubic one. Finally, we introduce MaxSQTSP, the maximization version of the quadratic traveling salesman problem.
Here it turns out that using some of the stronger subtour elimination constraints helps. For the special case of the MaxAngle TSP we can observe an interesting geometric property if the number of vertices is odd. We show that the sum of inner turning angles in an optimal solution always equals pi. This implies that the problem can be solved by the standard ILP model without producing any integral subtours. Moreover, we give a simple constructive polynomial time algorithm to find such an optimal solution. If the number of vertices is even the optimal value lies between 0 and 2 pi and these two bounds are tight.

1 - Towards quantifying customer needs from micro blog data in e-mobility
Marc Goutier, Niklas Kuehl

The identification and quantification of customer needs is an important process in order to design new products and services. As shown in previous work, it is possible to classify micro blog data (e.g. tweets) on their feature of containing a customer need or not by applying Machine Learning models. With such a model as a basis, we show that customer needs can be clustered and quantified in the relevant data for a domain of interest-in this case e-mobility-as long as the possibly occurring categories of needs are known in advance. To apply the proposed method to e-mobility, major needs in this field are identified from recent literature, resulting in four major categories: Cost-related, car-related, charging-related, and social-related needs. Four disjointive white lists containing keywords, generated from the previous literature review, serve as a foundation for the need quantification. A first study shows that a white-list-based automatic clustering- relying on occurrences of the keywords- already achieves a high precision in the categories cost (82.8%) and charging (95%). The recall is unsteady between poor 13.1% (car-related needs) and solid 70.5% (charging-related needs).

Further results are discussed and interpreted. In summary, the contribution of the paper is threefold: 1) It gives a state of the art overview of relevant literature for customer needs in the field of electric mobility. 2) It proposes, executes and evaluates an approach on how to quantify (previously known) needs from micro blog data. 3) It gives insights about the quantity of customer needs in electric mobility, being expressed on Twitter of a time span of six months in Germany.

2 - Flexibility Options for Lignite-fired Power Plants - A Real Option Approach
Barbara Glensk, Reinhard Madlener

The energy system transformation process "Energiewende" in Germany means, on the one hand, the promotion of (to a significant part intermittent) renewable energy technologies and, on the other hand, increasing difficulties in the profitable operation of many modern conventional power plants due to decreasing wholesale power prices (due to the so-called "merit order" effect). Nevertheless, the conventional power generation technologies are still needed for security of supply reasons when there is little wind or sunshine, and to keep power generation and demand for electricity in balance. In light of these aspects and the specific situation of the German federal state of North Rhine-Westphalia the more specific problem of a further profitable operation of the lignite-fired power plants arises. In our study, we wanted to answer the following research questions: Should the lignite-fired power plants be operated till the end of their lifetime without any flexibility-enhancing technical modifications? What are the implications of operating the already existing lignite-fired power plants more flexibly? Which flexibility options ought to be taken into consideration? What is the optimal investment time for the flexibility options investigated? Are the investments in other power generation technologies more suitable to ensure the system stability instead of retrofitting lignite-fired power plants? In order to shed some light on these research questions we propose an optimization model that is based on real options analysis (ROA) or, more precisely, on the option to choose. In the proposed model, both economic and technical aspects of power plant operation are explicitly taken into consideration for investigating their profitability under enhanced flexibility.

3 - Using Optimization Models for a Technology-Neutral Coordination of Flexibility Options on the Power Market
Lars-Peter Lauring, Jutta Geldermann

The increasing supply of volatile renewable electricity leads to an increased need for flexibility in the power market. In addition to using electricity storage facilities such as pump storages, numerous flexibility options have been identified on both the supply and demand side of the power market. On the supply side, certain generators can interrupt and resume their operation in relatively short time frames. On the demand side, the increasing numbers of electricity consumers that engage in Demand Response schemes mean that an imbalance of the power market can, to some extent, also be met by adjusting consumer demand. The determination of the most favorable options in specific situations becomes more complex with the number of available options. In addition to the direct costs of using a flexibility option, technical constraints such as minimal or maximal times of operation, lead times and capacity need to be considered. In the context of virtual power plants, which coordinate a variety of flexibility options, increasingly complex decision problems therefore need to be solved. In this work, a combination of binary optimization models is presented that help to determine a technology-neutral operational ranking for a portfolio of flexibility options.

4 - Demand Response in Industrial Sites - Energy cost reduction using mathematical optimization
Sleiman Saliba, Lennart Merkert, Reinhard Bauer

In this talk, we analyze the potential of energy cost reductions using mathematical optimization for demand response in industrial sites. The same models and concepts are applicable to commercial sites or residential areas. We speak of demand response when energy consumer dynamically increase or decrease their power consumption depending on the price or availability of energy.

In the power industry, we see an increase in business models where industrial sites profit from providing the flexibility of industrial processes to the power market using demand response. Industrial sites normally have own power generation units or regulated connections to the power grid or both. Moreover, they have critical industrial processes to the power market using demand response. Industrial sites normally have own power generation units or regulated connections to the power grid or both. Moreover, they have critical industrial processes to the power market using demand response. Industrial sites normally have own power generation units or regulated connections to the power grid or both. Moreover, they have critical industrial processes to the power market using demand response. Industrial sites normally have own power generation units or regulated connections to the power grid or both. Moreover, they have critical industrial processes to the power market using demand response. Industrial sites normally have own power generation units or regulated connections to the power grid or both. Moreover, they have critical industrial processes to the power market using demand response. Industrial sites normally have own power generation units or regulated connections to the power grid or both. Moreover, they have critical industrial processes to the power market using demand response. Industrial sites normally have own power generation units or regulated connections to the power grid or both. Moreover, they have critical industrial processes to the power market using demand response. Industrial sites normally have own power generation units or regulated connections to the power grid or both. Moreover, they have critical industrial processes to the power market using demand response. Industrial sites normally have own power generation units or regulated connections to the power grid or both. Moreover, they have critical industrial processes to the power market using demand response. Industrial sites normally have own power generation units or regulated connections to the power grid or both. Moreover, they have critical industrial processes to the power market using demand response.

We show how to combine production planning, energy management and energy trading in order to reduce the energy cost and increase the financial benefit from providing the flexibility to the grid operator. All this, without changing the production goals or moving production deadlines.

Finally we present successful real-world demand response applications, where industrial site operators could increase the productivity and the financial benefits using mathematical optimization for demand response. Demand Response is an essential component to benefit from the changing energy markets and to contribute to a sustainable power generation in the 21st century.

2 - Simulation and Evaluation of the Market Potential of Virtually Connected Photovoltaic-Battery Systems with Respect to Decentralized Prosumers
Hendrik Broering, Reinhard Madlener

The widespread deployment of rooftop photovoltaic systems has been a striking implication of the German energy transition. The self-generation of households turns them from passive consumers of electricity into active "prosumers" (consumer-producers). In 2012, the so-called "grid parity" was reached in Germany, meaning that self-generated electricity has become cheaper than that purchased from the grid or, in other words, PV remuneration has become lower than electricity purchase cost. Consequently, it is economical to maximize the self-consumption of PV electricity. Following this opening wedge
between purchase cost and remuneration, the number of battery systems in private households in Germany has risen sharply in the recent past. The focus of our research is the analysis of the economic merit of a virtual aggregation of spare capacities (unused storage capacities) from those batteries. We refer to the resulting capacity as cloud capacity. To this end we develop a MATLAB model that simulates battery state-of-charge values resulting from PV generation and load profiles for individual prosumers. We then define a geographically separated decision-maker (independent prosumer, without a battery system), who demands the spare battery-capacities of those households in order to maximize the self-consumption quota. We simulate an entire year and determine sensitivities with regard to electricity transport costs, feed-in tariffs, operation strategies and electricity prices. Moreover, we evaluate the economic merit depending on the number and degree of decentralization of the process. Based on our simulation results, we point out under which regulatory and technological conditions such a cloud model could indeed be profitable for the decision-maker.

**TB-05**

Thursday, 11:00-12:30 - Hörsaal 4

**Mechanism and Markets for IT Service Compositions**

Stream: Game Theory and Experimental Economics
Chair: Alexander Skopalik

1. **Economic Aspects of Service Composition: Price Negotiations and Quality Investments**
   Simon Hooft, Sonja Brangewitz

   We analyse the economic interaction on the market for composed services. Typically intermediaries as providers of composed services interact on the sales side with users and on the procurement side with providers of single services. Thus, in how far a user request can be met often crucially depends on the prices and qualities of the different single services used in the composition. We study an intermediary who purchases two complementary single services and combines them. The prices paid to the service providers are determined by simultaneous equations for the users and providers. We investigate the evolution of these service qualities and the corresponding service providers' investments within a differential game framework.

2. **Truthful Outcomes from Non-Truthful Position Auctions**
   Paul Dütting, Felix Fischer, David C. Parkes

   Adding to a long list of properties that explain why the VCG mechanism is rarely used in practice, we exhibit a relative lack of robustness to inaccuracies in the choice of its parameters. For a standard position auction environment in which the auctioneer may not know the precise relative values of the positions, we show that under both complete and incomplete information a non-truthful mechanism supports the truthful outcome of the VCG mechanism for a wider range of these values than the VCG mechanism itself. The result for complete information concerns the generalized second-price mechanism and lends additional support to Google’s use of this mechanism for ad placement. Particularly interesting from a technical perspective is the case of incomplete information, where a surprising combinatorial equivalence helps us to avoid confrontation with an unwieldy differential equation.

3. **Strategic Formation of Customer Relationship Networks**
   Sonja Brangewitz, Claus-Jochen Haake, Philipp Möhlemeier

   We analyze the stability of networks when two firms strategically form costly links to customers. We interpret these links as customer relationships that enable trade to sell a product. Equilibrium prices and equilibrium quantities are determined endogenously for a given network of customer relationships. We investigate in how far the degree of substitutability of the firms’ products and the costs of link formation influence the equilibrium profits and thus have an impact on the incentives to strategically form relationships to customers. For networks with n customers we analyze local stability regions for selected networks and determine their limits when n goes to infinity. It turns out that the shape of local stability regions for those networks does not significantly change compared to a setting with a small number of customers. In addition, we establish the existence of locally stable networks for complementary or independent products. More precisely, for these products either the empty, the complete or both networks are locally stable. We also relate local Nash stability for selected networks with n customers. For networks with three customers we characterize locally stable networks. In particular, existence is guaranteed for any degree of substitutability.

**TB-06**

Thursday, 11:00-12:30 - Hörsaal 5

**Robust Revenue Management**

Stream: Pricing and Revenue Management
Chair: Jochen Gönsch

1. **Multi-criteria Optimization for Airline Revenue Management**
   Felix Geyer, Catherine Cleophas

   Thus far, most airline revenue management research focuses on maximizing expected short-term revenue. However, from a business perspective, other success criteria can play a significant role, such as market share or average load factor. These indicators are believed to improve the airline’s stock market value and its long-term market. In practice, this discrepancy causes revenue optimal solutions – as calculated by automated systems – to be manually overridden by airline analysts. However, such manual interventions come at the risk of collateral damage. To avoid this, we suggest to add additional criteria to the revenue optimization problem’s objective function. We formulate a multi-criteria revenue management model and present a dynamic programming approach to solve it. The resulting efficient frontier can be used by decision makers to find a favorable trade-off between revenue and secondary goals.

2. **Practical Decision Rules for Risk-Averse Revenue Management using Simulation-Based Optimization**
   Jochen Gönsch, Sebastian Koch, Michael Hassler, Robert Klein

   In practice, human-decision makers often feel uncomfortable with the risk-neutral revenue management systems’ output. Reasons include a low number of repetitions of similar events, a critical impact of the achieved revenue for economic survival, or simply business constraints imposed by management. However, solving capacity control problems is a challenging task for many risk measures and the approaches are often not compatible with existing software systems. In this presentation, we propose a flexible framework for risk-averse capacity control under customer choice behavior. Existing risk-neutral decision rules are augmented by the integration of adjustable parameters. Our key idea is the application of simulation-based optimization (SBO) to calibrate these parameters. This allows to easily tailor the resulting capacity control mechanism to almost every risk measure and customer choice behavior. In an extensive simulation study, we analyze the impact of our approach on expected utility, conditional value-at-risk (CVaR), and expected value. The results show a superior performance in comparison to risk-neutral approaches from literature.

**TB-07**

Thursday, 11:00-12:30 - Hörsaal 6

**New Results for Shipping, Matching, and Covering**

Stream: Graphs and Networks
Chair: Ralf Borndörfer
1 - Integer Programming Formulations and Decomposition Algorithms for Maximum Induced Matching Problem
Z. Caner Taşkin, Betül Ahaat, Tinaz Ekim

We investigate the Maximum Induced Matching problem (MIM), which is the problem of finding an induced matching having the largest cardinality on an undirected graph. The problem is known to be NP-hard for general graphs. We first propose a vertex-based integer programming formulation, which is more compact compared to edge-based formulations in the literature. We also introduce vertex- and edge-weighted versions of MIM. We formulate the weighted problem as a quadratic integer programming problem based on our vertex-based formulation. We then linearize our quadratic programming formulation, and propose a decomposition algorithm that exploits a special structure of the linearized formulation. Our computational experiments show that our decomposition approach significantly improves solvability of the problem, especially on dense graphs.

2 - Optimization Formulations for Set Covering Open Locating Dominating Sets
Blair Sweigart, Rux Kincaid

In this paper we explore various mathematical formulations for extensions on Open Locating Dominating Sets (OLD). OLDS are similar to identifying codes, but on the open neighborhood of the sensor nodes, which adds a layer of robustness. The OLD is a subset of nodes on which we can place sensors that can detect events at nearby nodes, where the subset is such that when an event occurs, we immediately are alerted to the exact location of the event by the sensors that detect it. In a traditional OLD, all nodes must be covered. However, this proves overly restrictive on real-world graphs. For instance, scale-free graphs, with hub and spoke patterns, often have no feasible solution, because multiple leaves share the same neighborhood. To identify an optimal OLD for these graphs, we merge the traditional formulation with a set covering formulation. We present here linear and non-linear mixed integer binary programming formulations to identify traditional OLDS, OLDS with fixed number of sensors (fixed-p), and maximal set-covering OLDS. We further explore their results on random graphs of various constructs, and the influence of weighting parameters that govern the cost of each sensor and the value of covering certain nodes. We lay the ground work for further application of these formulations to real-world scenarios including actor identification in dark networks and time release contamination in a municipal water supply grid.

3 - Timetabling on Path Networks with Application to the Istanbul Metrobus
Ralf Borndörfer, Oytun Arslan, Ziena Elijazyer, Hakan Güler, Malte Renken, Guvenc Sahin, Thomas Schlechte

Bus rapid transit systems in developing and newly industrialized countries often consist of a trunk with a path topology. On this trunk, several overlapping lines are operated which provide direct connections. The demand varies heavily over the day, with morning and afternoon peaks typically in reverse directions. The construction of a timetable for such a system can be seen as a multiperiod covering problem on an interval graph. We study the complexity of this problem, derive some combinatorial properties in the static (or single period) case, consider the clustering of the demand into service periods, and the solution of the multiperiod version. An application to the Metrobus system in Istanbul will be discussed.

TB-08
Thursday, 11:00-12:30 - Seminarraum 101/103

Collaborative Transportation Planning I (i)
Stream: Logistics, Routing and Location Planning
Chair: Kristian Schopka
Chair: Mario Ziebuhr

1 - Event-Based Support for Collaborative Synchron-modal Logistics
Paul Grefen, Remco Dijkman

Modern (international) logistics is often of a multi-modal nature, which requires different modes of freight transport used in sequence. Modern logistics must also be flexible to deal with disturbances in transport, caused for example by traffic or weather conditions, while keeping overall transport times and/or costs as low as possible. This can be accomplished by the use of synchro-modal logistics, i.e., adapting planned transportation modalities on-the-fly during the execution of logistics processes. This requires collaborative planning and replanning based on (near) real-time, detailed transport data produced by a set of transport providers and infrastructure owners. In this presentation, the approach to synchro-modal logistics and real-time planning is presented that has been developed in the GET Service EU FP7 project. This approach is based on highly distributed, real-time generation of detailed, transport-related events and aggregation of these events in high-level information for logistics planners. The GET Service prototype system includes a core platform for logistics information and event processing and includes explicit logistics process execution support. The approach has been evaluated by several case studies in the logistics industry.

2 - Dynamic Vehicle Routing with Stochastic Travel Times Matrices Changes Induced by a Cooperative Traffic Management
Felix Köster, Dirk Christian Mattfeld, Marlin Wolf Ulmer

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

3 - Request-allocaton in Dynamic Collaborative Transportation Planning Problems
Kristian Schopka, Herbert Kopfer

To overcome the uncertainty associated with dynamic transportation planning problems, small and medium sized carriers (SMCs) use auction-based mechanisms to reallocate transportation requests. Game theoretical schemes like the Shapley value ensure a fair cost allocation for individual planning horizons. Nevertheless, shifts in the request portfolios of the individual SMCs are not taken into account. This issue could cause a collapse of the coalition, particularly when a rolling horizon planning over a long planning period is applied. In this presentation, the winner determination problem is restricted by additional restrictions that ensure an even allocation of transportation requests among SMCs. It means, all SMCs transfer and receive a proportional number of transportation requests through the auction-based request exchange over the considered planning period. In computational experiments, the collaboration profits are analyzed on the dynamic collaborative traveling salesman problem regarding the restricted winner determination problem. Both, the transportation planning problem and the winner determination problem are solved by a mathematical solver, while the calculation of bids is executed by an insertion algorithm.

TB-09
Thursday, 11:00-12:30 - Seminarraum 105

Algebraic Modeling Languages
Stream: Software and Modelling Systems
Chair: Robert Fourer
1 - Cloud services for optimization modeling software  
Robert Fourer

Optimization modeling systems first became available online soon after the establishment of the NEOS Server almost 20 years ago. This presentation describes the evolution of NEOS and other options in what came to be known as cloud computing, with emphasis on the modeling aspects of optimization. In comparison to solver services that compute and return optimal solutions, cloud services for building optimization models and reporting results have proved especially challenging to design and deliver. A collaboration between local clients and cloud servers may turn out to provide the best environment for model development.

2 - Recent Enhancements in GAMS  
Franz Nelinisen, Michael Bussieck, Frederik Fiant

Algebraic Modeling Languages (AML) are one of the success stories in Operations Research. GAMS is one of the prominent AMLs and has evolved continuously in response to user requirements, changes in computing environments and advances in the theory and practice of mathematical programing. In this talk we will begin with some fundamental principles and outline several recent enhancements of GAMS supporting efficient and productive development of optimization based decision support applications.

3 - Deploying MPL Optimization Models with Google Web Services API’s  
Bjarni Kristjansson, Sandip Pindoria

Over the past decade the IT has been moving steadily towards utilizing software on clouds using Web Services API’s. The old standard way of deploying software on standalone computers is slowly going away. Google has been one of the leading software vendors in this area and publishes several web API’s which can be quite useful for deploying optimization applications. In this presentation we will demonstrate several Google API’s, including the Google Sheets API, Google Maps API, and Google Visualization API and show how they can be integrated with the MPL OptiMax Library for deploying optimization to service both web and mobile clients.

2 - Multi-stage Hub-Location Routing Problem  
Dimitri Papadimitriou

The Hub-Location Routing Problem (HLRP) combines the Hub Location Problem (HLP) with the Location Routing Problem (LRP). The HLP deals with the design of hub- and spoke spatial structures to prevent direct point-to-point connections between sources and destinations by introducing distribution, collection and redirection nodes, called hubs, and possibly connections among them called hub edges. On the other hand, the LRP aims at determining the location of facilities, the allocation of demands to facilities, and designing the distribution or collection routes depending on the delivery or assembly properties of the system. The distinctive feature of the HLRP compared to the LRP resides in considering simultaneously both collection or distribution routes (and corresponding routing decisions).

In the context of this paper, hubs provide collective resource abstractions, i.e., the composition and/or aggregation of physical resources offered by individual non-hub facilities (along collection routes), and delivery to customers along distribution routes. This model contrasts with the one considered when each non-hub facility provides such functionality individually and the allocation of demands is performed independently. For this purpose, we introduce a mixed integer formulation covering setting with single- and multi-stage resource composition and/or aggregation. Its properties are then compared against path-, arc- and flow-based formulations considered in the context of multi-level facility-location problems (M(U)FLP). Then, we propose the design a flow-based iterative algorithm for solving this problem efficiently. Finally, we present results of computational experiments to assess its performance on representative settings.

3 - Bounds for stochastic multistage optimization problems  
Georg Pflug, Francesca Maggioni

Multistage stochastic optimization problems are typically of huge complexity. It is therefore important to obtain quick upper and lower bounds for the optimal value, which allow to decide to stop or to continue with some refinements.

We present bounding methods both for problems already defined on a discrete scenario tree as well as problem which are not yet discretized. In the latter case, we construct approximating scenario trees for which the optimal values are bounds for the true problem. Along with the bounding techniques, we may construct feasible solutions for the true problem, which are epsilon-optimal, with an epsilon, which one may choose.

1 - Minimizing work-in-process inventory in stochastic and time-dependent flow lines  
Justus Arne Schwarz, Raik Stolletz

Flow lines include inventory buffers to compensate stochastic influences such as random processing and repair times. In practice, the parameters characterizing the stochasticity vary over time, for instance, during production ramp-ups. Thus, we introduce a new mechanism for the allocation of inventory buffers in flow lines under stochastic and time-dependent operating environments. In contrast to approaches for systems with time-homogeneous parameters, the proposed approach uses information about the future development of the production system to proactively change the maximum inventory level of the buffers over time. We discuss the corresponding decision problem and preliminary results. Differences and commonalities with the buffer allocation problem are outlined.
2 - Modelling uncertainty in an automobile multi-stage production process
Andrea Borenich, Peter Greistortler, Marc Reimann

This work is inspired by a research project with a company from the automobile supplier industry. Such companies frequently have to make bids to obtain production orders. These bids are typically based on cost estimates for a multi-stage production process. In the automobile plant considered, this process involves four stages, namely the stamping plant, the body shop, the paint shop, and the final assembly. Additionally, these stages are linked by intra-plant logistics.

We focus on the various options of merging individual decisions taken in the different main stages to highlight the importance of coordinating the cost estimation process. In doing so, we have implemented three strategic model variables. First, each main stage takes an intra-plant location decision, thereby affecting logistics costs. Second, the degree of automation critically influences the volume flexibility within each main stage and drives capital investment. Third, the shift model is the main cause of human resources costs.

The model analysis combines two main questions: how should the cost estimation of the different main stages be organized to obtain an overall acceptable result and how should the firm handle the risk, induced by the cost estimation under input parameter uncertainty? The organizational question is addressed by comparing three different approaches. The first one imitates the current practice of our industrial partner. The second one considers a central authority taking all decisions. Finally, the third one sequences the main stages’ decisions. Our answer to the risk question is a comparison of a deterministic approach with two stochastic approaches, where uncertainty in the parameters is modelled through scenarios. The resulting MILPs are solved with CPLEX.

Scheduling and Sequencing: Applications
Stream: Metaheuristics
Chair: Franz Rothlauf

1 - A Heuristic Procedure for Integrated Cutting Stock and Sequencing Problem in the Marble Industry
Burcu Kubur, Adil Baykasoglu

In this study, we deal with knife dependent setup cost of one dimensional cutting stock problem with usable leftover (1D CSPUL) which is a specific case of the well-known one dimensional cutting stock problem (1D CSP). Even though the literature in the area of cutting and packing is growing rapidly, research seems mostly to focus on standard problem, while the practical aspects are less frequently dealt with. Despite its great applicability in several industries, this is particularly true for the combined cutting stock and sequencing problem because of its great complexity. In industrial cutting processes setup cost occur whenever changing over one cutting pattern to another and the cutting equipment has to be prepared in order to meet technical requirements of the new pattern. Setups involve the consumption of the resources and the loss of production time capacity. Therefore, cutting stock problem and sequencing problem have to be simultaneously considered in a cutting process. The goal here is to minimize transportation, overgrading and knife dependent setup costs. The main endeavor of this study is to specifically developed Stochastic Diffusion Search Algorithm (SDS) to solve the 1D CSPUL by taking into sequence dependent setups cost between cutting marble blocks. Computational experiments are conducted to assess the performance of the proposed heuristic by solving randomly generated instances and also practical instance from a marble company.

2 - Ensemble Techniques for Scheduling in Heterogeneous Wireless Communications Networks
David Lynch, Michael Fenton, Stepan Kucera, Holger Clausen, Michael O'Neill

Cellular network operators are struggling to cope with exponentially increasing demand. Heterogeneous Networks (HetNets) have been proposed as a means of increasing capacity without the need for additional bandwidth, which is expensive and scarce. HetNets consist of traditional high-powered Macro Cells supplemented with low-powered Small Cells.

Capacity can be increased in channel sharing HetNets by intelligently scheduling User Equipments to receive data from Small Cells. Grammar-based Genetic Programming (GBGP) has been shown to be a powerful framework for automatically devising Small Cell scheduling heuristics. In previous works, the single best model from many independent runs constituted the solution. This approach is naive because all but one of the evolved models are discarded. An ensemble technique which exercises N 25 models from a single run is proposed in this paper. Schedules must be generated at the beginning of every 40 ms ‘frame’ based on measurement reports assimilated over the previous frame. The ensemble generates N hypothesis schedules based on the measurement reports in frame t. Each hypothesis is rapidly evaluated with respect to a utility of downlink rates. The best performing schedule is executed in frame t + 1.

Simulations reveal that the proposed ensemble method significantly outperforms the naive approach and a state of the art benchmark scheme, at a significance level of alpha=0.01. In fact, the ensemble is within 1% of the best known optimum given by CMA-ES. Semantic analysis reveals that evolved GBGP phenotypes generate highly dissimilar schedules. Such strategic diversity enables the ensemble to specialise on particular cases. A single generalised model cannot achieve a comparable degree of specialisation.

3 - Don’t buy a pig in a poke: Supporting allocation decisions in multi-clouds
Leonard Heilig, Eduardo Lalla-Ruiz, Stefan Voss

The rise of cloud computing in recent years led to a plethora of different cloud services designed to be adapted to the individual resource demands and requirements of consumers. In multi-clouds, infrastructure as a service (IaaS) solutions are offered by multiple cloud providers and need to be combined and configured in such a way that individual cost and performance goals of consumers can be achieved. Due to the specific characteristics of multi-clouds, complex decision problems arise and need to be efficiently addressed for supporting decision makers in purchasing those cloud services. In this work, we propose a cloud brokerage approach to facilitate purchasing and scheduling decision processes for IaaS services under several rich constraints. In doing so, we model the problem and generate different problem instances consisting of various consumer and resource requirements in order to assess the quality and implications of our proposed mechanism.

Simulation Models I
Stream: Simulation and Stochastic Modeling
Chair: Brigitte Werners

1 - A macroscopic simulation model of the urban Viennese subway network with capacity constraints and time-dependent demand
David Schmaranzer, Roland Braune, Karl Doerner

We present a discrete event simulation model of the Viennese urban subway network with capacity constraints and time-dependent demand. Demand, passenger transfer and travel times as well as vehicle travel and turning maneuver times are stochastic. Capacity restrictions apply to the number of waiting passengers at a platform and within a vehicle. Passenger generation is a time-dependent Poisson process which uses hourly origin-destination-matrices based on mobile phone data. A statistical analysis of vehicle data revealed that vehicle interaction travel times are not time- but direction-dependent. The purpose of this model is to support strategic decision making by performing what-if-scenarios to gain managerial insights. Such decisions involve how many vehicles may be needed to achieve certain headways and what are entailed consequences. Headway optimization, for example, is a significant subject in urban public transportation: Population growth - a prognosis expects the Viennese population (currently 1.78 million) to break the 2 million mark by 2027 - as well as other reasons (e.g. efforts to reduce carbon emissions) call for frequent reevaluations whether provisions are - now or in future - indispensable. Economic factors namely, capital and operational expenditure (e.g. daily fleet size as well as driver headcount, infrastructure preservation and potential expansion) - are contrary to the goal of passenger satisfaction (i.e. service level, travel time). Our first results allow for bottleneck identification as well as a sensitivity analysis.
2 - Decision support for power plant shift configuration using stochastic simulation
Mohammad Darvizeh, Christian Stummer

Power generation companies have to ensure a secure supply of power to their customers at any time. Hence, appropriate personnel support has to be guaranteed. The application context implies that all business functions with varying qualification requirements have to be staffed at any time. In this regard, optimal shift scheduling is a highly important and complex task. For the purpose of comparing different proposed shift configurations, we conceptualise a simulation tool with a reactive structure incorporating an integer optimisation model. The stochastic simulation takes uncertainty associated with employee sickness into account.

3 - Simulating the diffusion of competing technology generations: An agent-based model and its application to the consumer computer market in Germany
Markus Günther, Christian Stummer

Consumer adoption of innovations is a key concern for strategic management in many companies, as adoption typically drives the market success of new products. Due to the inherent complexity of adoption processes arising from the underlying social system (i.e., the respective consumer market), analytical approaches more often than not fail at properly capturing the emergent market behavior. Agent-based modeling and simulation, on the other hand, allows for considering various inherent, underlying social influences as well as spatial and temporal aspects and have already shown promising results in these respects. Markets in which not just two, but multiple and successively advanced product features in each technology generation, the reluctance of (some) users to switch to a new (yet unfamiliar) technology, and various social influences between consumers. Based on data from several sources, the model is calibrated for the German consumer computer market from 1994-2013. Since simulation results indeed replicate the actual development of market shares on monthly bases, we can demonstrate the applicability of such an agent-based approach in principal.

4 - Self-regulated Multi-criteria Decision Analysis
Muhammad Umer Wasim, Tadas Limba

Multi-criteria Decision Analysis (MCDA) ranks different alternatives during the decision making process according to given criteria by a decision maker. However, the evaluation of available alternatives is prone to bias if decision maker has insufficient domain knowledge. The decision maker may exert one of the two different notions of factor analysis from the field of statistic. A proof of concept example using dataset on Quality of Service (QoS) by online Cloud storage provider was used to illustrate in-field execution. The criteria of QoS in the dataset were: Availability, Response Time, Price, Storage Space, Use, Technical Support, and Customer Service. The results showed that, in the given dataset, Storage Space is an irrelevant criterion and the rest account for more than 95% of change in the QoS, which endorse their presence as relevant criteria. In the next stage of this research, the goal is to implement and test self-regulated MCDA for structural uncertainty in Cloud Brokerage Architecture that often uses MCDA for retailing of Cloud services. The beneficiary of the research would be enterprises that view insufficient domain knowledge as a limiting factor for acquisition of Cloud services.

5 - Dynamic capabilities in new product development and its effects on firm performance
Mohammad Darvizeh, Jian-Bo Yang, Steve Eldridge

In dynamically competitive environment, it would be influential to examine the relationship between dynamic capabilities (DC) and the superior performance of firms through new product development (NPD) performance and this enable managers to make a sound and quick decision. While differential performances of firms in the high technology industry such as automotive or aerospace industry are so important for achieving sustainable competitive advantage, the study searches for the explanation of this phenomenon in the view of dynamic capabilities. Through a comparative multi cases study of fairly large R&D intensive manufacturing firms, the analysis focuses on identifying and evaluating the effects of organisational and managerial processes on the development of three capacities of sensing, seizing and reconfiguring that form dynamic capabilities through product development activities. While dynamic capability facilitates an efficient and effective product development, the integrated findings of the analysis is to show the performance assessment of dynamic capability using multi criteria decision analysis (MCDA) that determines the success and failure of manufacturing buyer’s firms in the recent volatile environment. The results contribute to the literature by verifying the conceptual framework of foundations and micro-foundations of dynamic capabilities, illustrating the transformation of its multiple roles, and introducing an extended framework for managerial actions. Most importantly, this research confirms that the superior performance of a company in the automotive or aerospace industry is best explained by the three core of dynamic capabilities. In short, the research provides an insight for managers to define relevant NPD strategies.

6 - Ressource Constrained Project Scheduling
Steve Eldridge

Stream: Project Management and Scheduling

Choosing the optimal project portfolio from a set of alternative projects is a critical decision for oil and gas companies. This significant decision is often complicated in practical applications due to the uncertainty associated with the value of projects and incomplete preference information on the evaluation criteria. Especially when the number of projects and criteria is large, the efficiency of the resource allocation and the quality of the decision making process requires a suitable systematic approach. Hence, this study proposes a Stochastic Multi-criteria Acceptability Analysis (SMAA) based approach for project portfolio selection. Thereby, a multi-criteria evaluation is carried out using SMAA method in order to evaluate each project individually based on various criteria. Based on this, a linear-programming model is applied to maximize the total value of the projects selected for the optimal portfolio while ensuring some constraints related to the resources available. The proposed approach can provide a scientific basis for oil and gas companies to make robust decisions based on uncertain and incomplete information. It also helps to decrease the subjective blindness in the investments, and to save cost and time in data elicitation process. Finally, an example case study of exploration project portfolio selection in oil and gas industry is carried out to illustrate the proposed approach.
1 - A decomposition method for the Multi-Mode Resource-Constrained Multi-Project Scheduling Problem (MRCMPSp)  
Mathias Kühn, Sebastian Dirkmann, Michael Völker, Thorsten Schmidt  
Multi-Mode Resource-Constrained Multi-Project Scheduling Problems (MRCMPSp) with large solution search spaces, commonly realized in assembly planning of aircrafts (up to 20,000 activities), cannot be optimized in an acceptable computation time. In this paper, we have focused on decomposition strategies for such large scale problems. Based on literature review, a time-based decomposition approach was adopted for the present problem. With time-based decomposition approaches a schedule is divided into several time periods. All activities in a time period describe an independent problem, termed as a sub-problem. Although state-of-the-art research in the area of time-based decomposition approaches proves reduction in computation time for the Resource-Constrained Project Scheduling Problem (RCPSP), application of these concepts on MRCMPSp was observed to provide insufficient results. Due to the independent optimization of these sub-problems project information regarding the relationships among activities in different time periods is not considered. This loss of information has a negative impact on the overall solution quality. We developed a decomposition strategy to improve the interactions between the sub-problems for a better target performance while reducing the computation time. Based on an initial solution the sub-problems are created and sequentially optimized in a concept similar to rolling horizon heuristics. We introduce a crossover with a constant and a variable component at the end of each partial schedule to improve the interactions among sub-problems and thus taking the volatile nature of the examined problems into account. In comparison, our approach proved to provide significant improvements in runtime and target performance.

2 - Solving the resource-constrained multi-project scheduling problem with a flexible project structure  
Luise-Sophie Hoffmann, Carolin Kellenbrink  
In flexible projects, jobs that have to be scheduled are not fully known in advance. Hence, in addition to scheduling, the project structure needs to be determined. The resource-constrained project scheduling problem with a flexible project structure (RCPSP-PS) deals with this problem. In application fields such as the regeneration of complex capital goods, multiple projects use the same renewable and non-renewable resources. Therefore, they have to be planned simultaneously. In this talk, the RCPSP-PS is extended to the RCMPSp-PS with the goal of minimizing the total costs consisting of job costs and penalties for delay. For the purpose of solving flexible multi-project problems in practice-oriented project sizes, different heuristic methods are considered. A two staged priority rule-based method is presented in which firstly the project structure is fixed and secondly the selected jobs are scheduled. Furthermore, genetic algorithms with different solution encodings are presented. A comparative study indicates the performance of the heuristic and the exact methods.

3 - Monte Carlo Tree Search for the Resource-Constrained Project Scheduling Problem  
Kristina Bayer, Robert Klein, Sebastian Koch  
Monte Carlo Tree Search (MCTS) is a heuristic algorithm from the field of Artificial Intelligence combining classical tree search with Monte Carlo simulations. It is therefore suited for problems that can be represented as trees of sequential decisions. MCTS has recently attracted a lot of attention because of its success in the board game Go. However, little research has been done investigating the suitability of MCTS for planning problems of Operations Research. In this talk, we adapt MCTS to the well-known Resource-Constrained Project Scheduling Problem (RCPSP). In particular, we show how to appropriately define and search tree representations of the RCPSP. We conduct a number of computational experiments on standard RCPSP data sets from the literature to investigate the applicability and performance of our approach.

1 - Queue management for operating theatres  
Belinda Spratt, Erhan Kozan  
Australian public hospitals are facing an increase in the demand for elective surgeries due to a number of factors including the aging population and improved access to diagnostic tools. It is important to ensure that the current hospital infrastructure is being utilised efficiently so as to combat the increase in demand. We propose a Mixed Integer Non-Linear Programming (MINLP) formulation for the combined master surgical scheduling problem (MSSP) and surgical case assignment problem (SCAP) under a block scheduling policy. This problem of assigning specialties, surgeons and patients to operating theatre time blocks. Inspired by a case study of a large Australian public hospital, we incorporate stochastic surgical durations, surgeons and theatre capacity and availability, and current government policy aimed at reducing elective surgery waiting times for public patients. Due to the size of the case study considered, we use a number of meta-heuristics inspired by Simulated Annealing (SA) and Reduced Variable Neighbourhood Search (RVNS). Based on a real world case study, we validate the proposed approach which promises to significantly improve the efficiency of operating theatre scheduling.

2 - Optimizing Intensive Care Unit (ICU) Planning by Markov Decision Process  
Jie Bai, Jens Brunner  
Intensive care units (ICU) are known as a crucial and expensive resource largely affected by uncertainty and variability. As a result, the capacity is often limited causing many negative effects for the ICU itself, and even making ICU a bottleneck in hospital patient flows. To solve this problem, both admission control of newly arrival patients and demand driven discharge of currently residing patients could be options. However, the rejection of new patients could increase the mortality rate, and the demand driven discharge might cause the patient health deterioration and then resulting in readmission. We use the discrete time Markov decision process (MDP) to model the optimal decision making problem in such a complex system. Both exact solution and approximate solution approaches are applied. We analyze the performance of the model by a case study based on empirical data.

3 - Flexible break assignment in physician scheduling  
Melanie Erhard, Jens Brunner  
In hospitals, personnel generates the biggest and most important cost. This research focuses on physician scheduling in hospitals with the main objective to investigate break assignment in the scheduling process. In particular, we consider three different approaches for modeling the flexible placement of breaks. Current scheduling literature mainly neglects the consideration of breaks whereas practice uses manual approaches that are time and cost intensive. Focusing on a strategic planning problem, we minimize the number of assigned physicians subject to demand coverage and labor regulations. We formulate the problem as a mixed-integer program and test various parameter settings. The problem is solved with standard software (like CPLEX). For our experimental study, real world data from a large hospital in Germany is used. Results show that consideration of breaks has little impact on the workforce size but ensures legal regulated rest periods for physicians.

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**TB-17**  
Thursday, 11:00-12:30 - Seminarraum 310  
Coordination and Collaboration  
Stream: Supply Chain Management  
Chair: Thomas Spengler  
1 - Partial Cooperation Opportunities in a Two-Echelon Supply Chain  
İsmail Serdar Bakal, Betul Diler, Ozgen Karaer  
In this study, we consider a two-echelon supply consisting of two manufacturers and a single retailer. Each manufacturer produces a single product, and the products are substitutable. The demand for the products is random. Before the retailer determines the order quantities, the manufacturers set their wholesale prices simultaneously. In this setting, we consider the decentralized setting where each party acts independently, and model the vertical competition between the retailer and the manufacturers as well as the horizontal competition between manufacturers.
the manufacturers. We first characterize the order quantities of the retailer. Then, we consider the pricing problem of the manufacturers and determine the equilibrium wholesale prices. We also consider the setting where the prices are determined sequentially. We next consider different alternatives for cooperation. We first investigate the retailer’s choice in forming a coalition with one of the manufacturers and observe its effect on the ordering decisions. Then, we aim to quantify the benefits that the manufacturers can generate by coordinating their pricing decision.

2 - Drivers and Resistors for Supply Chain Collaboration
Verena Jung, Tjark Vredeveld, Marianne Peeters

In the last decades companies have been realizing the need for looking outside their organizational boundaries for new opportunities. This is due to various factors such as a constantly growing competition amongst organizations, rising globalization, a growing product variety and a wide access to sophisticated IT and web-based technologies. According to Sukaiti et al. (2012) and Horvath (2001) a new vital base of competitive advantage, that has not yet been fully exploited and thus offers a huge potential for growth and performance improvements, is supply chain collaboration (SCC). Although the idea of SCC may sound easy in theory collaborations in practice often fail, which indicates a gap between theory and practice. This is due to the fact that for a specific SCC a huge amount of drivers and resistors has to be taken into account by all parties involved. However, these drivers and resistors are often unknown or misunderstood by the participants. Despite of the fact that a great amount of research has been published in that field, the literature shows a great amount of ambiguity. With this paper a clear structure for the drivers and resistors is provided, which will close the gap between theory and practice and thus lead to more successful SCCs. This helps to understand for example differences in what are the important drivers and resistors for a certain kind of relationship. Preliminary results show that the structure can help to identify important drivers and resistors for the different parties even in a more complex triangular relationship.

3 - Coordination in contracts in distributed product development processes with complete substitution
Kerstin Schmidt, Thomas Volling, Thomas Spengler

In distributed product development processes system integrators collaborate with suppliers to provide marketable products. Considering a converging supply chain with two suppliers and one system integrator, we apply a Stackelberg game to model the contract-based coordination of such processes under uncertain development results, complete substitution and maximum price clause. Assuming uniformly distributed development results, we analyze the coordination ability of a wholesale price contract and a penalty contract and present numerical illustrations of centralized and decentralized solutions.

### TB-18

**Container and Terminal Operations II (i)**

**Stream: Logistics, Routing and Location Planning**

**Chair: Julia Funke**

**1 - Optimal dynamic assignment of internal vehicle fleet at a maritime rail terminal with uncertain processing times**

Ying Xie, Dongping Song

The growing traffic volume puts a huge pressure on container port as an interface between seaborne transport and hinterland transport. The deployment of mega-vessels has added further challenges to container ports to cope with the surge effect of container flows. In addition, traffic congestion and emissions caused by truck movements in the surrounding area of seaports have raised serious concerns to the society. Rail transport is regarded as an effective way to tackle the above challenges due to its high capability and low emission. Therefore, improving the efficiency of rail terminal operations at seaports is essential to ensure the sustainability of global container transport chains. This study aims to investigate and improve the efficiency of container loading process at a seaport by optimising the container flows. Our model is able to balance the container pre-staging decision and the container flow rate control within the time window. In addition, the model can dynamically determine the optimal container flow rates from storage yard to rail terminal buffer and from rail terminal buffer to the train by taking into account the uncertainties in the handling activities.

### TB-19

**Stream: Traffic and Passenger Transportation**

**Chair: Matis Mihalák**

**1 - Robust Routing in Urban Public Transportation: How to find reliable journeys based on past observations**

Tobias Pröger, Katarina Böhmova, Matis Mihalák, Peter Widmayer

We study the problem of robust routing in urban public transportation networks. In order to propose solutions that are robust for typical deviations, we assume that we have past observations of real traffic situations available. In particular, we assume that we have “daily records” containing the observed travel times in the whole network for a few past days. We introduce a new concept to express a solution that is feasible in any record of a given public transportation network. We adapt the method of Böhmann et al. (2013) for optimization under uncertainty, and develop algorithms that allow its application for finding a robust journey from a given source to a given destination, and propose possible generalizations. The robust routing concepts presented in this work are suited specially for public transportation networks of large cities that lack clear hierarchial structure and contain services that run with high frequencies.

**2 - Robust Routing in Urban Public Transportation: Evaluating Strategies that Learn from the Past**

Katarina Böhmova, Matis Mihalák, Peggy Neubert, Tobias Pröger, Peter Widmayer

Given an urban public transportation network and historic delay information, we consider the problem of computing reliable journeys. We propose new algorithms based on our recently presented solution concept (Böhmová et al., 2013) and perform an experimental evaluation using real-world delay data from Zürich, Switzerland. We compare these methods to natural approaches as well as to our recently presented solution model. The decision variables include: the pre-staged number of containers from storage yard to rail terminal buffer; the dynamic flow rates from yard to buffer and the dynamic flow rates from buffer to the train within the time window. A case study will be constructed based on the data from a real container rail terminal. Numerical experiments will be performed to illustrate the effectiveness and the sensitivity of the methods and the results. Our model is able to balance the container pre-staging decision and the container flow rate control within the time window. In addition, the model can dynamically determine the optimal container flow rates from storage yard to rail terminal buffer and from rail terminal buffer to the train by taking into account the uncertainties in the handling activities.
proposed method which can also be used to measure typicality of past observations. Moreover, we demonstrate how this measure relates to the predictive quality of the individual methods. In particular, if the past observations are typical, then the learning-based methods are able to produce solutions that perform well on typical days, even in the presence of large delays.

3 - Bi-directional Search for Min-Max-Relative-Regret Routes in Time-dependent Bi-criteria Road Networks
Matti Mihalák, Sandro Montanari

Based on time-dependent travel times for N past days, we consider the computation of robust routes according to the min-max relative regret criterion. For this method we seek a path minimizing its maximum weight in any one of the N days, normalized by the weight of an optimal route for the respective day. In order to speed-up this computationally demanding approach, we observe that its output belongs to the Pareto front of the network with time-dependent multi-criteria edge weights. We adapt a well-known algorithm for computing Pareto fronts in time-dependent graphs and apply the bi-directional search technique to it. We also show how to parameterize this algorithm by a value K to compute a K-approximate Pareto front. An experimental evaluation for the cases N = 2 and N = 3 indicates a considerable speed-up of the bi-directional search over the uni-directional.

TB-20
Thursday, 11:00-12:30 - Seminarraum 404
Analytics in Mobility
Stream: Business Analytics and Forecasting
Chair: Jennifer Schoch

1 - Accounting for Range Anxiety in Smart Charging Strategies for Electric Vehicles
Jennifer Schoch, Johannes Gärttner, Alexander Schuller, Thomas Setzer

Electric vehicles (EVs) can considerably contribute to the reduction of global CO2 emissions and are a promising alternative for conventionally propelled vehicles. One of the primary factors limiting a broader and faster distribution of EVs is the energy storage system, i.e., the high voltage battery. While the battery capacity is limited by the high cost per kWh as well as its weight, the range of a compact EV is considerably lower than that of vehicles with an internal combustion engine.

Empirical studies of charging behavior of EV drivers reveal that they often experience range anxiety resulting in a diurnal full re-charging of the battery to maximize a vehicle’s range available.

While the operative SoC range strongly impacts battery degradation in terms of capacity fade and the resulting range decline, it has been shown that the time to end of life (EoL) can be considerably increased by applying the degradation optimal charging strategy. However, the optimal point of operation in terms of SoC range implies a minimization of available range, in contrast to full-charging where the available range is maximized.

Hence, there is a clear trade-off to be solved regarding short and long term objectives. In order to analyze the trade-off between both strategies, we evaluate the degradation optimal charging strategy and the influence on battery life prolongation resulting from the establishment of different levels of range buffers. The time to end of life influenced by different charging strategies and range buffers is evaluated using simulation-based analysis based on more than 1000 empirically-derived driving profiles.

2 - Towards mathematical programming methods for predicting user mobility in mobile networks
Alberto Ceselli, Marco Premoli

Motivated by optimal orchestration of virtual machines in a mobile cloud computing environment to support mobile users, we face the problem of retrieving user trajectories in urban areas. We partition the region covered by a mobile network into cells, one for each access point, and we suppose to be given: (a) the adjacency matrix between cells, and (b) the demand in each cell at each point in time, that is the number of users connected to the corresponding access point. We also assume that an aggregated information about user mobility is given, like the probability distribution of trajectory lengths. Our aim is to

find an estimate on the trajectory of each user, in terms of sequence of cells traversed during the considered time horizon. Our modeling approach is the following: first, we perform both a time discretization and a trajectory length discretization. Then, we introduce extended mathematical programming formulations, inspired by flows over time models, having a polynomial number of constraints, but an exponential number of variables. We include two hierarchical objectives and we experiment on two forms of flow balancing constraints. We devise column generation algorithms: pricing turns out to be a resource constrained shortest path problem, for which we provide an ad-hoc dynamic programming procedure. We experiment on both synthetic datasets, obtained through generative models from the literature, and real world datasets from a major mobile carrier in Paris for which ground truth is not available. Our methods turn out to be accurate enough to predict mobility on the synthetic datasets, and efficient enough to tackle real world instances; while fine time discretization increases their effort, fine length discretization is not an issue.

3 - Simulation-based Data Selection and Reduction for Battery Degradation Modeling in Electric Vehicles
Philipp Staudt, Jennifer Schoch

Traction batteries are one of the most cost intensive components of electric vehicles (EV) and therefore limit their driving range. Due to battery degradation and the resulting capacity fade, this phenomenon is amplified. The influence of usage patterns on degradation has not been fully investigated by now and sufficient data is not yet available. Consequently, OEMs are facing the challenge of selecting and reducing the relevant features of the potentially vast amount of data created by electric vehicles in the field in order to optimize the ratio of information gained and the data volume transmitted.

To address this challenge, a simulation-based analysis is conducted, which captures the influence of the dynamic user behavior and the resulting degradation on EV batteries. The simulation is based on a realistic aging model and more than 1000 representative driving profiles. The simulation includes variable selection using Lasso regression and dimension reduction techniques, such as PCA, different forecasting models are developed. Furthermore, the trade-off between forecasting ability and the required data volume is evaluated. Additionally, the models are tested for their ability to predict the battery’s end-of-life. We find that by using a small amount of data, which is suitable for mobile transmission, a satisfactory forecasting accuracy can be achieved. All developed models use driving behavior features as input factors. This suggests changes in the warranty design of OEMs. Furthermore, the results of the end-of-life prediction are promising regarding a predictive maintenance strategy.

TB-21
Thursday, 11:00-12:30 - Seminarraum 405/406
Facility and Hub Location Problems
Stream: Logistics, Routing and Location Planning
Chair: Teresa Melo

1 - The stochastic single allocation hub location problem
Nicolas Kämmerling, Borzou Rostami

The design of hub-and-spoke transport networks is a strategic planning problem as the choice of hub locations has to remain unchanged for long time periods. The future transport volumes are not known in advance and can only be estimated by a stochastic distribution during the planning process. Moreover, the demand in transport networks changes dynamically over the time due to seasonal effects. This paper considers the inclusion of uncertainty to the single allocation hub location problem. From the deterministic problem we derive two stochastic two-stage program formulations for the problem where the allocation to the hubs can be viewed as fixed or flexible over the time.

In case of fixed allocation pattern we observe that all structural decision are taken within the strategic planning phase. In fact we show that the stochastic single allocation hub location problem is equivalent to the deterministic problem where the average demand values are taken as input data. In case of flexible allocation pattern the resulting optimization problem is significantly harder as allocation decision depends on the current demand. We develop a dual decomposition procedure which unifies the hub location choice after having decomposed the problem into a set of independent subproblems.
2 - Competitive hub location for the leader; considering followers in the future
Babak Farhang Moghaddam, Amir Afshin Fatahi

This research addresses the hub location problem in competitive markets. From the view point of the company that has entered the market for the first time (the leader), hub location aims at: 1) meeting the market demand fully with the least possible costs, and 2) reducing the expected profits of those companies that want to enter the market in the future (the followers). A two steps algorithm has been proposed to solve such a competitive hub location problem. The market shares of the leader and followers are determined based on their announced prices and the rate customers are sensitive to them, and then each company’s profit is calculated. This research studies Iran’s airlines market in 2013, analyzes the elements that affect location through adjusting the problem parameters under different conditions, and solves the problem by the dynamic programming exact method. The results have shown that a jump (turning) point is possible in the profit reduction rate of the competing companies with respect to the number of the hubs of the leader. Also, using the regression analysis, the effects of the model parameters on the companies’ maximum profits have been tested.

3 - Multi-period facility location with dynamic capacity planning and delayed demand satisfaction
Teresa Melo, Isabel Correia

We consider a facility location problem that takes into account changing trends in customer demand and costs. To this end, facilities may have their capacities dynamically adjusted over a planning horizon. It is assumed that a set of existing facilities are operating with given capacities. These capacities can be removed, expanded and/or contracted over the time horizon. Once removed, a facility cannot be reopened. Additionally, a set of potential locations for establishing new facilities is also considered. Once a new facility has been installed, its configuration may be modified through capacity expansion and/or contraction over multiple periods. New facilities must remain open until the end of the time horizon. Our problem setting addresses situations in which space and equipment can be rented or operations can be subcontracted. This allows a company to dynamically adjust the configuration of its facilities, e.g. to respond to seasonal demand trends. A further distinctive feature of our problem is that two customer segments are considered with different sensitivity to delivery lead times. Customers in the first segment require timely demand satisfaction, whereas customers in the second segment tolerate late deliveries. A tardiness penalty is incurred to each unit of demand that is satisfied with delay. We develop alternative mixed-integer linear programming models to redesign the facility network so as to minimize the total cost. Additional inequalities are proposed to enhance the original formulations. A computational study is performed with randomly generated instances and using a general-purpose solver. Useful insights are derived from analyzing the impact of different demand patterns and delivery lead time restrictions on the network structure and total cost.

Thursday, 13:30-14:15

■ TC-02
Thursday, 13:30-14:15 - Hörsaal 1
Semi-Plenary Walther
Stream: Semi-Plenaries
Chair: Stefan Wolfgang Pickl

1 - OR for Future Mobility: Designing Sustainable Means of Transportation
Grit Walther

The transportation sector contributes significantly to global fossil CO2 emissions, and is still almost totally reliant on petroleum-derived fuels. Therefore, a transformation is needed and sustainable means of transportation have to be launched and disseminated. In this context, strategic investment decisions have to be taken, e.g., regarding the installation of charging infrastructure for battery electric vehicles or the design of production networks and supply chains for biofuels and E-fuels. Additionally, complex planning problems arise at an operational level, e.g., by routing battery electric vehicles with limited range and need for (partial) recharging in a still scarce infrastructure, or by integrating load management of the electricity grid with charging of large electric vehicle fleets. This talk will give an overview on how OR can contribute to solve these new challenges in the transportation sector. Examples on projects will be given, current challenges will be discussed, and requirements for OR models will be derived. Some of the models and applications will be discussed in more detail, and insights on how these approaches can be implemented in practice will be given.

■ TC-03
Thursday, 13:30-14:15 - Hörsaal 2
Semi-Plenary Correa
Stream: Semi-Plenaries
Chair: Tobias Harks

1 - Dynamic pricing with forward-looking consumers
José Correa

Determining effective pricing policy when selling to strategic consumers that arrive over time is a growing area that is posing challenging questions with practical implications. In this talk we study a basic pricing problem in which a single unit is on sale and consumers are forward looking. We first discuss a model in which the price can only change at discrete times. Then, we derive optimal pricing schemes for the case in which the price can change continuously. All these pricing schemes require that the seller has commitment power. This is an important assumption that we discuss in detail.

■ TC-04
Thursday, 13:30-14:15 - Hörsaal 3
Semi-Plenary Hurink
Stream: Semi-Plenaries
Chair: Guido Voigt

1 - Decentralized Energy Management: New Challenges for Operations Research
Johann Hurink

Our energy systems undergo a fundamental change. Whereas in the past the energy mainly was generated in large power plants using fossil fuels, in the future a large part of the generation will result from small plants in decentralized locations using uncontrollable renewable
Semi-Plenary Spieksma

1 - Scheduling a soccer league
Frits Spieksma

Soccer has become a major business involving many stakeholders, such as teams, police, fans, sponsors, and broadcasting companies. Huge amounts of money are being paid for the broadcasting rights, illustrating the economic value of soccer competitions. It also emphasizes the relevance of finding a good schedule. Each involved party has numerous (possibly conflicting) constraints and wishes, and a schedule that satisfies all constraints and wishes simply doesn’t exist. Hence, developing a schedule that is considered fair, and that is acceptable to all parties, is a challenge. We describe our experience in scheduling the ProLeague, Belgium’s highest professional league, over the last seasons. We outline some of the different models we used, and we emphasize the advantages of using model-based schedules: transparency, perceived fairness, or simply said: the quality of the schedule.

Thursday, 14:45-16:15

■ TD-02
Thursday, 14:45-16:15 - Hörsaal 1

Advances in Mixed Integer Programming (I)

Stream: Discrete and Integer Optimization
Chair: Sven Wiese

1 - SCIP-Jack: A Solver for the Steiner Tree Problem and Variants
Daniel Reichfeldt

Spawned by practical applications, numerous variations of the classical Steiner tree problem in graphs have been studied during the last decades. Despite the strong relationship between the different variants, solution approaches employed so far have been prevalently problem-specific. In contrast, we pursue a general-purpose strategy that is based on new graph transformations and a branch-and-cut framework. This approach results in a solver able to solve both the classical Steiner tree problem and ten of its variants without modification. These variants include well-known problems such as the prize-collecting Steiner tree problem, the maximum-weight connected subgraph problem, or the rectilinear minimum Steiner tree problem. Bolstered by a variety of new methods, most notably reduction techniques, our solver is not only of unprecedented versatility, but furthermore competitive or even superior to specialized state-of-the-art programs for several Steiner problem variants.

2 - Experiments with conflict analysis in SCIP
Jakob Witzig, Timo Berthold, Stefan Heinz

Conflict analysis plays an important role in solving Mixed-Integer Programs (MIPs) and is implemented in most major MIP solvers. The analysis of infeasible nodes has its origin in solving satisfiability problems (SAT). SAT solvers use the concept of aging to drop conflicts that do not frequently yield variable fixings. The age of a conflict approximates the distance between the current node and the node at which the conflict was generated, assuming a depth-first-search node selection. In contrast to SAT solvers, modern MIP solvers frequently “jump” within the tree. Thus, the concept of aging is often not strong enough to control the set of active conflicts, especially, if a variety of conflicts is generated. In this talk, we introduce the idea of a dynamic pool to manage conflict constraints. We present computational experiments conducted within the non-commercial MIP solver SCIP.

3 - MILP experiments with wide split cuts
Sven Wiese, Andrea Lodi, Andrea Tramontani, Pierre Bonami, Felipe Serrano

In the classical theory for split cuts, the ‘width’ of a split set is always equal to one. We investigate cutting planes that arise when widening the associated disjunctions. This allows, e.g., to model non-contiguous domains of (integer) variables (or, stated differently, ‘holes’ in the domains). The validity of the disjunctions in a MILP can come from either primal or dual information, and we present examples and computational results in both cases. We further explore an exact MILP approach based on these cutting planes, that in addition tackles non-contiguity directly via branching and as a side-effect reduces the model size.

■ TD-03
Thursday, 14:45-16:15 - Hörsaal 2

Sustainable Resource Management

Stream: CANCELED
**TD-04**

**Thursday, 14:45-16:15 - Hörsaal 3**

**Investment planning and portfolios in energy markets**

**Stream: Energy and Environment**

**Chair: Michael Zipf**

1. **Turning Brown into Green Electricity: Economic Feasibility of Pumped Storage Hydro Power Plants in Open Pit Mines**
   
   Reinhard Madlener, Michael Wessel, Christoph Hilgers

   In the course of the German "Energiewende" a radical shift from fossil and nuclear to renewable power production is underway. However, with increasing shares of intermittent generation from wind and photovoltaic power, maintaining security of supply becomes a challenge, making the extension of the electric grid and bulk storage capacity necessary. The most efficient storage technology is pumped storage hydro (PSH), which allows to generate revenues on the spot market by buying (selling) electricity in off-peak (peak) hours, or on the balancing market by offering positive or negative reserve capacity. Natural sites for PSH power plants are scarce, and likely to encounter substantial public resistance. Abandoned open pit mines are thus interesting candidate locations that may not face as much public resistance as greenfield projects. In our study we investigate the investment decision concerning two variants of PSH power technology erected in an open pit mine: In Variant 1, the pit lake forms the lower basin, and the higher basin is built on the mine dump. In Variant 2, the lower basin is established as a tank under the pit lake which is used as the higher basin. In the model-based analysis, we apply the NPM method, sensitivity analysis, and Monte Carlo simulation (to account for electricity price uncertainty). Variant 1 shows that a PSH plant can be constructed at reasonable costs and operated at low unit production costs. However, the investment has to be made before flooding the pit lake, which may take up to 20 years, and render profitability rather unlikely, especially in light of further adverse environmental impacts that may imply additional cost. In contrast, underground storage in the form of tanks in light of further adverse environmental impacts that may imply additional cost. In contrast, underground storage in the form of tanks is found to be non-economic.

2. **A Mathematical Programming-Based Approach for an Energy Investment Planning of a Private Company**
   
   Semra Agrali, Fulya Terzi, Ethem Canakoglu, Neslihan Yilmaz

   We consider a private electricity generating company that plans to enter the market that is partially regulated. There is a cap and trade system in operation in the industry. There are nine possible power plant types that the company considers to invest on through a planning horizon. Some of these plants may include a carbon capture and sequestration technology. We develop a mixed-integer linear program for this problem where the objective is to maximize the expected net present value of the profit obtained. We include restrictions on the maximum and minimum possible amount of investment for every type of investment option. We also enforce market share conditions such that the percentage of the total investments of the company over the total installed capacity of the country stay between upper and lower bounds. Moreover, in order to distribute the investment risk, the percentage of each type of power plant investment is restricted by some upper bound. We tested the model for a hypothetical company operating in Turkey. The results show that the model is suitable to be used for determining the investment strategy of the company.

3. **Optimising the natural gas supply portfolio of a gas-fired power producer**
   
   Nadine Kumbartzky

   The expansion of gas-fired power plants has led to increasing interactions between the natural gas and electricity market. In order to effectively manage risk of volatile energy prices, operators of gas-fired power plants need to take natural gas procurement and power plant resource planning simultaneously into account. An industrial company is considered that owns a gas-fired combined heat and power (CHP) plant. To ensure a stable heat and power supply, the amount of gas needed to operate the CHP plant must be available at any time. Natural gas can be procured by signing supply contracts or by engaging in the natural gas spot market. A two-stage stochastic MILP is proposed that optimises the gas supply portfolio and the CHP plant operation according to revenue potential in the electricity spot market. Uncertainty of gas and electricity spot prices is appropriately addressed by means of stochastic processes. Price risk is explicitly taken into account by the Conditional Value-at-Risk (CVaR). A convex combination of expected total costs and CVaR allows for representing different risk preferences of the decision maker. The efficient performance of the presented approach is illustrated in a case study using the example of German energy markets. The results reveal the significant influence of different risk preferences on the optimal gas supply portfolio composition as well as on CHP plant operation.

**TD-05**

**Thursday, 14:45-16:15 - Hörsaal 4**

**Sequential Scheduling Games (i)**

**Stream: Game Theory and Experimental Economics**

**Chair: Matüs Mihalák**

1. **The Price of Anarchy for Set Packing Games**
   
   Marc Uetz, Jasper de Jong

   The talk addresses set packing games where each of n players selects a subset of items with corresponding values to maximize the total value of the selected items. Players are restricted in their choice of items by downward-closed feasibility constraints, and each item can only be chosen by a single player. The problem is motivated by scheduling problems to maximize throughput. When each player is able to choose an a-approximation, we show that the price of anarchy is equal to (a+1). We improve upon this result in two directions. First, when players make sequential decisions and we consider subgame perfect equilibria instead of Nash equilibria, we show that the price of anarchy drops to about (a+1/2). Second, when coalitions of k players are allowed to cooperate and use an arbitrary profit sharing protocol, we give a parametric result and show that the price of anarchy equals (a+(k-1)/k).

2. **Tighten Bounds on the Inefficiency Ratio of Stable Equilibria in Load Balancing Games**
   
   Paolo Penna, Akaki Mamageishvili

   In this paper we study the inefficiency ratio of stable equilibria in load balancing games introduced by Asadpour and Saberi (WINE 2009). We prove tighter lower and upper bounds of 3/6 and 4/3, respectively. This improves over the best known bounds for the problem (19/18 and 3/2, respectively). Equivalently, the results apply to the question of how well the optimum for the $L_{\infty}$-norm (makespan) in identical machines scheduling.

3. **Sequential solutions in machine scheduling**
   
   Akaki Mamageishvili, Paul Duetting, Matins Mihalak, Paolo Penna

   We study the sequential machine scheduling problem. In this setting players join the game one by one and make decisions based on previous and/or future moves of other players. We are interested in the ratio between the makespan of the solution and the social optimum. First we show matching lower bounds for identical machine scheduling. In particular 2-1/m lower bound for the sequential price of anarchy and 4/3 - 1/(3m) lower bound for the permutation with decreasing weights. These lower bounds are matching to upper bounds proved by Hassin and Yovel. Next we show that there is always a permutation which gives optimum solution if players act greedily and each player chooses the least loaded machine. To the end we consider unrelated machines and show that for 2 machines there is an adaptive order of players which results into the optimum solution, while for already 3 machines there is no such ordering.

**TD-06**

**Thursday, 14:45-16:15 - Hörsaal 5**

**Revenue Management for Urban Transportation**

**Stream: Pricing and Revenue Management**

**Chair: Michael H. Breitner**
1 - Revenue Management meets Carsharing: Optimizing the Daily Business
Justine Broihan, Max Möller, Kathrin Kühne, Marc-Oliver Sonneberg, Michael H. Breitner

Carsharing is a transportation alternative that enables flexible use of a vehicle instead of owning it by paying trip-dependent fees. In recent years, this service denotes a considerable increase of new providers, which face an exponentially growing number of customers worldwide. As a consequence, rising vehicle utilization leads providers to contemplate revenue management elements. When focusing on station-based carsharing concepts, these are typically based on advance reservations. This makes them perfectly suitable for the application of demand-side management approaches. Demand-side management allows providers to optimize their revenues by accepting or rejecting certain trips. We respectively develop an optimization model for revenue management support. Based on an existing model of the hotel business, special consideration is drawn to carsharing related features. For instance, the implementation of a heterogeneously powered fleet allows providers to choose a certain limit of emissions to fulfill local requirements. We implement the mathematical model into the modeling environment GAMS using the solver Couenne. Conducted benchmarks show sensitivities under the variation of different input values, for example risk tolerances. Instead to the often used first-come first-serve-principle, the results indicate the usefulness of the developed model in optimizing revenues of today’s carsharing providers.

2 - Revenue management approach for electric vehicles in two-way carsharing systems
Isa von Hoesslin, Kerstin Schmidt, Thomas Völling, Thomas Spengler

In two-way e-carsharing systems an allocation of customer requests to electric vehicles with the "first come, first served" principle currently used in industry leads to an inefficient usage of electric vehicles and a loss of revenues. Therefore e-carsharing operators need a decision support system for the efficient acceptance of customer requests. Special challenges arise from the limited and perishable capacity of the electric vehicle in combination with a second limited and perishable but also storable capacity with dynamic replenishment - the battery capacity of the electric vehicle with the corresponding charging process. For each incoming customer request, the e-carsharing operator has to decide whether to accept the request in consideration of intertemporal interdependencies that arise between the requests due to different user profiles depending on start and length of booking as well as starting station. To address these characteristics, we present a revenue management approach using a randomized version of certainty equivalent control. The performance of the proposed approach in comparison to a "first come, first served" approach and an ex-post optimal solution is illustrated in a simulation study.

3 - E-Fulfillment for Attended Last-Mile Delivery Services in Metropolitan Areas
Magdalena Lang, Catherine Cleophas, Jan Fabian Ehmke, Charlotte Köhler

With two-digit growth rates predicted for e-commerce revenues, cost efficient, customer-oriented, and sustainable delivery services gain importance. This contribution focuses on planning attended last-mile delivery services, i.e., the final leg of the supply chain. As the customer takes over the final service of unloading the package, a service time window has to be agreed upon already when the order is accepted. Thus, we consider service time windows as a scarce resource and as the critical interface between order capture and order delivery. To optimally utilize this scarce resource, we propose combining concepts from revenue management and vehicle routing to extend tactical and operational planning for e-fulfilment. This presentation will focus particularly on opportunities for forecasting customer requests and customer characteristics and related requirements for data availability, and forecast quality. We will present first results and provide an outlook on ongoing research.

1 - Capacity management in gas networks
Claudia Gotzes

The focus on the use and the transportation of natural gas is getting stronger and stronger while trying to reduce energy production coming from coal and crude oil. Not only the gas for heating in households, but also to supply the industry with power is very important. On the other side, due to the liberalization of the gas market in Europe, it is getting more and more difficult for the transportation companies to calculate the use of exit and entry points by the customers. In this talk we will not only focus on the non-deterministic customer behavior, but also on the modeling of the gas physics that determine the gas flow through the network.

2 - Two-stage Stochastic Semidefinite Programming and Application to AC Power Flow under Uncertainty
Tobias Wollenberg, Rüdiger Schultz

We consider risk neutral and risk averse two-stage stochastic semidefinite programs with continuous and mixed-integer recourse, respectively. For these stochastic optimization problems we analyze their structure, derive solution methods relying on decomposition, and apply our results to unit commitment in alternating current (AC) power systems.

3 - Analysis of operation modes in gas compressor stations
Tom Walther, Benjamin Hiller, René Sattenmacher

We consider operation modes of compressor stations in gas networks, which are used to control the global gas flow in the network. Following the modelling in [1], each compressor station is represented by a single subnetwork that is suited to model all possible operation modes for it, but in return contains redundancy. Our main goal is to obtain non-redundant models for the operation modes in order to improve the performance of MIPs that use these models. In particular, we determine the feasibility of an operation mode and detect redundancy between different operation modes. We also obtain simplified network models in this process.

Operation modes for compressor stations are given as decisions which are joint specifications of switching states for all valves and compressors in a station. We represent a decision by the flow network that is described by it. To determine whether a decision admits a physically feasible flow/pressure combination, we employ bound tightening. We developed a fast, approximate method based on propagation and an exact optimization based method at reasonable computational cost.

In terms of redundancy detection, we face the problem that decisions’ networks are difficult to compare as they usually contain complex redundant structures. We developed a network reduction process allowing us to simplify decisions’ networks such that they can then be more effectively tested for isomorphisms between them. As a side-product, we obtain equivalent, but simplified network models.

We provide extensive test results that demonstrate the success of our approach.


55
Minimization of emissions has become an important issue for logistics companies operating in urban areas. We model emissions based on the Comprehensive Emissions Model (CEM), which derives emissions from speed, load, and engine type. Based on the CEM, we plan routes for a combined cost objective consisting of fuel and driver costs. The CEM is embedded within a tabu-search heuristic that was originally developed for the time-dependent vehicle routing problem. The procedure is adapted to include the computation of time-dependent, expected emissions- and cost-minimized paths between each pair of customers on the route. For computational experiments, we use instances derived from a real road network dataset and 230 million speed observations. We compare the emissions- and cost-optimal routes with solutions arising from more traditional objectives, e.g., minimizing distances and travel times, to understand how the planned routes differ. We then analyze how routes change with different fleet compositions, where emissions and cost objectives can lead to quite different results than traditional objectives.

2 - An emission-minimizing vehicle routing problem with heterogeneous vehicles and pathway selection

Thomas Kirschstein, Martin Behnke, Christian Bierwirth

In addition to cost- and time-orientation, greenhouse gas emission has become a further command variable for planning processes in the transportation industry. A lot of scientific literature is devoted to the development of planning approaches taking into account the emissions of transport processes. In order to minimize a transport process’ emissions, a lot of factors affecting the emissions have been studied. Besides the total distance covered by a transport process, the modal split, payload, travelling speed as well as vehicle type are identified as most influential planning parameters. In this talk, we formulate an emission-minimizing vehicle routing problem with heterogeneous vehicles and pathway selection (EVRF-VC-PS). The model seeks to find a set of tours such that total emission quantity of all vehicles employed is minimized, all customers are served, and the vehicles’ capacity restrictions are met. We use an emission model taking into account vehicle specific characteristics, payload, speed as well as traffic conditions as parameters. In the model, we assume a problem setting often met in city logistics systems. For travelling between customers among two pathways can be chosen. First option is the direct path (through the city) using urban roads with low average speed and frequent acceleration processes. Alternatively, a city highway can be used resulting in a detour (compared to the direct path) but higher average speed and less acceleration processes. Experiments with artificial data sets illustrate the pathway selection effect on total emissions comparing classic distance-minimizing and emission-minimizing tours.

3 - Vehicle Re-Use for Fuel Minimization by Solving the Capacitated Vehicle Routing Problem with Different Vehicle Classes

Jörn Schönberger

The capacitated vehicle routing problem with different vehicle classes has been proposed in the context of the fleet fuel consumption minimization. Here, light vehicles (like limousines, minibuses or vans) are dispatched simultaneously with heavy vehicles (like trucks and/or truck/trailer compositions). Instead of using a heavy truck to carry only a light payload the usage of a light vehicle can lead to reduced fleet fuel consumption since the movement of the dead weight of a light vehicle requires less fuel than the movement of the dead weight of a heavy truck. Since the payload capacity of a light vehicle is low and since the marginal fuel consumption induced by each additional payload ton is large (compared to a heavy vehicle) the length of a route assigned to a light vehicle is relatively short compared to the distance of the route assigned to a heavy vehicle. Therefore, a light vehicle can process two or even more round trips starting and ending in the depot while a heavy vehicle is still processing its only route. The re-use of the small vehicle helps to keep the number of vehicles in the fleet small. A mathematical model for this problem is proposed and initial computational experiments are reported.

1 - Solving routing and scheduling problems using LocalSolver

Frederic Gardi, Thierry Benoist, Julien Darlay, Bertrand Estellon, Romain Megel, Clément Pajean

In this talk, we introduce LocalSolver, a heuristic solver for large-scale optimization problems. It provides good solutions in short running times for problems described in their mathematical form without any particular structure. Models supported by LocalSolver involve linear and nonlinear objectives and constraints including algebraic and logical expressions, in continuous and discrete variables. LocalSolver starts from a possibly infeasible solution and iteratively improves it by exploring some neighborhoods. A differentiator with classical solvers is the integration of small-neighborhood moves whose incremental evaluation is fast, allowing exploring millions of feasible solutions in minutes on some problems.

We will present the set-based modeling formalism recently introduced in LocalSolver. Offering set decisions (sets/lists of integers) and operators (count, at, indexOf, contains, disjoint, partition), this mathematical formalism allows to model routing and scheduling problems naturally and compactly, as well as to solve them more efficiently than the traditional Boolean modeling approach related to mixed-integer linear programming. We will show application examples on basic combinatorial problems (traveling salesman, vehicle routing, flowshop scheduling) together with performance benchmarks.

2 - The MOSEK Fusion API: a simple and safe framework for conic optimization

Andrea Cassioli

Conic optimization is a mainstream tool nowadays, and so dedicated tools are taking the stage and improve their functionalities and user-friendliness. MOSEK provides a dedicated API for conic optimization, the Fusion API. It provides an object-oriented framework for conic optimization with emphasis on safety, readability and portability. The new MOSEK 8 release contains substantial improvements of the Fusion API: a new C++11 interface, more operators, support for Python3 and Pppy, pretty printing and an overall simplification of the API. During this talk we will walk through the Fusion general design and new features, as well discuss common pit-falls and tricks.

3 - On the Role of Optimization Modeling in the Algorithm Economy

Ovidiu Listes

Based on our experiences in applying Analytics and Optimization using AIMMS, we describe concrete aspects of the role the optimization modeling can already play in the new algorithmic business. Such aspects include: starting with a model addressing a decisional problem, moving on to full app development, deploying apps in enterprise wide systems with client-server architectures and user-friendly, local or web-based interfaces, and further on performing these actions in the cloud as the platform of the digital organization. For such aspects we provide illustrative AIMMS-based solution examples. By this, we support the idea that algorithms define action and therefore, the companies are not just valued based on their big data, but on the algorithms which turn the data into action and impact customers.
a procedure for demand modeling in such a setting. For this purpose, we rely on Conditional Value-at-Risk (CVaR) as a prevalent risk measure. Second, the value and inter-dependencies of process and volume flexibility are analyzed for supplier production networks which are related to product (re-)allocation and capacity balancing decisions. An extensive numerical study is used to evaluate the approach and to derive managerial insights based on a real-life case example from the industry.

2 - Optimal replenishment under price uncertainty

Esther Mohr

We aim to find optimal replenishment decisions without having the entire price information available at the outset. Although it exists, the underlying price distribution is neither known nor given as part of the input. Under the competitive ratio optimality criterion, we design and analyze online algorithms for two related problems. Besides the reservation price based decision how much to buy we additionally consider the optimal scheduling of orders. We suggest an online algorithm that decides how much to buy at the optimal point in time. Results show that the problem of finding a replenishment strategy with best possible worst-case performance guarantees can be considered as an extension of the online time series search problem.

3 - Stochastic optimization of modular production networks considering demand uncertainties

Tristan Becker, Pascal Lutter, Stefan Lier, Brigitte Werners

In the process industry markets are facing new challenges. While product life cycles are becoming shorter, the differentiation of products grows. This leads to uncertain product demands in time and location. In contrast to large commodity markets, where a vast amount of orders compensates variation in demand, this does not apply for niche markets. Due to low production flexibility and long time to markets, large-scale conventional plants are not well suited for production in these highly volatile markets. The focus of research therefore shifts to modular production units, which can be installed in standardized transportation iso-containers. Using modular units, the supply chain design is becoming more flexible, as production locations can be located in direct proximity to resources or customers. In answer to short-term demand changes, modifications to capacity can be made by numbering-up containers. Utilizing modular production units, the structure of the production network requests dynamic adoptions in each period. Subsequently, once the customer demand realizes, an optimal match between available production capacities and customer orders has to be determined. This decision situation imposes new challenges on planning tools, since frequent adjustments of the network configuration have to be computed for a large amount of specialty products based on uncertain demand. To cope with uncertainty we develop different mathematical models. We present stochastic and robust mixed-integer programming formulations to hedge against demand uncertainty. In a computational study the novel formulations are compared and evaluated based on real-world data sets in terms of runtime and solution quality.

2 - Regionalized Assortment Planning for Multiple Chain Stores

Michael Hopf, Benedikt Kasper, Clemens Thielem, Hans Corsten

In retail, assortment planning refers to selecting a subset of products to offer that maximizes profit. Assortments can be planned for a single store or a retailer with multiple chain stores where demand varies between stores. In this paper, we assume that a retailer with a multitude of stores wants to specify her offered assortment. To suit all local preferences, regionalization and store-level assortment optimization are widely used in practice and lead to competitive advantages. When selecting regionalized assortments, a tradeoff between expensive, customized assortments in every store and inexpensive, identical assortments in all stores that neglect demand variation is preferable. We formulate a stylized model for the regionalized assortment planning problem (APP) with capacity constraints and given demand. In our approach, a ‘common assortment’ that is supplemented by region-alized products is selected. While products in the common assortment are offered in all stores, products in the local assortments are customized and vary from store to store.

Concerning the computational complexity, we show that the APP is strongly NP-complete. The core of this hardness result lies in the selection of the common assortment. We formulate the APP as an integer program and provide algorithms and methods for obtaining approximate solutions and solving large-scale instances.

Lastly, we perform computational experiments to analyze the benefits of regionalized assortment planning depending on the variation in customer demands between stores.

3 - Application of Ant Colony Optimization in Solving Facility Layout Problem of an Elevator Automatic Door Production Plant

Tuba Ulusoy, Mehmet Aktan

Facility layout design studies aim to reach different qualitative and quantitative objectives. Minimizing material handling cost is the most considered and common objective and it can be achieved by an effective facility layout design. In this study, an attempt is made to solve facility layout problem (FLP) of an elevator automatic door production plant which is located in Konya, Turkey and it is aimed to find a layout design that has minimum material handling cost. Material handling cost is equal to 80259.43 in current layout. Wooden pallets that are transported by hydraulic transpalets are used for material handling in the plant. These transpalets are moved between departments by man power. It is known that each component of elevator automatic door has different size, so handling of big components is not as easy as small ones. For this reason, size of components is considered as a cost of material flow from department i to department j. It is added to the objective function by multiplying with distance and flow between departments in the plant. The FLP was formulated as a Quadratic Assignment Problem (QAP) and it was linearized. Linearized model was run by GAMS and a feasible solution could not be found. To find a solution for this FLP, Ant colony optimization (ACO) that usually gives good solutions for QAP was used. Taguchi experimental design was applied by Minitab to find the best combination of ACO’s parameters that can help to find an objective function value which is close to optimal. 25 different combinations of parameters were generated by Taguchi experimental design and a new method was applied in Matlab. Material handling cost is equal to 54487 in proposed layout which is found by using ACO.
1 - Alternative fitness functions in the development of models for prediction of patient recruitment in multi-centre clinical trials
Gilyana Borlikova, Michael Phillips, Louis Smith, Michael ONeill

For a drug to be approved for human use, its safety and efficacy need to be evidenced through clinical trials. At present, patient recruitment is a major bottleneck in conducting clinical trials. Pharma and contract research organisations (CRO) industries are actively looking into optimisation of different aspects of patient recruitment. One of the avenues to approach this business problem is to improve the quality of selection of investigators/sites at the start of a trial. This study builds upon previous work that used Grammatical Evolution (GE) to evolve classification models to predict the future patient enrolment performance of investigators/sites considered for a trial. Selection of investigators/sites, depending on the business context, could benefit from the use of either especially conservative or more liberal predictive models. To address this business need, decision-tree type classifiers were evolved utilising different fitness functions to drive GE. The functions compared were classical accuracy, balanced accuracy and f-measure with different values of parameter beta. The issue of models’ generalisability was addressed by introduction of a validation procedure. The predictive power of the resultant GE-evolved models on the test set was compared with performance of a range of machine learning algorithms widely used for classification. The results of the study demonstrate that flexibility of GE induced classification models can be used to address business needs in the area of patient recruitment in clinical trials.

2 - Integrated Biorefinery Planning using a Nested Evolutionary Strategy
Tim Schröder, Lars-Peter Launen, Jutta Geldermann

Biorefinery concepts provide a manifold product portfolio capable of fulfilling many needs of modern societies from biomass. The profitability, and thus the practical realization of such biorefineries, depends heavily on the availability of the spatially distributed biomass inputs, which in turn influences the optimal location, capacity, and setup of potential biorefineries. We present an integrated approach for simultaneously planning a Fischer-Tropsch biorefinery’s location, capacity, and configuration in a continuous solution space while. Detailed consideration of the spatial availability yields a noisy objective function. While such noisy objective functions can generally be solved using metaheuristics, the problem at hand does not converge reliably when solved with an Evolutionary Strategy (ES) algorithm due to strict constraints and interferences between variable dimensions. In order to tackle this problem, a nonlinear program (NLP) is nested inside an ES algorithm. Through repeated de- and recomposition, the integrated problem can be solved handling the noise inducing variables in the ES and optimizing the remaining smooth variables in the exact NLP.

3 - Branch-and-cut for forest harvest scheduling problems subject to clearcut and core area constraints
Isabel Martins, Miguel Constantino

Integrating forest fragmentation into forest harvest scheduling problems adds substantial complexity to the models and solution techniques. Forest fragmentation leads to shrinking of the core habitat area and to weakening of the inter-habitat connections. In this work, we study forest harvest scheduling problems with constraints on the clearcut area and constraints on the core area. We propose a mixed integer programming formulation where constraints on the clearcut area are the so-called cover constraints while constraints on the core area are new in the literature as far as we know. As the number of constraints can be exponentially large, the model is solved by branch-and-cut, where the spatial constraints are generated only as necessary or not before they are needed. Branch-and-cut was tested on real and hypothetical forest data sets ranging from 45 to 1363 stands and temporal horizons ranging from three to seven periods were employed. Results show that the solutions obtained by the proposed approach are within or slightly above 1% of the optimal solution within three hours at the most.

1 - MetaSimLab: A laboratory for validating and calibrating agent-based simulations for business analytics
Janina Knepper, Catherine Cleophas

Simulations are frequently used to develop and evaluate new and improved approaches for business analytics and decision support. Whenever the result depends on the interaction between independent actors, agent-based simulation models are the tools of choice. Examples are the interaction of supplier and customer in automated revenue management or the interactions of analysts with decision support systems. To be reliable, agent-based simulation models have to be empirically calibrated and validated. After calibration determines input parameters, validation measures the deviation between simulation results and empirical observations. Existing calibration approaches are rarely automated, manual calibration is costly in terms of time and effort. Therefore, new calibration methods and a tool for their evaluation are needed. This contribution introduces the laboratory environment MetaSimLab, which is designed to evaluate the efficiency and effectiveness of alternative calibration approaches. It is capable of comparing calibration approaches given exchangeable simulation models, validation approaches, and empirical data sets. We present both a numerical example to illustrate the MetaSimLab’s functionality, a perspective on novel calibration methods, and an outlook on further research.

2 - Trajectory Optimization under Kinematical Constraints for Moving Target Search
Manon Raap

Various recent events in the Mediterranean sea have shown the enormous importance of maritime search-and-rescue missions. By reducing the time to find floating victims, the number of casualties can be reduced. A major improvement can be achieved by employing unmanned aerial systems for autonomous search missions. In this text, the need for efficient search trajectory planning methods arises. Existing approaches either consider K-step-lookahead optimization without accounting for kinematics of fixed-wing platforms or propose a suboptimal myopic method. A few approaches consider both aspects, however only applicable to stationary target search. We present a novel method for Markovian target search-trajectory optimization. This is a unified method for fixed-wing and rotary-wing platforms, taking kinematical constraints into account. It can be classified as K-step-lookahead planning method, which allows for anticipation to the estimated future position and motion of the target. The method consists of a mixed integer linear program that optimizes the cumulative probability of detection. We show the applicability and effectiveness in computational experiments for three types of moving targets: difusing, conditionally deterministic, and Markovian. This approach is the first K-step-lookahead method for Markovian target search under kinematical constraints.

3 - Scheduling of a Partially Automated Production
Frank Herrmann

In recent years, a considerable amount of interest has arisen for scheduling problems with technological restrictions. For example, no-buffer flow-shop scheduling problem are well investigated. Here a real world flow shop with a transportation restriction is regarded. It has to produce small batches, very often with a lot size of one, with short response times. Thus, scheduling algorithms are needed to ensure that under the constraint of a high average load of the flow shop, the due dates of the production orders are met. This transportation restriction reduces the set of feasible schedules even more than the no-buffer restrictions discussed in the literature in the case of limited storage. Still this problem is NP-hard. Due to the transportation restriction, the duration of a job A on the flow-shop depends on the other jobs processed on the flow-shop in the same timeframe which is called a cycle. Realistic processing times are achieved by a simulation of the scheduling of A which includes the next jobs until A has left the flow-shop. The usage of such realistic processing times instead of net processing times improved by around 16%. There are pools of jobs where a large variance of the cycle times is beneficial and pools of jobs where a small variance is better. This is partially detected by a genetic algorithm. This improves the performance by another 34%.

TD-13
Thursday, 14:45-16:15 - Seminarrbraum 204
Simulation Models II
Stream: Simulation and Stochastic Modeling
Chair: Frank Herrmann

TD-14
Thursday, 14:45-16:15 - Seminarrbraum 206
Rankings, Goals and (Integer) Linear Programming
Stream: Decision Theory and Multiple Criteria Decision
1 - The minimal angle jump technique for the simplex method
Monsicha Tipawanna, Krung Sinapiromsaran

In this paper, we present the minimal angle jump for the simplex method. The essence of this method is to move from an initial basic feasible solution to another basic feasible solution, corresponding to the lowest angle between normal vector of linear constraints and gradient of the objective function. If the new current basic feasible solution is not optimal then the simplex method with Dantzig’s pivot rule is applied until the optimal solution is obtained. We can illustrate by examples that our method improves the simplex method by the number of iterations for solving linear programming problems.

2 - Multi-objective formulation of a multi-attribute decision making problem
M. Karimi-Nasab

In a multi-attribute decision making problem, we are given m alternatives, A(1), . . . , A(m), each scored by k different criteria, C(1), . . . , C(k). In other words, S(i,j) denotes the score of alternative A(i) by criterion C(j). Also, we can divide the criteria into two subsets: pleasant criteria and unpleasant criteria. A pleasant criterion is the one that a rational decision maker is expected to be happier if we have alternatives of higher scores in that criterion. Similarly, an unpleasant criterion is the one that a rational decision maker is expected to be happier if we have alternatives of smaller scores in that criterion. For example, if the decision maker wants to decide which automobile to buy among a set of automobiles in the market, one criterion would be the “price” and naturally it is an unpleasant criterion because the decision maker would become happier if the price is asked to pay less. On the other hand, “maximum speed” can be regarded a pleasant criterion. The problem is to determine the best ranking of these alternatives in order to know which alternative should be suggested at the first priority A[1] to the decision maker, and which alternative should be suggested to him/her at the second priority A[2] and so forth till determining which alternative should be suggested to him/her at the last priority A[m]. Further, once we know the ranking of the alternatives, we can just recommend A[1] to the decision maker. Potentially, there is m! different rankings, but some of them are superior to the others or dominate the others because the non-dominated rankings are nearer to the desires of the decision maker. Here, every criterion is considered as an objective function and the problem is formulated as a mixed integer multi-objective optimization problem.

3 - Generalized Imprecise Multi-Choice Goal Programming
Hocine Mouslim, Sakina Melloul

Herbert A. Simon states that modern managers wish to “satisfice” to reaching goals subject to the optimization of a single objective. In such situations, Multi-Choice Goal Programming (MCGP) model can be used and applied to solve this type of problems. In other words, the technique of MCGP reflects a good approximation of these real world situations. However, in some management problems, it may exist situations that the decision maker could not be interested in presenting his preferred goals in a precise manner. In this paper, an efficient methodology is presented, which is considered as a combination between the (MCGP) model suggested by Chang for standard goal programming (GP), and the technique of fuzzy GP (FGP), where the concept of utility functions (UTFs) is used for modelling the fuzziness and the managers preferences of all kinds of the goals. The model of MCGP is adapted in a very evident to introduce the technique of FGP for solving this type of problems. One of the main advantages of the proposed model is that it provides the decision makers (managers) with more control over their preferences. Finally, an illustrative example demonstrates the effectiveness of our proposed model.

1 - The Introduction of a New Algorithm to Determine Buffer’s Size in Critical Chain with Use of Environmental Indices: A Case Study
Mohammad Khalizadeh

In this paper, we introduce a new algorithm to determine buffer sizes in critical chain with environmental indices such as suppliers, contractors, and sponsors. In this research, the expert judgment has been used to determine the importance weights of criteria. These criteria have been evaluated by six sub criteria using Analytic Hierarchy Process. As a case study, we collected historical data from the project of Sodium Carbonate production plant. Then, we calculated and compared Feeding Buffers and Project Buffer with different methods. As a result, we showed the proposed method is more reliable and accurate due to the practical indices. Also we demonstrated that the results of this algorithm are between the APD and APRT algorithms which clearly proved the validity of the proposed algorithm.

2 - Search Algorithms for Improving the Pareto Front in a Timetabling Problem with a Solution Network-based Robustness Measure
Can Akkan, Gulcin Ermis

We develop search algorithms ((i) local search, and (ii) matheuristic that solves a set of MIP models) for creating and improving a network of solutions for an academic timetabling problem. This network of solutions, in which edges are defined by the Hamming distance between pairs of solutions, is used to calculate a robustness measure. The robustness measure is based on a definition of disruption (the time slot to which an entity had been assigned is no more feasible for that entity) and a predefined heuristic for responding to this disruption (which is, choosing one of the neighbors of the disrupted solution). Taking into account the objective function of the timetabling problem and this robustness measure results in a bi-criteria optimization problem where the goal is to improve the Pareto front. The fact that robustness measure is defined for a set of neighboring solutions differentiates the problem from most bi-criteria scheduling models where both criteria can be measured for a given solution only. Furthermore, the matheuristic uses the solution pool feature of CPLEX to essentially use it as the main building block of a search algorithm. These two characteristics make the approach used here applicable to most other combinatorial optimization problems with robustness criterion. We compare the performance of the heuristics on seven semesters’ actual data. Results show that highly robust solutions can be found with 3-5 objective vectors on the Pareto front. More generally, in discrete optimization problems such as timetabling, with lots of symmetries that yield a large number of good alternative solutions, simple local search heuristics can be used to identify robust solutions in a reasonable amount of time (supported by TUBITAK Grant 214M661).

3 - Recoverable robustness in scheduling problems
Han Hoogeveen, Marjan van den Akker, Judith Stoet

Solving optimization problems is normally done with deterministic data. In practice, however, all kinds of disturbances may occur, which are modeled by distinguishing several discrete scenarios that occur with a given probability. The occurrence of a disturbance may make the planned solution infeasible, and to repair these infeasibilities, we are allowed to update the plan according to a prespecified, simple recovery algorithm, as soon as we know which disturbances have occurred. A solution then consists of a solution for the undisturbed case and a predefined heuristic for responding to this disruption (which is, choosing one of the neighbors of the disrupted solution). Taking into account the objective function of the timetabling problem and this robustness measure results in a bi-criteria optimization problem where the goal is to improve the Pareto front. The fact that robustness measure is defined for a set of neighboring solutions differentiates the problem from most bi-criteria scheduling models where both criteria can be measured for a given solution only. Furthermore, the matheuristic uses the solution pool feature of CPLEX to essentially use it as the main building block of a search algorithm. These two characteristics make the approach used here applicable to most other combinatorial optimization problems with robustness criterion. We compare the performance of the heuristics on seven semesters’ actual data. Results show that highly robust solutions can be found with 3-5 objective vectors on the Pareto front. More generally, in discrete optimization problems such as timetabling, with lots of symmetries that yield a large number of good alternative solutions, simple local search heuristics can be used to identify robust solutions in a reasonable amount of time (supported by TUBITAK Grant 214M661).

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We apply the concept of recoverable robustness to the problem of minimizing the number of late jobs on one machine where the processing times of the jobs are uncertain. The undisturbed problem can be solved by the algorithm of Moore-Hodgson, and we can update it for a given scenario by applying Moore-Hodgson to the initial solution. Nevertheless, the problem turns out to be NP-hard, even if there is only one scenario. We present a dominance rule, which can be used to identify jobs that will be on-time in the optimum solution. We further consider several enumerative methods, like branch-and-bound, branch-and-price, and dynamic programming.
**TD-16**

**Thursday, 14:45-16:15 - Seminarraum 308**

**Decision Support and Scheduling**

**Stream: Project Management and Scheduling**  
**Chair: Marcus Wiens**

1. **Integrated scheduling approach for future capability development based on genetic algorithm**  
   **Michael Preuß**

   Based on continuous future development and the current capability state including strategic objectives and guidelines of the German Federal Ministry of Defense the medium-term planning is a key function to provide proper capabilities in the future. To ensure a continuous, efficient and target-oriented capability management, we developed an integrated approach to meet challenges of the dynamic and complex environment. Regarding all constraints like predecessor relationships, different categories of budgets or fixed projects, there are roughly more than 810250 different possibilities in setting of 200 projects. The underlying resource-constrained scheduling problem was used to formalize the task definition. We developed a holistic process which determines project priorities deduced from a scenario based capability approach. Subsequently, an adapted genetic algorithm (GA) is used to identify feasible schedules minimizing the makespan subject to resources availabilities and precedence constraints. We analyze the structural similarity of already existing schedules due to the cost tradeoff between replanning and the benefits of the optimized solution. With the help of a comprehensive management cockpit, we involve decision makers into the optimization process. In order to provide an appropriate decision support, we visualize the results in an intuitive way.

2. **Endogenous Risks in Project Exploration**  
   **Marcus Wiens, Frank Schultzmann**

   Project delay and cost overrun are the two main problems in project management with increasing importance for large projects. In interviews, experts frequently mention an insufficient (ex ante) project exploration as one of the major causes. The argument runs as follows: As the investment in project exploration is sunk if the planned project is given up there is a tendency towards underinvestment in project exploration. This paper applies an approach from signal detection theory to analyze this argument in detail. It works out the basic mechanisms of this incentive problem for varying assumptions and discusses potential solutions to mitigate this risk.

3. **Risk Analysis in Airport Construction Projects**  
   **Ahmet Gokhan Tiryaki, Burze Yasar, Oncu Hazır**

   Considering the fact that the most of the contractors face difficulties and problems while dealing with risks and uncertainties which lead not only to financial losses, but also to motivational and reputation damages; the need of developing knowledge of risk management in construction industry becomes essential. This risk management study focuses on the airport construction projects (ACPs) which are designed not to have only terminal building with its ancillary buildings, but also to have hotels, conference halls and recreation areas which make them to be distinguished from the others. High interaction between the stakeholders like investors, contractors, consultants, suppliers, employees, travelers, customers who are interested in airport retail areas reinforces this need. Contribution to the literature which suffers lack of risk-related studies on ACPs is the other motivation of this study by which it is aimed to warn project managers who are willing to work for ACPs for the risks and risk management methods. For the purpose of analyzing the risks in ACPs, semi-structured interviews were conducted with the experienced company managers, project directors and managers, consultants, department leaders, and prominent subcontractors' representatives. The results of the semi-structured interviews were assessed by Analytic Network Process (ANP) since it is easier and more convenient method to apply for numerous criteria and assessing the results comparing to others. In addition, financial and technological risks were assessed deeper by simulation techniques like Monte Carlo Analysis. The results of these qualitative and quantitative techniques applied are reported to enlighten the ways of project managers and other stakeholders for the risks in ACPs.

**TD-17**

**Thursday, 14:45-16:15 - Seminarraum 310**

**Supply Chain Reliability and Risk**

**Stream: Supply Chain Management**  
**Chair: Moritz Fleischmann**

1. **Supply Chain Reliability and the Role of Individual Suppliers**  
   **Simeon Hagspiel**

   We study a one-period supply chain problem consisting of numerous suppliers delivering a homogeneous good. Individual supply is uncertain and may exhibit dependencies with other suppliers as well as with the stochastic demand. Assuming that reliability of supply represents an economic value for the customer that shall be paid accordingly, we first derive an analytical solution for the contribution of an individual supplier to supply chain reliability. Second, applying concepts from cooperative game-theory, we propose a payoff scheme based on marginal contributions that explicitly accounts for the statistical properties of the problem. A number of desirable properties is thus achieved, including static efficiency as well as efficient investment incentives. Lastly, in order to demonstrate the relevance and applicability of the concepts developed, we consider the example of payoffs for reliability in power systems that are increasingly penetrated by independent variable renewable energies. We investigate empirical data on wind power in Germany, thereby confirming our analytical findings. In practice, our approach could be applied to design and organize supply chains and their reliability more efficiently. For instance, in the field of power systems, the approach could improve designs of capacity or renewable support mechanisms.

2. **Total Supplier Risk Monitoring - Wissensmanagement als Grundlage einer präventiven Lieferantenbewertung**  
   **Anja Wilde**


**TD-18**

**Thursday, 14:45-16:15 - Seminarraum 401/402**

**Liner Shipping Optimization II (I)**

**Stream: Logistics, Routing and Location Planning**  
**Chair: Kevin Tierney**

1. **Design of Container Liner Services - A literature review and Simulation Results**  
   **Jürgen Böse, Joachim R. Daduna**

   Considering the fact that the majority of the contractors face difficulties and problems while dealing with risks and uncertainties which lead not only to financial losses, but also to motivational and reputation damages; the need of developing knowledge of risk management in construction industry becomes essential. This risk management study focuses on the airport construction projects (ACPs) which are designed not to have only terminal building with its ancillary buildings, but also to have hotels, conference halls and recreation areas which make them to be distinguished from the others. High interaction between the stakeholders like investors, contractors, consultants, suppliers, employees, travelers, customers who are interested in airport retail areas reinforces this need. Contribution to the literature which suffers lack of risk-related studies on ACPs is the other motivation of this study by which it is aimed to warn project managers who are willing to work for ACPs for the risks and risk management methods. For the purpose of analysing the risks in ACPs, semi-structured interviews were conducted with the experienced company managers, project directors and managers, consultants, department leaders, and prominent subcontractors’ representatives. The results of the semi-structured interviews were assessed by Analytic Network Process (ANP) since it is easier and more convenient method to apply for numerous criteria and assessing the results comparing to others. In addition, financial and technological risks were assessed deeper by simulation techniques like Monte Carlo Analysis. The results of these qualitative and quantitative techniques applied are reported to enlighten the ways of project managers and other stakeholders for the risks in ACPs.
The presentation is canceled. 05.08.2016, Juergen Boese

Today, scientific literature provides numerous publications for the design of liner services in container shipping. The contribution presents a review of related publications associated with a survey of (quantitative) methods and concepts used for service design. Moreover, the discussed approaches are critically evaluated regarding their benefit for problem solving in practice. A second part of the contribution introduces the main results of a simulation study systematically analyzing the impact of liner service parameters (e.g., vessel size and speed or number of loop ports and vessels) and operational conditions (e.g., "weather") on performance and economic figures of services.

2 - A chance constrained approach for heterogeneous fleet scheduling in liner shipping service

Sinan Gürel, Aysan Shadmard

We deal with a schedule design problem for a heterogeneous fleet of liner shipping service under uncertain waiting and handling times. Due to variability in waiting and handling times, ships may depart later than the published schedule which deteriorates customer satisfaction. We measure service level at a port as the probability of on-time departure of a ship from that port. The problem is to determine the departure times at ports and speeds of ships on each leg so as to minimize the total fuel burn while satisfying an overall target service level. We consider three new aspects of the problem. The first one is a heterogeneous fleet where each ship type may have different fuel efficiency. The second one is considering critical ports in schedule, i.e., considering the fact that on-time performance at critical ports might be more important for the shipping company. Third one is proposing a new service level measure for the schedule of a liner shipping company. We propose a chance constrained nonlinear mixed integer programming formulation for the problem. We employ second order cone programming inequalities to solve the problem. Finally, several experimental factors are defined and effects of these factors on fuel consumption cost and optimal solutions are analyzed.

3 - Service Design for Liner Shipping with Service Levels

Kevin Tierney, Jan Fabian Ehmke, Ann Campbell

We consider the liner shipping route design problem, where each port has a time window, and travel times between ports are assumed to be stochastic. Service reliability and on-time arrival guarantees are important for many liner shippers and carriers, but have not been addressed in the literature for building new routes. To this end, given a set of ports with time windows when they can be visited, we construct new routes ensuring that each time window is satisfied with a given service level while minimizing the costs of a single route. We investigate how different service levels affect the costs of a route, and allow the model to increase the speed of a vessel to ensure the service level. Finally, we analyze the trade-off between vessel costs and the costs of speeding.

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Passenger Routing in Public Transportation Problems (i)

Stream: Traffic and Passenger Transportation
Chair: Jonas Harbering

1 - Causal structure learning on travel mode choice based on structural restrictions and model averaging algorithm

Tai-yu Ma, Joseph Y.J. Chow, Jia Xu

This work contributes to develop a new heuristic methodology to overcome the NP-hard complexity of identifying and estimating the causal structure of travel mode choice as a Bayesian Network (BN). We propose an algorithm as a two-stage procedure by first drawing relevant prior partial relationships between variables (i.e., structural restriction) from our domain knowledge, and then using them as structure constraints in a BN structure learning task. The latter is performed using the model averaging approach (Korb and Nicholson, 2010) to obtain a statistically sound BN. Two experiments are set up to test the effects of structural restriction and model averaging approach on the obtained BN structures. The first experiment compares the obtained BN structures with and without the restrictions. The second experiment is related to the effect of resampling size in the model averaging method for identifying significant arcs in the best BNs and to determine which learning algorithm is more effective. Different BN structure learning algorithms (Hill-Climbing algorithm, Max-Min Hill-Climbing algorithm and Incremental Association algorithm) have been tested. The results show the proposed method can effectively improve the quality of obtained BNs structures. The advantage of BNs is that it can capture more sophisticated relationships between the variables that are missing in both decision tree models and random utility models. Empirical study for travel mode choice behavior modeling is based on the mobility survey of the cross border workers of Luxembourg in 2011.

2 - Predictive Clustering of Public Transport Boarding Data for Planning and Smart Passenger Information Systems

Uğur Elitürk, Efendi Nasibov

We consider a clustering problem involving the analysis of passengers using a multimodal public transportation system in Izmir, Turkey. Daily ridership of the network in four transport modes of bus, ferry, metro and suburban rail systems amounts to 1.8 million boardings on the average. The city has employed an electronic fare collection system since 1999, which integrates existing and newly built rail systems, and handles ticketing operating information from contactless smart cards. Each boarding record contains the time, location, mode, route, vehicle, and fare data for the individual trip. A large portion of the urban central network allows free transfers between all modes. Moreover, some passenger fare types are defined to waive the boarding fees of the disabled and senior citizens totally, or students and teachers partially, regardless of trip times or modes. In this study, we examine the individual trip patterns of passengers according to different fare types, boarding locations (bus stops, stations, piers, major intermodal transfer centers, schools, hospitals, etc.) and daytimes over a moving horizon of consecutive days. By observing repetitive transfer points, times or preferred route information of regular passengers, self-organizing maps are formed for clustering trips by fare type, origin location and boarding time. In this manner, it is possible to predict the trip behavior of passengers according to specific criteria, determining final destinations, mode choice, reason for trip (work, school or leisure) and vehicle congestions. A Kohonen network is designed, which will help to form an important information base for both transport planning purposes and trip planning applications in passenger information systems.

3 - Delay Resistant Line Planning with a View Towards Passengers’ Transfers

Jonas Harbering

In modern public transportation networks, delays are the main issue for disturbing smooth operations and hence the dissatisfaction of passengers. This work is intended to show gains achievable by considering measures reducing the impact of delays when planning a public transportation network. Important phases in the planning of a public transportation system are, among others, line planning, timetabling and delay management. The delay resistance of such a system is usually measured at the delay management stage. The measures which are to decrease the effect of delays are usually taken at the stages of timetabling (adding buffer, rearranging slack times) and delay management (developing methods which prevent the spreading of delays). One major reason for the propagation of delays, which is not controlled by those measures, are the passenger transfers. They can even be handled at the line planning stage. In the literature there exists only few work studying the implication of the line planning stage towards delay resistance. Hence, the aim in this work is to provide a line planning model which forms the basis of highly delay resistant public transportation systems. The idea is to explicitly take control of the passenger paths which allows to minimize the number of passenger weighted delays in the line planning problem. By this a positive effect towards delay resistance can be recognized. We present an algorithmic solution procedure, which is shown to give the optimal solution on small instances. Furthermore, the transfer-minimizing line planning model is compared to other well-known line planning models - e.g., cost model, direct travelers model - by computing a timetable of similar quality, introducing and propagating delays, and measuring their delay resistance.


**TD-20**  
**Thursday, 14:45-16:15 - Seminarraum 404**  

**Sequential and Temporal Data Analysis**  
**Stream: Business Analytics and Forecasting**  
**Chair: Julian Bruns**

1. **Reducing debiasing model uncertainty with revisioning**  
   **Florian Knoell, Thomas Setzer**

   In today’s enterprises, the accuracy of forecasts is of crucial importance to corporate decision-making and planning quality. For instance, in corporate reporting and planning systems expert cash flow expectations are consolidated in order to derive liquidity plans and managerial means to hedge expected foreign exchange risks. However, usually local experts of a corporation’s subsidiaries generate cash flow forecast data in a decentralized fashion. As human judgment is known to be prone to cognitive biases, in the literature it has been regularly found that by diagnosing biases in past forecasts and applying models to remove the determined biases in future forecasts increases accuracy and improves overall decision making.

   But the conditions often change and therefore the strength and influence of bias might change as well. With a change of bias the outcome of correction methods become uncertain. However often corrections conducted automatically will actually increase instead of decrease error. We argue that if an expected bias in a judgmental forecast takes place, there also should be evidence for biased decision making the way the expectations have been revised before deriving the final forecast. This evidence should overall increase the confidence in whether a correction is advised or not.

   We use known and novel measures to characterize the structure in revisioning and use these measures as features for prediction if a correction or the original estimate is favorable. The approach is evaluated using empirical cash flow forecast data of a large international corporation. Results show a significant reduction of uncertainty whether a correction is beneficial for future forecasting.

2. **Metrics and Aggregation Mechanisms for Temporal Information in Sequential Data**  
   **Katerina Shapoval, Thomas Setzer**

   Nowadays, large amounts of data are available for analysis. The sequential type of data, which accumulates e.g. about customer purchases over time, implies large combinatorial complexity stemming from exponential growth of possible sequence instances with respect to sequence length and number of possible sequence symbols. Often, such information is aggregated by simple ways, e.g. by count functions or binary representations for occurrence of sequence symbols, as predictive models often are not able to handle such high-cardinality features. Several approaches exist to handle sequential information; some of these are using temporal discounting for weighting more recent information higher, which is reasonable for most applications.

   In this paper we first propose metrics for estimation of additional predictive value of sequential information compared to simple aggregation techniques prior to incorporation into a class-prediction model. Second, we link this metrics to an appropriate discounting factor and number of segments for sequence aggregation method, so that approximate optimal level for these parameters can be determined upfront. Proposed metrics are then evaluated on a data set of a telecommunications provider, which offers different product and services on international market. The results demonstrate the ability of proposed metrics to capture the added value of sequential information and to serve as a guiding value for model parametrization.

3. **Forecasting local temperatures in urban context**  
   **Julian Bruns, Boris Anmbarg, Thomas Setzer**

   It is known that cities are typically hotter than their surrounding areas as a result of impervious surfaces that drive temperatures. This phenomenon has been coined Urban Heat Island (UHI). One regularly observes also large temperature differences and local extremes within the scope of a city itself, denoted as Intra-Urban Heat Islands. The determination, anticipation, and avoidance of such IUHI is crucial to human health of citizens and of pivotal importance for proactive health-aware city planning. Unfortunately, high spatial resolution of temperature differences with respect to key received scarce attention in the literature. Standard procedures for UHI assessment either measure a whole urban area (or large portions of it) by satellite images (with low spatial resolution), or point measurements available only at fixed weather stations, with low overall density. Hence, the heat-information we gain from such models are either rather coarse-grained or valid for large geo-coordinates only, and are thus of limited value for city planners.

   We propose a joint model relating satellite measurements of land surface temperature to ground based measurements of air temperature. By including the relative position of each ground based point as well as the land use to a number of nearest satellites, we predict temperatures for small areas such as streets throughout a city. To model the inherent volatility of the forecast we use approaches like Bayesian hierarchically modelling. Based on residual diagnostics we determine areas that are well predictable versus areas with high error variance to recommend promising points of interest, based on a hot spot analysis, for the placement of additional weather stations within a city to improve overall prediction in an economic fashion.

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**TD-21**  
**Thursday, 14:45-16:15 - Seminarraum 405/406**  

**Bi-Objective Vehicle/Ship Routing**  
**Stream: Logistics, Routing and Location Planning**  
**Chair: Kjetil Fagerholt**

1. **Finding the trade-off between gas emissions and disturbance in an urban context**  
   **Jasmin Grabenschweiger**

   We introduce the bi-objective emissions-disturbance TSP (BEDTSP) that aims at the simultaneous minimisation of gas emissions and disturbance in the context of delivering customers in urban areas. The objective of total emissions is assumed to be dependent on travelled distance and carried load weight. With the objective function of disturbance we want to measure how much residents are affected by noise, pollution, risk, vibration, etc. caused through traffic resulting from freight transportation. We identify population density to be a proper indicator for this. So the more people are living next to a street the more disturbing it is. The particularity of disturbance data is that the triangle inequality does not hold for it because the shortest distance path between two points may go through very densely populated areas, whereas a detour through sparser populated areas may yield less disturbance. We present several bi-objective mixed integer programming formulations for the BEDTSP. In a first, rather naive model only the shortest distance paths between nodes are considered. Three more sophisticated models are then introduced that all make use of the idea to use other paths than the shortest distance one in order to decrease total disturbance of a tour (at the expense of emissions). Computational experiments on randomly generated instances show up the benefits and shortcomings of the different approaches - in terms of solution quality as well as CPU performance. Moreover, a text world case study is conducted in order to compare the solutions of our problem to tours carried out in reality.

2. **The bi-objective k-dissimilar vehicle routing problem**  
   **Sandra Zajac**

   In cash-in-transit operations, significant amounts of money need to be delivered or picked up from a set of customers. As a result, a significant risk of robbery arises. A potential approach to decrease this risk is to generate k spatially dissimilar vehicle routing alternatives. By periodically changing the routes to dissimilar ones, the unpredictability of the actually driven routes can be increased which in turn can reduce the risk of robbery. An alternative to the k-dissimilar vehicle routing problem is therefore a set of k distinct routing alternatives. We assume that it will only be accepted by the decision maker if the difference between the distance of the longest routing alternative in the set and the distance of the best known routing alternative in the considered instance is within reasonable limits. Since the k shortest routing alternatives are often similar to each other, the k-dissimilar vehicle routing problem is inherently a bi-objective problem. We examine the tradeoff between the minimization of the distance of the longest routing alternative in the set and the maximization of the minimum dissimilarity between two routing alternatives. As the solution concept is tested on selected instances of the capacitated vehicle routing problem. The results are promising and,
using the hypervolume indicator as a solution quality metric, suggest that the approach is able to find a good coverage of the true Pareto front for varying k.

3 - Bi-objective optimization in offshore supply vessel planning

Kjetil Fagerholt, Thomas Borthen, Henrik Loennechen, Xin Wang

We consider the supply vessel planning problem (SVPP) faced by Statoil, the largest oil and gas company operating on the Norwegian continental shelf. A set of offshore installations requires supplies by a chartered fleet of offshore supply vessels (OSVs) from an onshore depot on a regular basis. The problem in its original form consists of determining the fleet of OSVs and their corresponding weekly routes and schedules that minimize the total chartering and operating costs. The SVPP is closely related to the periodic vehicle routing problem, except for that in the SVPP each route will typically span two to three days. Furthermore, Statoil maintain the given weekly schedule for a longer period until some changes in input parameters occur, such as for example the arrival of new drilling rigs that require services. The planners then need to update the existing plan. An important requirement is to keep the new plan as close to the previous one as possible with respect to at which days the offshore installations get services. This introduces an additional persistence objective in addition to the costs and the SVPP becomes a bi-objective planning problem.

Since the SVPP with persistence has two objectives, we aim at generating a Pareto front of optimal solutions. We propose an exact solution method based on a path flow formulation of the problem. Since we are only able to solve medium-sized problems with this approach we also propose a hybrid genetic algorithm that combines the exploration breadth of population-based evolutionary search, the improvement capabilities of local search, and advanced population diversity management schemes. It is shown through a computational study that the proposed algorithm performs very well and can provide valuable decision support.
Stefan Irnich, Timo Gschwind, Ann-Kathrin Rothenbühcher, Christian Tilk

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

2 - On the minimum quartet tree cost problem
Sergio Consolvi, Jan Korst, Gijs Geleijnse, Stefan Pauws

Given a set of n data objects and their pairwise costs (or distances), the goal of the minimum quartet tree cost (MQTC) problem is to construct an optimal tree from the total number of possible combinations of quartet topologies on n, where optimality means that the sum of the costs of the embedded (or consistent) quartet topologies is minimal. Since the MQTC problem is an NP-hard combinatorial optimization problem, some heuristics have been proposed in the literature. Here we summarize the details of the heuristics to date for the problem and provide the preliminaries for an exact solution approach under development.

3 - Better s-t-Tours by Gao Tree
Corinna Gottschalk, Jens Vygen

We consider the s-t-path TSP: given a finite metric space with two elements s and t, we look for a path from s to t that contains all the elements and has minimum total distance. We improve the approximation ratio for this problem from 1.599 to 1.566. Like previous algorithms, we solve the natural LP relaxation and represent an optimum solution as a convex combination of spanning trees. Gao showed that there exists a spanning tree in the support of the LP solution that has only one edge in each narrow cut (i.e., each cut with total LP-value less than 2). Our main theorem says that the spanning trees in the convex combination can be chosen such that many of them are such “Gao trees” simultaneously at all sufficiently narrow cuts. This can be used for an improved analysis of the best-of-many Christofides algorithm.

1 - Coordination mechanisms for decentralised production planning in energy-flexible factories: matching theory and applications
Lukas Stroh, Thomas Volling

The trend towards an increasing share of renewables results in time- and weather dependent fluctuations in energy supply. Energy-flexible factories seize this opportunity by actively participating in the energy trading or balancing markets. For this purpose, appropriate flexibility instruments need to be installed as part of the production planning process. Current planning approaches assume centralized decision making regimes based on monolithic models. Yet, reality is usually different. In order to handle complexity, factories are organised in different production sections that are managed partially autonomously as business units and cost centres. The question arises how to coordinate the decentral plans of these production sections in a way that is efficient and favourable for the entire factory.

We analyse the suitability of common coordination mechanisms known from the literature to facilitate energy-flexible factories. Based on the application-oriented analysis of distributed production planning in energy-flexible factories we derive requirements for coordination mechanisms. We discuss how common coordination mechanisms such as auctions and iterative solution procedures are suitable to achieve an efficient coordination of flexibility plans in a network of several production sections. Additionally, we present results of a numerical example and point out issues for future work.

2 - Deployment and relocation of semi-mobile facilities in a thermal power plant supply chain
Tobias Zimmer, Patrick Breun, Frank Schultmann

Co-firing of biomass in coal-fired power plants is considered one of the most economic ways of carbon dioxide abatement. We investigate the deployment and relocation of several semi-mobile processing facilities in order to supply a large coal-fired power plant with high-quality renewable energy carriers. Semi-mobile facilities are characterized by a containerized design and can be relocated in case of changes in supply and demand. The energy carriers which are produced by different types of semi-mobile technologies are bulky goods with high density and properties comparable to those of coal and fuel oil. Thus, intermodal transportation is required to achieve transportation costs which are competitive with the delivered cost of fossil fuels at the plant’s gate. The optimization of the investigated supply chain therefore requires simultaneous planning of semi-mobile facility deployment and intermodal transportation. To this end, we present a mixed-integer linear program which optimizes the number of semi-mobile facilities, their respective relocation over time and the intermodal transportation of produced energy carriers to the power plant. In the case study, the intermodal transportation is characterized by a low geographical coverage of the railway network and restrictions representing minimum shipping volumes per railway line. The model minimizes the objective function of total supply chain costs including electricity generation, transportation, maintenance, the operation and relocation of the semi-mobile plants and the necessary forestry operations associated with the deployed facilities. The model is implemented in GAMS and solved using the CPLEX solver. We discuss a numerical example based on data from the forestry and energy sector in Chile.

3 - An investment planning approach for energy and resource efficiency measures for cross-sectional technology
Matthias Gerhard Wichmann, Ina Schlet-Peters, Thomas Spengler

Due to legislation, cost pressure and customer requirements, industries are faced with the need to increase energy and resource efficiency. To increase energy and resource efficiency, several measures have to be implemented in order to reach or exceed predetermined efficiency objectives. Investment planning approaches, which allow for the consideration of interdependencies
between individual measures are sparse as well. In our contribution an investment planning approach for energy and resource efficiency measurements for complex production systems is given. The approach presents a modelling approach of complex production systems, which allows for the quantification of relations between starting points and efficiency measures and their impact on energy and material flows in the production system. Based on the modelling, an investment planning model is introduced. The planning approach is applied to a case study of a cooling system. As a result the energy efficiency can be increased by 16%.

Optimisation and decomposition in energy markets

Stream: Energy and Environment
Chair: Michael Zipf

1 - Two-stage Robustness Trade-off: TRusT in the design of energy systems
Dinah Elena Majewski, Marco Wirtz, Matthias Lampe, Andre Bardow

Designing energy supply systems aims at finding a configuration of energy conversion units that covers all energy demands at minimal expenses. The resulting complex design problems are best addressed by employing mathematical optimization. However, energy demands and prices are usually uncertain. Assuming certainty for the data yields suboptimal or even infeasible solutions: If energy demands are higher than assumed during design, a lack of supply occurs for the optimal solution. To incorporate uncertainties in the optimization to guarantee security of energy supply, robustness concepts can be employed. However, strictly robust solutions are very conservative in general and often expensive.

We propose the Two-stage Robustness Trade-off (TRusT) approach to design energy supply systems that are both cost efficient and strictly robust. The TRusT approach is based on bi-objective optimization evaluating the trade-off between nominal costs and robust costs. Thereby, the TRusT approach reflects the inherent two-stage nature of energy system optimization: The first stage is the design of the energy system; the second stage determines the operation of each unit in the system and can be adapted to the occurring scenario after the design is fixed. The TRusT approach evaluates how strictly robust designs perform in the nominal and the worst-case scenario.

In a real-world case study, we identify a strictly robust design which increases the nominal total annual costs only by 1.2 % compared to the nominal optimal design. The results show that the TRusT approach reveals strictly robust design options which guarantee security of energy supply at low additional costs.

2 - Optimization Problem for the Installation of Equipment to Control Power Flow
Takayuki Shitina, Jun Imaizumi, Susumu Morito, Chunhui Xu

We consider the optimization problem with combinatorial constraints that represent the installation of the equipment to control the power flow, called loop controller. The installation of the equipment is formulated as a mixed integer programming problem. Its solution is difficult because the calculation of optimal power flow is a non-convex and nonlinear programming problem. In this problem, a set of scenarios of power demand is given as input data and the location for installation that minimizes cost under the operational constraints of the network is determined. These constraints are formulated as the voltage operating range and the line thermal capacity. A conventional technique used for the optimal installation resolves the mixed problem of combinatorial and nonlinear optimization, based on searching for a location of installation and computing the capacity for the equipment in two stages. If this type of technique is applied, then many cases might happen in a location search for the installation location in which no feasible flow exists. It is difficult to search the location efficiently. Thus, we present a new technique which approximates the installation cost without relying on local search. The approximation method called dynamic slope scaling procedure has the advantage that, this method always can provide a feasible solution. Since the method does not include 0-1 variables representing the installation, and so always retrieves a feasible value for the location and power flow. Finally, the effectiveness of the developed technique is demonstrated.

3 - Benders Decomposition on Large-Scale Unit Commitment Problems for Medium-Term Power Systems Simulation
Andrea Taverna

The Unit Commitment Problem (UCP) aims at finding the optimal commitment for a set of thermal power plants in a Power System (PS) according to some criterion. Our work stems from a collaboration with RSE S.p.A., a major industrial research centre for PSs in Italy. In this context the UCP is formulated as a large-scale MILP spanning countries over a year with hourly resolution to simulate the ideal behaviour of the system in different scenarios. Our goal is to refine existing heuristic solutions to increase simulation reliability. In our previous studies we devised a Column Generation algorithm (CG) which, however, shows numerical instability due to degeneracy in the master problem. Here we evaluate the application of Benders Decomposition (BD), which yields better conditioned subproblems. We also employ Magnanti-Wong cuts and a “two-phases scheme”, which first quickly computes valid cuts by applying BD to the continuous relaxation of the problem and then restores integrality. Experimental results on weekly instances for the Italian system show the objective function to be flat. Even if such a feature worsens convergence, the algorithm is able to reach almost optimal solutions in few iterations.

Congestion Games (i)

Stream: Game Theory and Experimental Economics
Chair: Max Klimm

1 - Approximate Pure Nash Equilibria in Cost Sharing Games
Matthias Feldotto, Grammatika Kotsialou, Alexander Skopulik

In this talk, we discuss the computation of approximate equilibria in cost sharing games. We consider weighted congestion games with polynomial cost functions for the resources. Compared to standard (weighted) congestion games, the cost functions are only given for the whole resource, but not for each player. A cost sharing method is then used to determine the costs of each player. Next to the trivial proportional cost sharing where each player has to pay a share proportional to her weight, the Shapley cost sharing method is the most accepted one since each player has to pay her marginal contribution to the overall costs. In this game setting, lots of research is going on. Especially, questions about the existence of equilibria and their quality are the topic of current research. We go one step further and look at approximate equilibria and especially the computation of them. In this talk, we present the game setting, some of its properties and our algorithmic approach.

2 - Competitive Packet Routing with Priority Lists
Daniel Schmand, Tobias Harks, Britta Peis, Laura Vargas Koch

In competitive packet routing games, packets are routed selfishly through a network and scheduling policies at edges determine which packets are forwarded first if there is not enough capacity on an edge to forward all packets at once. We analyze the impact of priority lists on the worst-case quality of pure Nash-equilibria. A priority list is an ordered list of players that may or may not depend on the edge. Whenever the number of packets entering an edge exceeds the inflow capacity, packets are processed in list order. We derive several new bounds on the price of anarchy and stability for global and local priority policies. We also consider the question of the complexity of computing an optimal priority list. It turns out that even for very restricted cases, i.e., for routing on a tree, the computation of an optimal priority list is APX-hard.
3 - Bottleneck Routing with Elastic Demands
Max Klimm, Tobias Harks
Bottleneck routing games are a well-studied model to investigate the impact of selfish behavior in communication networks. In this model, each user selects a path in a network for routing their fixed demand. The disutility of a used only depends on the most congested link visited. We extend this model by allowing users to continuously vary the demand rate at which data is sent along the chosen path. As our main result we establish tight conditions for the existence of pure strategy Nash equilibria.

Many firms are selling different types of products. Typically sales applications are characterized by substitution effects, limited information, and competitive settings. The demand intensities of a firm’s products are affected by its own product prices as well as the competitors’ product prices. Due to the complexity of such markets, smart pricing strategies are hard to derive. We analyze stochastic dynamic multi-product pricing models under competition for the sale of durable goods. In a first step, a data-driven approach is used to measure substitution effects and to estimate sales probabilities in competitive markets. In a second step, we use a dynamic model to compute powerful heuristic feedback pricing strategies, which are even applicable if the number of competitors’ offers is large and their pricing strategies are unknown.

2 - Particle-Image Velocimetry and the Assignment Problem
Armin Fügenschuh, Michael Breuer, Franz-Friedrich Butz, Jens Nikolaus Wood
The Particle-Image Velocimetry (PIV) is a standard optical contactless measurement technique to determine the velocity field of a fluid flow for example around an obstacle such as an airplane wing. Tiny density neutral and light-reflecting particles are added to the otherwise invisible fluid flow. Then two consecutive images (A and B) of a thin laser illuminated light sheet are taken by a CCD camera with a time-lag of a few milliseconds. From these two images one tries to estimate the local shift of the particles, for which it is common to use a cross-correlation function. Based on the displacement of the tracers and the time-lag, the local velocities can be determined. This method requires a high level of experience by its user, fine tuning of several parameters, and several pre- and post-processing steps of the data in order to obtain meaningful results. We present a new approach that is based on the matching problem in bipartite graphs. Ideally, each particle in image A is assigned to exactly one particle in image B, and in an optimal assignment, the sum of shift distances of all particles in A to particles in B is minimal. However, the real-world situation is far from being ideal, because of inhomogeneous particle sizes and shapes, inadequate illumination of the images, or particle losses due to a divergence out of the two-dimensional light sheet area into the surrounding three-dimensional space; to name just a few sources of imperfection. Our new method is implemented in MATLAB with a graphical user interface. We evaluated and compare it with the cross-correlation method using real measured data. We demonstrate that our new method requires less interaction with the user, no further post-processing steps, and produces less erroneous results.

1 - Product Line Optimization in the presence of preferences for compromise alternatives
Georg Bechler, Claudius Steinhardt
Recent advances in customer choice modeling have demonstrated the strong impact of compromise alternatives on the behavior of decision-makers in a wide range of decision contexts. Compromise alternatives are defined as alternatives that have an intermediate performance on the relevant attributes. For example, it is well known from consumer research that customers often seek for price compromises in the sense that they tend not to buy the cheapest or the most expensive alternative from a given offer set. However, by now, such context effects are not considered in the literature on product line optimization.

In this talk, a new approach for optimal product line selection incorporating customers’ preferences for compromise alternatives is proposed. It is based on a demand model that recently has been published in the econometric literature and includes compromise variables into a standard multinomial logit model. It is shown that the seller’s resulting decision problem of optimal product line selection can be formulated as a fractional programming model. The formulation significantly differs from existing models of product line selection, as the endogenous effects of the chosen products or attribute levels on other alternatives’ utility via the compromise variables has to be adequately captured.

2 - Optimal Service Design at the Interface of Marketing and Operations: What Benefits to Provide to Customers, how to Create them, and what Price to Charge?
Fabian Strohm, Cornelia Schoen
Service design involves making decisions with regard to what benefits to offer to the customer (incl. what price to charge) and how to create these benefits. We present an integrated optimization approach for service design that links the design decisions on service pricing, service outcome and underlying front- and back-office service processes. Considering this interdependence allows to take into account service value and the costs of service delivery simultaneously. We thereby make a contribution to the problem of evaluating the financial performance of service systems, which has been identified as a top research priority in the service research community. Our problem formulation is very flexible with regard to what types of customer value propositions and production/delivery processes can be considered. Further, our optimization approach provides a standardized interface to common process modeling techniques such as flowcharts, blueprints, process chain network diagrams, or simulation models. As a result, our approach can be applied to a number of different business environments and industries, and selected case studies from a pizza delivery service and from a large railway transport service provider demonstrate real-world applicability of the optimization model. Regarding its mathematical structure, the initial problem formulation is nonlinear mixed-integer; however, we show how to transform it to a mixed-integer linear program.

1 - Technical Operations Research and Technology Management
Ulf Lorenz
Within the last years, we have seen an increasing number of optimization applications for technical systems. Examples are advanced fluid systems, sticky separation in waste paper processing, or the synthesis of transmissions. The solution processes have been based on Discrete Mathematics and advanced algorithms, mixed with the desire to model as near to Physics as possible. Therefore, Technical Operations Research is mostly associated with applying methods of Operations Research to the synthesis of technical systems. This, however, is only half of the truth. There is an additional dimension dealing with Technology Management, what we emphasize in this talk. Traditional engineering is based on the divide-and-conquer principle which has lead to bad systems with highly sophisticated components in various applications. Our task is to bring all the pieces together again and to design good systems consisting of the same highly sophisticated components. On the one hand, this is already a management task. On the other hand, Technical Operations Research also deals with the question, how the specialized research results of Discrete Mathematics, Algorithmics etc. can be made more ergonomic for users of other specialized segments of customers.
3 - A Mixed-Integer Nonlinear Program for the Design of Mechanical Transmission Systems
Thorsten Ederer, Bastian Dörig, Peter Pelz, Marc Pöttsch, Jan Wolf

Gearboxes are mechanical transmission systems that provide speed and torque conversions from a rotating power source. As central element of the drive train, they are relevant for the efficiency and durability of motor vehicles. Through decades of evolutionary improvements, modern gearboxes have become highly specialized systems – but their complexity has also increased and makes it difficult to adapt them to changes in the requirements. An novel approach to find alternative gearbox designs is needed.

In this work, we present an approach on how to formulate the gearbox design problem as a mixed-integer nonlinear program (MINLP). This enables us to create gearbox designs from scratch for arbitrary requirements and – given enough time – compute provably globally optimal designs for a given objective. We show on realistic examples how different requirements and degrees of freedom influence the computation time and the resulting gearbox design.

FA-08
Friday, 9:00-10:30 - Seminarraum 101/103
Liner Shipping Optimization I (I)
Chair: Kevin Tierney

1 - Modelling bunker consumption for optimization models in maritime transportation
Daniel Mueller, Kevin Tierney

In recent years, advanced mathematical models have been developed for optimizing a variety of optimization problems in the area of maritime transportation. A key cost in these models is the fuel consumption of vessels, which is known as the bunker consumption. As the industry seeks to reduce fuel consumption and CO2 emissions as well, modelling variable speed has become a key component of maritime optimization. The bunker consumption varies approximately with the speed of a ship and proportionally to factors such as load and trim. Researchers have modeled bunker consumption in several different ways, including using linearized, piecewise linear or non-linear functions. So far, no rigorous study has been performed to see what affect the various approximations of bunker consumption have on the solution quality and the runtime of optimization approaches. To this end, we present preliminary computational experiments analyzing the runtime and quality of various approximations for the liner shipping cargo allocation problem. Our results suggest that simple modeling methods may provide equivalent solutions to more expensive ones.

2 - Comparing Two Optimization Approaches for Ship Weather Routing
Laura Walther, Srikanth Shetty, Anisa Rizvanoli, Carlos Jahn

Weather routing in maritime shipping is related to a shipping company’s objective to achieve maximum efficiency, economy and cost competitiveness by optimizing each voyage of a ship. A voyage can be optimized regarding costs, time, safety or combinations of these, while taking into account forecasted meteorological and oceanographic information as well as constraints given by geographic conditions, ship characteristics, emission regulations, safety requirements or time restrictions. A wide variety of mathematical models of the ship weather routing problem can be found in the literature. The formulations vary from constrained graph problems to nonlinear optimization problems and from one objective to multiple objective optimization problems. Numerous commercial systems and academic developments apply different approaches for solving the optimization problem, which range from calculus of variations, dynamic programming or discrete optimization methods to evolutionary methods. In this paper two ways to approach the ship weather routing problem using a discrete optimization method on the one hand and an evolutionary algorithm on the other are presented. For both models, the ship's heading and its delivered engine power are introduced as control variables to allow route and speed optimization. The two approaches aiming at minimum fuel costs are compared based on numerical examples with real-world data.

FA-09
Friday, 9:00-10:30 - Seminarraum 105
Evacuation Planning
Chair: David Willems

1 - Interwoven systems modeling in civil security
Stefan Ruzika, Kathrin Klamroth, Tobias Kuhn, Margaret Wiecke

In civil security research, it is quite common that location decisions and transport decisions have to be made, e.g. when planning a large-scale evacuation. Location decisions might address gathering points or shelters, while transport decisions address evacuation routes and/or means of transport. Certainly, these two problems interfere with each other since the decisions of the one are input of the other. In situations like this, it is common to follow a linear or consecutive modeling approach. First, a location problem is solved and gathering points are computed and then, these are used as starting points for the transportation process. Although this modeling approach seems natural, it is not the only one possible and the question whether a different way of composing these two sub-models leads to better results suggests itself. This talk addresses the general question of how to decompose a complex, interwoven system into sub-systems. Different modeling paradigms are presented and relationships between them are studied. In particular, we
highlight an all-in-one model based on multiobjective programming and use this as a reference model for other composition/decomposition architectures. This research is motivated by civil security application, however we aim at a general theory.

2 - A complementary optimisation-simulation framework for a single- and biobjective timetabling problem

David Willems, Carolin Torchiani, Stefan Ruzika

For almost every large public event, a shuttle bus service is installed. At first, bus stops have to be chosen with respect to several criteria like distance to the event, space for waiting people et cetera. In this talk, we will focus on the security aspect, as we want to achieve that the total waiting time of visitors is minimised. Since the travel routes from the bus stops to the event are fixed after locating the bus stops, a passenger’s travel time cannot be influenced by the timetable. The only way to improve the quality of service is to reduce the waiting time of the passengers at the stops by using an in a sense optimal timetable.

We introduce a network flow based shuttle bus model that minimises the total waiting time of the passengers. The problem considered can be interpreted as a variant of a multicommodity flow problem over time. Both busses and passengers are represented by a commodity and the two flows are linked by a coupling condition. In contrast to usual timetabling problems, we assume that the passengers arrive within a certain timeframe. At first we minimise the overall waiting time of the waiting passengers. We develop an IP-formulation and apply the model to a realistic scenario. Afterwards, we utilise a macroscopic simulation based on cellular automata to the optimal timetable in order to investigate the “quality” or robustness of such optimal timetables with respect to slightly perturbed input data like modified number of visitors, departure rules for delayed buses or different passenger behaviour concerning entering or getting off the bus, respectively. If the results of the simulation are not satisfactory to a practitioner, the corresponding input parameters can be changed and the optimisation-simulation cycle can be restarted.

2 - The Robustness Gap in Multiobjective Linear Optimization with Decision Uncertainty

Corinna Krüger, Anita Schöbel, Margaret Wiecek

We investigate multiobjective optimization problems with uncertain decision variables, i.e., problems whose solutions cannot be put into practice exactly as planned. Examples for decision uncertainty can be found in the optimization of growing media in the horticultural sector, where mixing ratios can generally not be realized exactly due to the habit of working rather fast than exact. When aiming at a mixing ratio that is profitable and sustainable at the same time, a biobjective optimization problem with decision uncertainty is encountered.

The uncertain perturbations of the decision variables are considered as elements of a polyhedral uncertainty set. The uncertainty is modeled with a point-to-set map by adding the set of all possible perturbations to the considered decision variable. Hence, the robustness of efficient solutions is defined by a set rather than vector domination in the objective space.

We study multiobjective linear optimization problems (MOLPs) with decision uncertainty. We first show that the deterministic set-valued optimization problem being the robust counterpart (RC) to the original uncertain MOLP can be reduced to a deterministic MOLP over a restricted feasible set. While the latter can be easily solved with any suitable algorithm, it does not provide any information about the robustness gap, which is defined as the difference between two weighted objective values: that of an RC-efficient solution and that of an efficient solution for the worst-case scenario. To quantify this gap, we formulate a bilevel problem in which RC-efficient solutions are sought at the lower level, and a scenario that performs worst with respect to the active constraints at the RC-efficient solution is looked for at the upper level.

3 - Using Uncertainty Theory on the Facility Layout Problems

Seyyed Hassan Taheri

One of the most interesting and well-known problems in NP-hard combinatorial optimization and facility layout problems is the Quadratic Assignment Problem-QAP. Since it has many practical applications, such as allocation of facilities, design of electronic devices, etc. But in real-world the data of these problem are not exact. So we need a method that could solve this problem near the reality. I this research, we propose the Uncertainty Theory-UT tools for solving this problem. Moreover we considered Generalized Assignment Problem and solved it by UT tools. To demonstrate the efficiency of our method, we tested on 114 problems of QAPLIB and also on a data set we generated based on distribution of data of real-world problems. For solving this problem we used evolutionary algorithms. We compared our method with the best proposals from the related literature and we conclude that our method is able to report high-quality solutions and could be an effective in real-world problems.
as well as on strategic oscillation. Technically, the problem is transformed into an equivalent nonlinear minimization problem by constructing an aggregated penalty function from classical constraints. We suggest two procedures. First, a construction procedure builds an initial solution using a variant of adaptive memory projection in a greedy randomized multi-start framework. Second, a tabu search algorithm, exploiting critical memory for switching the two groups of variables, is used to possibly improve the initial solution. The main concern is the presentation of comprehensive computational results for a vast number of instances known from relevant literature, thus enabling a detailed performance analysis of the solution procedures suggested.

2 - A genetic algorithm for two-dimensional retail shelf space problems
Fabian Schäfer, Kai Schaal, Sandro Kühn, Alexander Hübner

In order to maximize retail profits, retailers regularly determine how items should be allocated to retail shelves. One common characteristic in existing shelf space literature is the assumption that customers have a frontal perspective on shelves and observe only the foremost unit of an item, i.e. the facing. This implies that retailers must decide how to allocate the one-dimensional, front-row space by positioning different items side-by-side, but not behind one another. These types of optimization models are applied to standard supermarket shelves for the ambient assortment. However, there are other types of shelves which allow retailers to position two different items not only side-by-side but also behind one another. Examples are tilted shelves for meat, bread, fish, cheese or clothes. Customers have a total perspective on these shelves and can observe facings horizontally and vertically. This adds another degree of complexity to the shelf-space planning, because of the two-dimensional space restriction and shelf quantities need to be presented in a rectangular form. We develop the decision model, which optimizes the two-dimensional shelf-space assignment of items to a restricted, tilted shelf. We account for stochastic demand and space-elasticity effects. To solve the model we develop a genetic algorithm. By comparing it to a full enumeration, we prove its efficiency and show that results are near-optimal, with an average solution quality of above 99.1% in terms of profit.

3 - Planning strategies of Smart Grids: An approach based on meta-heuristics and simulation
Ederson Santos, Carlos Teixeira, Marcelino Silva, Gizele Júlio, Diego Cardoso

Smart Grids are regarded as the new generation of electric power systems (EPS), as aggregate in traditional systems the information and communication technologies that serve as an aid in energy management, particularly in regard to maintenance, auto recovery network, distributed generation through renewable sources, communication with smart meters, etc. Among the main benefits that this technology offers, are the ability to include consumers in process management and operation of the network, the ability to automatically detect, analyze, respond and restore failures, reducing the time and cost of maintenance, among others. However, this trend to be fully exploited, there are still a number of standards and research to be conducted. In this context, this work presents a meta-heuristic algorithm repeaters allocations in a Smart Grid, considering how data communication technology standard Power Line Communication (PLC). For this, there was the expansion of the IEC 61850 - Communication networks and systems in substations, considering the applications for Smart Grids on a power distribution scenario. The results, the optimized network, were tested in the NS3 software (Network Simulator) to analyze the performance of the optimized network as throughput, delay and to validate the data achieved. It is expected that the results achieved serve as a new tool for planning Smart Grid systems.

Behnam Soleimani
We consider nonconvex vector optimization problems with variable ordering structures in Banach spaces. Under certain boundedness and continuity properties we present necessary conditions for approximate solutions of these problems. Using a generic approach to subd e- rentials we derive necessary conditions for approximate minimizers and approximately minimal solutions of vector optimization problems with variable ordering structures applying nonlinear separating functionals and Ekeland’s variational principle.

2 - A variational inequality formulation of migration models with random data
Fabio Raciti, Baasansuren Jadamba

The last decade has witnessed a renewed interest in mathematical models of human migration. We consider here a model of economic equilibrium theory, which falls in the "micro" approach, i.e. it focuses on the individual behaviour of migrants. The equilibrium conditions are equivalently written and modified successive approximations. The talk is based on the authors’ paper “Approximations and Generalized Newton Methods”, Optimization online, February 2016.

3 - Approximations and Generalized Newton Methods for Equations and Inclusions
Diethard Klatte, Bernd Kummer

In this talk, we study local convergence of generalized Newton methods for both equations and inclusions by using known and new approximations and regularity properties at the solution. Including Kantorovich-type settings, our goal are statements about all (not only some) Newton sequences with appropriate initial points. Our basic tools are concepts and results on nonsmooth and generalized Newton methods published in the 1990ies, in particular those developed in the authors’ book “Nonsmooth Equations in Optimization” (Kluwer 2002) about Newton maps and modified successive approximations. The talk is based on the authors’ paper “Approximations and Generalized Newton Methods”, Optimization online, February 2016.

4 - Strong well-posedness for a class of hemivariational inequalities
Morteza Oveisiha

The classical notion of well-posedness for the optimization problem, which has been known as the Tykhonov well-posedness, is due to Tykhonov [3]. A minimization problem is said to be well-posed if there exists a unique minimizer and every minimizing sequence converges to the unique minimizer. In the last decades, various kinds of well-posedness for optimization problems, such as Levitin-Polyak well-posedness, Hadamard well-posedness and well-posedness by perturbations has been introduced and studied by many researchers; see, e.g. [1,2,4] and references therein. In this talk, we consider a generalization of well-posedness for a class of hemivariational inequalities which include as a special case the classical variational inequalities. By using the Mordukhovich subdifferential for set-valued maps, we obtain a metric characterization for the well-posedness of hemivariational inequalities and give some equivalence results for them.

References
1 - OR in Modern Decision Support: The Case of Critical Infrastructure Protection

Martin Zsifkovits, Stefan Wolfgang Pickl

Modern states and cities are strongly dependent on a functioning infrastructure. This makes it even more vulnerable and attractive for terrorists. The situation gets even more severe when people are directly involved, such as in public transport, as they are - at least for some groups - more susceptible to the main aim of attacks. In the main funded projects RiKoV and RE/HO/STRAIN we strongly consider OR techniques for getting an overall risk management framework in the domain of critical infrastructure protection. In a multilayered analysis, quantitative network analysis is coupled to fuzzy logic and agent-based simulation. Experiments, expert interviews, and table top exercises were used for parameterization and validation. The framework is applied to the case of public rail bound transport, where the analysis focuses on both, the macro and the micro view in the system.

2 - A Macroscopic System Dynamics Model for a Generic Airport

Maximilian Moll, Stefan Wolfgang Pickl, Jan-Peter Neutert, Andreas Tahedl

The overall dynamics of an airport are multifaceted and very complex. With the ever increasing number of visitors everyday it is important to understand them. In this paper we present a new macroscopic system dynamics model of the overall workings of a generic airport. The model starts by distinguishing the various modes of transportation and their impact on the arrival rate. It continues to follow passengers through to the gates modelling various different behaviours on the way there. It concludes with flight composition, the number of lanes and the impact on the noise level. Extra effort was taken to allow for the inherent stochasticity of many of these multi-layered processes. To make it more adaptive various on- and off-peak times are implemented as well.

3 - Impact of Imitation on the Dynamics of Long Wave Growth

Olivier Gallay

Building on the insights of R. E. Lucas and M. Staley, economic growth emerges as the collective result of the productivity of a large collection (swarm) of individual agents. We assume that the individual productivity of each agent can be represented on an abstract line, where movement in the positive direction represents an enhancement in productivity. The evolution in each individual agent’s productivity is idealized as a Brownian motion with a positive drift. This drift is composed of two parts. On the one hand, an individual component which takes the form of a positive constant and on the other hand, a time-dependent component resulting from the interaction with other agents. The latter component is interpreted here as an imitation mechanism, where the higher productivity state of leaders is to be a source of inspiration for laggards. The noise affecting the dynamics models the ubiquitous environmental uncertainties that affect the evolution of productivity over time. For a given agent, the imitation-based drift component depends in real-time on the number of productivity leaders detected within a range of observation and by their relative distance to the swarm’s barycenter. For very large swarms, we are able to show that, depending on the strength of the imitation process, a bifurcation exists between two drastically different productivity propagation regimes. Weak imitation between the agents leads to a diffusive bifurcation exists between two drastically different productivity propagation regimes. Weak imitation between the agents leads to a diffusive bifurcation exists between two drastically different productivity propagation regimes. Weak imitation between the agents leads to a diffusive bifurcation exists between two drastically different productivity propagation regimes. Weak imitation between the agents leads to a diffusive bifurcation exists between two drastically different productivity propagation regimes. Weak imitation between the agents leads to a diffusive bifurcation exists between two drastically different productivity propagation regimes. Weak imitation between the agents leads to a diffusive bifurcation exists between two drastically different productivity propagation regimes.
Project Scheduling

Stream: Project Management and Scheduling
Chair: Patrick Gerhards

1 - Introducing system dynamics functionalities in project management by playing a game
David Rumeser, Margaret Emsley

The importance of implementing System Dynamics (SD) in Project Management (PM) is due to the limitation of traditional PM methods resulting in gaps in PM practice. SD can fill these gaps by showing its uniqueness compared to the conventional PM methods, particularly in dealing with project complexity and dynamics. Project managers, however, may not be able to apply SD effectively without knowing how to use it correctly in their projects. Analogous to a tool (e.g. a knife) which can only be used properly when one knows its function (i.e. to cut things), SD will only be used effectively in PM if project managers know the functions it has, which are: • As a communication tool; • As a prediction tool (including scenario analysis); • As an optimization tool. This research shows and analyzes the four functions of SD in PM practice by designing and playing a web-based project management game called ManPro. The game is then discussed in the context of an example case study in project management.

2 - Providing Lower Bounds for the Multimode Resource-Constrained Project-Scheduling Problem
Christian Stürck, Patrick Gerhards

We present lower bounds (LB) for the multi-mode resource-constrained project scheduling problem (MRCPSP). In the MRCPSP multiple execution modes are available for each activity. The aim of the MRCPSP is finding a feasible schedule (maintaining all precedence and resource constraints) with a minimal makespan. The tested instances from the MMLIB have up to four renewable and non-renewable resources and the activities up to nine modes. Traditionally, the LB for the MRCPSP are derived from the critical path method (CPM). Here, the mode with the shortest duration of each activity is chosen. We improve these LB. New earliest starting times (EST) are calculated by solving several integer programs with a standard solver. These new EST partially improve the EST calculated by the critical path method. This also reduces the number of variables in the model and, in the best case, proves optimality of the best known solutions. Computational results show that these new starting times provide a tighter bound than the LB obtained from the critical path method.

3 - A hybrid metaheuristic for the multi-mode resource investment problem with tardiness penalty
Patrick Gerhards, Christian Stürck

In this talk we propose and analyze a hybrid approach for the multi-mode resource investment problem with tardiness penalty (MRRIPT). The MRRIPT is a project scheduling problem where, for a given deadline, the objective is to minimize the costs of resources allocated to the project as well as tardiness penalty costs for not respecting the given deadline. For each project activity multiple execution modes with different resource requirements and durations are given. While the resource constrained project scheduling problem and its multi-mode extension have been extensively studied, the resource investment problem and especially its multi-mode extension received relatively little attention. In particular, we propose a large neighborhood search where destroy operators are applied to a feasible solution to obtain subproblems. These subproblems are solved with MIP-based recreation operators to obtain an improved solution.

A Decision Support System for Optimizing the Food Stock Distribution in Unilever
Eda Nur Çankaya, Kübra Deligöz, Aylin Yağman, Tülin Aktin

This study aims to develop follow up mechanisms to reach correct stock levels and provide quicker decision making in Unilever Food Solutions (UFS). Food products (Knorr, Calvé, Becel, Sana, Carte d’Or) are delivered to hotels, restaurants and catering companies via 40 distributors based on forecasting and replenishment stock models. These distributors offer service to four regions in Turkey. Purchase power, storage capacity and shelf life of products are three major criteria for them. However, mismatch between physical inventory and forecast data is the main problem, causing accumulated stocks or unsatisfied demand.

In order to overcome these issues, an Excel-based decision support system is designed to provide the balance between production and usage quantities, and to manage stock levels optimally. This system is integrated with the currently used softwares. Product and distributor data, annual/monthly target and realized sales data of Unilever and each distributor, instant stock status at distributors, age of products are some of the data retrieved from the existing system. The design phase has started by analyzing the problematic factors and determining the critical levels for each. Then, by applying Excel formulations, warning mechanisms are built according to these levels with the aim of giving a quick notification to the user, so that an immediate action will be taken. The developed system alerts the user on factors such as, remaining shelf life of products each week, differences between the monthly target and realized sales of distributors/Unilever, current stock and that month’s closing stock kept by the distributor. The developed Excel-based control mechanism and its results are discussed with the managers of UFS, and found to be useful and applicable.

A mixed-integer linear programming for harvesting planing and transportation for coconut fruit supply chain in Chumphon province Thailand
Pramote Kuson, Monsicha Tipawanna

In this research, we used the mixed-integer linear programming model to meet the minimum cost for farmers to harvest and transportation for coconut fruit. The numerical results are presented to illustrate the feasibility of the real world coconut fruit harvesting and shipping model.

3 - 3-D Printing as an Alternative Supply Option in Spare Parts Management
Marko Jaksic

3-D printing has lately received a considerable attention in the practical and research community. However the ways that the quickly developing technology will earn its spot in production environments and supply chains usually revolves around a radical redesign of conventional manufacturing and supply chain processes. We take a different approach, and explore how novel technology can be combined with existing operational practices to attain operational benefits. We study a spare parts continuous replenishment stochastic production/inventory problem of a manufacturer, where he has an option to source parts from a relatively inflexible conventional supplier ordering in large batches, or alternatively from a flexible in-house or outsourced 3-D printing facility. We derive the optimal policy and the optimal policy parameters for the hybrid sourcing strategy and compare its performance with the two single sourcing options. We show some of the relevant properties of the optimal policy, and reveal several managerial insights by means of numerical analysis.

Complex Vehicle Routing Problems

Stream: Logistics, Routing and Location Planning
Chair: Andreas Bortfeldt

1 - The capacitated vehicle routing problem with three-dimensional loading constraints and split pickup - a case study
Junnin Yi, Andreas Bortfeldt
The capacitated vehicle routing problem with three-dimensional loading constraints (3L-CVRP) combines vehicle routing and three-dimensional loading with additional packing constraints concerning, for example, the stability of packed goods. We consider a Shanghai automotive logistics company that serves many car makers in metropolitan Shanghai and whole China. The company performs milk-run operations in and around Shanghai where goods are picked up at different sites by identical vehicles. Often, the load of one site exceeds the volume capacity of a vehicle. Therefore, we focus on the 3L-CVRP with split pickup. We propose a hybrid algorithm for this problem. It consists of a tabu search procedure for routing and some packing heuristics with different tasks. One packing heuristic generates packing plans for shuttle tours involving sites with large-volume sets of goods. Another heuristic cares for packing plans for tours with greater numbers of sites. The hybrid algorithm is tested by a set of instances which differs from usual 3L-CVRP test instances but comes from real industrial data, with up to 46 sites and 1549 boxes to be transported. The algorithm yields good results within short computing times of few minutes.

2 - Combined manpower teaming and routing problem
Yulia Anoshkina, Frank Meisel

In the context of workforce routing and scheduling there are many applications in which workers must perform geographically dispersed tasks, each of which requires certain qualifications. In many such applications, a group of workers is required for performing a task due to the different qualifications of the workers. Examples are found in maintenance operations, the construction sector, healthcare operations, or consultancies. In this paper, we analyze the combined problem of composing worker groups (teams) and routing these teams, under various goals like minimizing total completion time. We develop mathematical optimization models for a sequential solution of the teaming problem and the routing problem as well as a combined model that includes both decisions. The resulting problem shares similarities with the VRP but it also differs in relevant aspects that result from the teaming decisions and the qualification requirements. Computational experiments are conducted for identifying the tradeoff of better solution quality and computational effort that comes along with combining the two problems into a single monolithic optimization model. We also discuss additional settings, where tasks require a cooperation of two or more teams.

3 - A Hybrid Algorithm for the Vehicle Routing Problem with Pickup and Delivery and Three-dimensional Loading Constraints
Dirk Männel, Andreas Bortfeldt

We extend the classical Pickup and Delivery Problem (PDP) to an integrated routing and three-dimensional loading problem, called PDP with three-dimensional loading constraints (3L-PDP). There are given a set of requests and a homogeneous fleet of vehicles. A set of routes of minimum total length has to be determined such that each request is transported from a loading site to the corresponding unloading site. In the 3L-PDP customer demands are represented as sets of parallelepips (called boxes) and the vehicle capacity is replaced by a 3D loading space. This allows for a more detailed modeling of mixed cargo transportation by vehicles. Several packing constraints, e.g. concerning stacking of goods, can be only be considered if customer demands are viewed as sets of 3D items. In the problem formulation, we focused on the question under which conditions any reloading effort, i.e. any movement of boxes after loading and before unloading, can be avoided. A spectrum of 3L-PDP variants is introduced with different characteristics in terms of reloading effort. We propose a hybrid algorithm for solving the 3L-PDP consisting of a routing and a packing procedure. The routing procedure modifies a well-known large neighborhood search for the 1D-PDP. A tree search heuristic is responsible for packing the boxes. To ensure a reasonable computational effort, the integration of routing and packing is made according to the principle “evaluating first, packing second” and a cache for already checked routes is used. We tested the hybrid algorithm by using 54 newly proposed 3L-PDP benchmark instances with up to 100 requests (200 nodes) and up to 300 boxes. The results for the three 3L-PDP variants are plausible in that there is a clear tradeoff between travel distance and packing effort.

3 - Improving traffic assignment and periodic timetable optimization by constraint propagation
Michael Kümmeling, Jens Optitz, Peter Großmann

Usually, timetable optimization follows a simple route-wise traffic assignment based on ideal assumptions of conveyance times and interchange times. The feedback of the optimized timetable on the traffic assignment is ignored or modelled iteratively, leading to the amplification of the first found solution and potentially unexplored solutions. We apply techniques like constraint propagation to deduct general, but as close as possible, information on conveyance and interchange times of the lines in a given network. Our goal is to minimize the travel time for the passengers, in order to provide an attractive transport system. This requires the consideration of the passengers’ travel paths. We investigate periodic timetable optimization models with integrated passenger routing and compare different variants. We show that the routing models have substantial impact on the quality of the timetable. We present computational experiments on real-world networks.

1 - Integrating Periodic Timetabling and Passenger Routing
Heide Hoppmann

Periodic timetabling is an important strategic planning problem in public transport. The task is to determine periodic arrival and departure times of the lines in a given network. Our goal is to minimize the travel time for the passengers, in order to provide an attractive transport system. This requires the consideration of the passengers’ travel paths. We investigate periodic timetable optimization models with integrated passenger routing and compare different variants. We show that the routing models have substantial impact on the quality of the timetable. We present computational experiments on real-world networks.

2 - Periodic Timetabling for Fixed Driving and Waiting Times
Julius Pätzold, Anita Schöbel

Various investigations for solving the periodic timetabling problem in public transportation research make the assumption that a train (or a public transport vehicle in general) should travel between two consecutive stations in the least possible time. This assumption is even extended for the time a train waits at a station, meaning that these waiting times are also fixed to their minimal possible values. What remains to optimize are only the starting times of all lines. This should be done in such a way that the time passengers have to wait when changing between two lines that both stop at the same station is as small as possible. Since the times for staying within the same train are fixed, the resulting objective function minimizes the sum of all traveling times.

The first result presented is an investigation of how much the objective value of an optimal solution increases due to the aforementioned assumptions. Furthermore, some algorithms will be proposed for solving the timetabling problem with the described assumption. A special structure for solutions of this particular timetabling problem will be shown, which then allows to solve several instances exactly in reasonable time. For all remaining instances the idea of a matching-merge approach on the set of lines will be introduced in order to solve this special periodic timetabling problem heuristically. Numerical results for close-to real world instances will be presented.

3 - Improving traffic assignment and periodic timetable optimization by constraint propagation
Michael Kümmeling, Jens Optitz, Peter Großmann

Usually, timetable optimization follows a simple route-wise traffic assignment based on ideal assumptions of conveyance times and interchange times. The feedback of the optimized timetable on the traffic assignment is ignored or modelled iteratively, leading to the amplification of the first found solution and potentially unexplored solutions. We apply techniques like constraint propagation to deduct general, but as close as possible, information on conveyance and interchange times from the timetable. This allows for the reduction of reasonable itineraries in a multi path traffic assignment. A set of rules especially fitted to railway journeys reduces the search space further. Using the determined multiple paths, a cyclic timetable optimization is conducted, based on the periodic event scheduling problem. First computational results are presented.
1. A Column Generation Approach to Multi-Period Railway Rolling Stock Assignment
Susumu Morito, Jun Imaizumi, Motoki Miura, Takayuki Shina

Railway companies construct daily schedules of assigning rolling stocks to utilization paths. A utilization path consists of a series of trains that a particular rolling stock performs in a day. The multi-period rolling stock assignment problem is modeled as a network flow problem in which nodes correspond to utilization paths of each day in the planning horizon, and a flow from a dummy source to a dummy sink is sought so that the departing station of a utilization path coincides with the departing station of a utilization path. The model can be expressed as an integer program in which variables correspond to assignment of rolling stocks to a series of utilization paths in the planning horizon. Constraints require that each utilization path is always assigned to a rolling stock, and that each rolling stock selects a particular series of utilization paths for the planning horizon. A column generation algorithm is developed to the above integer problem, but it was found that the solvable length of the planning horizon was 5 to 7 days and inappropriate assignment schedules were generated due to end effects. We show that the model can be modified to alleviate these difficulties, and that the repeated applications of the optimization model in the rolling horizon allow to generate a feasible assignment for a longer period of time, thus indicating the feasibility of the optimization approach. The modifications of the model is based on the idea of relaxing the constraints that each utilization path is assigned to a single rolling stock except for the immediate future, thus leading to a mixed set covering/set partitioning formulation as opposed to the pure set covering formulation. The memory contains all feasible columns enables us to solve the master problem using the splitting procedure to create a complete memory of all valid trips as feasible columns. We used a greedy heuristic to select a solution in the master problem. The results of computational experiments are given based on the real data.

2. Freight Train Routing and Scheduling in a Large Railway Network
Shripad Salingkar, Narayan Rangaraj

As the need for railway transport is increasing, existing infrastructure capacity is getting saturated. Available capacity of railway network depends on infrastructure, traffic mix, volume, heterogeneity, speed, direction, etc. Many of the traffic related factors which impact available capacity can be controlled by effective routing and scheduling of trains.

Freight trains are planned closer to service execution, have less strict departure, arrival time windows, and no fixed route to follow. Flexible routes of freight trains also offer operational flexibility. Effective routing and scheduling of freight trains in the network can achieve balanced network, lower delays, better capacity utilization, and higher throughput.

Given a railway network with pre-scheduled passenger trains and a set of freight trains with origin and destination, the problem of finding a feasible route and schedule for each freight train without disturbing the passenger train schedule is defined as Freight Train Routing and Scheduling Problem (FTRSP). The objective is to minimize total time spent by the freight train in the network. The problem involves three decisions, namely, i) Routing, ii) Releasing and iii) Scheduling of trains in the railway network.

In this paper we present a methodology to solve FTRSP and its application to a sub-network of Indian Railways. We partitioned FTRSP into two sub-problems, i) Routing and Releasing and ii) Scheduling and solved these problems in sequence. We modeled ‘Routing and Releasing’ as a time indexed multi-commodity flow model. We used a priority based travel advanced greedy heuristics to schedule the trains. We present experimental results on the performance of this approach under different complexity level and report the findings.

3. A resource conflict graph for energy efficient rescheduling of rail traffic
Ambra Toletti

Growing environmental awareness has pushed politicians, industry and common citizens to promise and (sometimes) implement measures to reduce pollution and energy consumption. Rail transport has often found a place among these measures, as large quantities of goods and passengers can be moved with relatively low energy costs if compared to private motorized transport.

Since the energy needed for building and maintaining railroads is very high, rail infrastructure has to be used very intensively to obtain low energy costs per passenger/km. Unfortunately, the denser the traffic, the lower the operational stability. In fact, dense traffic means reduced buffer times between trains, and small perturbations may spread very quickly through the network and result in delays and even in unplanned stops, which cause large energy losses. Industry has already started implementing solutions to energy saving (e.g. via speed advices) and to conflict resolution at junctions.

At the same time, new methodologies and tools to speed profile optimization and optimized conflict resolution have resulted from academic works. Few approaches combine energy saving and conflict resolution, and they usually face the two issues during different and disjoint steps of iterative or hierarchical processes.

In this work, a unique optimization instance faces both issues. The model is a Resource Conflict Graph, based on conflict avoidance according to the blocking time theory, and its input parameters (including energy consumption data) are obtained via off-line simulations, which reduces the on-line computational effort considerably. Experiments on simulated disturbed operations have shown that this approach allows to save large amounts of energy with respect to non-optimized and delay-oriented conflict resolution.

- Split Methods for the Clustered Team Orienteering Problem
Ala Eidinne Yahiaoui, Aziz Moukrim, Mehdi Serairi

The Clustered Orienteering Problem (COP) is a variant of the Orienteering Problem (OP) where customers are divided into groups called clusters with the possibility to have customers present in more than one cluster. A profit is associated with each cluster and is gained only if all customers of the cluster are served. We present in this paper a generalization of the COP called the Clustered Team Orienteering Problem (CTOP) by introducing a fleet of identical vehicles. In this problem, customers of the same cluster can be served by different vehicles and a vehicle can visit customers from several clusters with no constraints on the order of visits. Our contribution is based on the route first-cluster second approach. The routing or ordering step, which consists of generating a predefined order/sequence of visits on the clients, is generally handled by a meta-heuristic framework. In our case we choose a memetic algorithm with an adapted version of the Iterative Construction/Destruction Heuristic (IDCH) as a local search procedure. On the other hand, the clustering or splitting step consists of selecting a subset of clients to be visited based on a given sequence. The objective is to maximize the profit while respecting the distance constraint. To handle this phase, we propose heuristic split algorithm based on branch-and-bound scheme. We present also a second method based on LP formulation with suitable relaxations to accelerate the resolution. We present a comparative study between the different splitting methods based on benchmarks from the literature with discussions about the results.

- Splitting procedure of genetic algorithm for column generation to solve a Vehicle Routing Problem
Martin Scheffler, Christina Hermann, Mathias Kasper

This paper considers a Vehicle Routing Problem with Simultaneous Pickup and Delivery and Time Windows (VRPSPDTW) extended by two kinds of demands assigned to specific nodes, introduced by Liu et al. (2013). As a practical application home health care logistics can be mentioned. The first demand concerns delivery from specific node one, e.g. a drugstore to customers and the second concerns pickup from customers to specific node two, e.g. a lab. Given the difficulty of this problem as NP-hard the use of metaheuristics for its solution is recommended. There is an abundance of studies about tuning common heuristics and using them for similar problems without a detailed view on the utilization of the generated informations. Therefore, this paper describes a relatively simple but effective extension of a genetic algorithm (GA) based on permutation chromosome and a splitting procedure. Using the splitting procedure to create a complete memory of all valid trips as feasible columns enables us to solve the master problem of a set partitioning formulation. The memory contains all feasible columns generated by the splitting procedure regardless of the offspring admisibility and the iteration productivity. The result is a hybrid metaheuristic with parallel search for a feasible solution (trip schedule for each vehicle) and integrated column generation. In a first step, a suitable frequency of solving the master problem is determined. Since it still is a heuristic the quality is evaluated in comparison to the
optimal solution identified by CPLEX for small instances. For large instances it is obvious to use the original GA as benchmark. These approaches are tested on test instances for the considered problem and by adjusted input data on classic VRPTW instances.

Friday, 11:00-11:45

FB-02
Friday, 11:00-11:45 - Hörsaal 1

Semi-Plenary Klein

Stream: Semi-Plenaries
Chair: Natalia Kliewer

1 - Revenue Management: Selected Concepts and Applications
Robert Klein

During the last three decades, Revenue Management has evolved into one of the most important fields of application of Operations Research. Basically, it is concerned with the task of optimally selling a fixed capacity of perishable resources within a given booking horizon, thereby maximizing the overall profit or contribution. This is essentially achieved by the application of two instruments: In a first step, "price differentiation" is performed, leading to a variety of differently priced products defined on the set of available resources. In a second step, the availability of these products is permanently adjusted by means of "capacity control" according to the current forecast of future demand. Beyond generating theoretical results concerning methods for capacity control, new concepts for modeling demand have been introduced recently and new application areas are emerging. To reflect these developments, this talk provides an overview on all three topics. Examples from well-known application areas like the airline industry, but also from recent ones like e-fulfillment are discussed.

FB-03
Friday, 11:00-11:45 - Hörsaal 2

Semi-Plenary Schultz

Stream: Semi-Plenaries
Chair: Georg Pflug

1 - Stochastic Programs in Gas and Power Networks
Rüdiger Schultz

Up to fairly recently, power and gas suppliers have been at the sunny side, both technologically and politically. Due to market regulation, the economic actions of these companies were taken almost "with complete information" under granted sales prices. Some uncertainty remained regarding power and gas demand. But this comes close to nothing when looking at it from today’s perspective: Deregulation led to unbundling of activities and, as a consequence, unbundling of knowledge on data. While before minimization of fuel costs for gas compression clearly dominated other expenses, it is the slogan of today to deliver gas to the right place at the right time in the right quantity, and with the right quality. Mathematical models facing these new developments will provide the guidelines for this lecture. A particular role will be taken by mild nonlinearities and their handling with both techniques from polynomial algebra and analysis.

FB-06
Friday, 11:00-11:45 - Hörsaal 5

Semi-Plenary Sörensen

Stream: Semi-Plenaries
Chair: Stefan Voss

1 - A history of metaheuristics
Kenneth Sörensen

Even though people have used heuristics throughout history, and the human brain is equipped with a formidable heuristic engine to solve an enormous array of challenging optimization problems, the
study of heuristics (and by extension metaheuristics) is a relatively young endeavour. It is not an exaggeration to claim that the field of (meta)heuristics, especially compared to other fields of study like physics, chemistry, and mathematics, has yet to reach a mature state. Nevertheless, enormous progress has been made since the first metaheuristics concepts were established. In this talk, we will attempt to describe the historical developments this field of study has gone through since its earliest days. Taking a bird’s eye view of the field of metaheuristics, one has to conclude that there has been a large amount of progressive insight over the years. Moreover, this progressive insight has not reached its end point: the way researchers and practitioners look at metaheuristics is still continually shifting. In our view, it is this shifting paradigm that deserves attention, as it allows us to truly understand the past and perhaps learn a few lessons that could be useful for the future development of research in metaheuristics. No history is ever completely neutral. We therefore do not attempt to hide the fact that certain ways in which the field has been progressing seem less useful, and sometimes even harmful to the development of the field in general. It is our conviction that the metaheuristics community itself is, at least partially, to blame for this. We will therefore also touch on some ways in which more scientific hygiene can be introduced in metaheuristics research. Nevertheless, a preliminary conclusion is that the field of metaheuristics has been steadily progressing towards becoming a mature field of research, and will continue to do so in the foreseeable future.

Friday, 11:45-13:15

Two-dimensional Packing Problems

Stream: Discrete and Integer Optimization
Chair: Isabel Friedow

1 - New lower bound based on relaxed model for the two-dimensional Variable Sized Bin Packing Problem
Mohamed Maiza, Billal Merhoun, Mohammed Bourjane

The variable sized bin-packing problem (VSBPP) is a natural extension of the well-known bin-packing problem (BPP) where the aim is to find the minimal possible cost generated by the use of heterogeneous bins required within a supply chain to store given items. This variant of problem arises in many practical applications such as cutting-stock problems, loading truck problems, assignment of process to processors, machine and telecommunication scheduling. In the addressed problem we consider several categories of identical bins, each bin category is characterized by the height, the width and the using cost. We consider also that expensive bins are those with a large surface. In this study, we propose a mathematical model that used to identify a new lower cost bound. The principle of the proposed lower bound is based on the relaxation of some constraints of the mathematical model. Solving both initial and relaxed mathematical models using CPLEX solver for different instances with up 250 items shows that the solution obtained by the relaxed model is close to the optimal. Our proposition presents an interesting trade-off between computation time and accuracy. Hence, for large instances, the relaxed model allows finding pseudo-optimal solutions within reasonable time.

2 - Creating Worst-Case Instances for Lower Bounds of the Two-Dimensional Strip Packing Problem
Torsten Buchwald, Guntram Scheithauer

We present a new approach to create instances with high absolute worst-case performance ratio of common lower bounds for the two-dimensional Strip Packing Problem. The idea of this new approach is to optimize the length and the width of all items regarding the absolute worst case performance ratio of the lower bound. Therefore, we model the pattern related to the lower bound as a solution of an ILP problem and merge this model with the Padberg-model of the two-dimensional Strip Packing Problem. The merged model maximizes the absolute worst-case performance ratio of the lower bound. We introduce this new model for the horizontal bar relaxation and the horizontal contiguous bar relaxation.

3 - An exact approach for the 2D rectangular strip packing problem
Isabel Friedow

We consider the 2D rectangular strip packing problem (SPP) which consists in packing a set of rectangles into a strip of fixed width and unrestricted height with the objective to minimize the strip height needed. In our case rotation of rectangles is not allowed. We investigate an exact approach based on the horizontal bar relaxation (HBR), in which a rectangle is represented by a unit-height item-type with demand corresponding to the rectangle height. The items are packed into one-dimensional bins and the aim is to minimize the number of bins used to meet demand of all items. Which items are placed in one bin is represented by a one-dimensional pattern. That continuous linear problem is solved by column generation. A stronger relaxation of the SPP is provided by the contiguous bin packing problem, in which all items of one item-type have to be placed in consecutive bins. Thus, we try to generate a set of consecutive patterns, called sequence, that contains all items. For that purpose, we add constraints to the master (HBR) which ensure that if a pattern, belonging to a sequence, is used in the solution all predecessors and at least one follower are used too. In the slave, we generate continuing patterns that are 2D-feasible, which means that every set of contiguous patterns represents a feasible partial 2D packing. To reduce the number of variables and constraints, we exclude sequences depending on lower bounds and sequences that represent identically shaped partial 2D packings. During the cutting plane approach we compute sequence depending upper bounds to obtain a strong upper bound for the SPP. Numerical experiments show that our approach is competitive with other exact methods proposed in literature.
1 - Analyzing Policies for E-Mobility Services with Renewable Energy
Stephan Meisel, Tanja Merfeld

We analyze an innovative business model in which an operator of a renewable energy system provides an e-mobility service to customers. The operator is equipped with a source of renewable energy, an energy storage device, and a fleet of electric vehicles. The vehicles are used for offering a car-sharing service as well as for providing additional storage capacity while on-site. We propose and analyze policies that allow the operator to make decisions about the use of energy at each point in time while operating the system. The operator's goal is to maximize profits from both car sharing and trading energy at the market. We formulate the resulting dynamic decision problem as a Markov Decision Process and compare two alternative types of policies for solving the problem: Lookahead policies as well as a policy function approximation. Our computational results show how the operator's preferred policy depends on problem characteristics such as the per km fee charged to car-sharing customers.

2 - Stochastic bidding of electric vehicles at different energy markets
Maren Kier, Christoph Weber

The replacement of combustion engine based vehicles by electric vehicles (EVs) leads to new challenges for the German power grid especially when EVs can provide power to the grid (V2G). Thereby it is possible to use multiple EVs as a new form of flexibility for the power grid. From the perspective of an electric utility (EU), it is important to optimize simultaneously the trading strategies for the different German electricity markets and the unit commitment of the power plant fleet including the EVs. Therefore we use a multi-stage stochastic bidding model optimizing a MIP. At the first stage, the EU makes an offer for the minute reserve power market. The second stage constitutes the day-ahead market. The optimization considers different price scenarios and produces a bidding curve for energy trading. To trade the optimal amount of electricity, technical restrictions are taken into account. After this the traded quantities are given to the model for the last stage with the unit-commitment planning. Different usage patterns of several EV-pools are used, based on the behavior recorded in the German mobility study Kd 2010. Through trading with a virtual power plant consisting of EVs, the EU may optimize the use of the power plant fleet and achieve additional profit. The power drawn from EVs is not inducing additional costs or constraints like start-up costs or a minimum power output of a conventional starting power plant. Therefore an EV fleet could be used to avoid a start up of an expensive power plant consisting of EVs, the EU may optimize the use of the cavern storages. The best storage allocation is found by local adjustments of the stored medium. The simulation results show that the estimated cost-efficient power plant operations can be supported by (pumped) storages and their ability to flatten the residual demand for remaining plant activities. Scheduling and coordinating power plants and storages lead to the NP-hard Unit Commitment Problem with hydrothermal coordination (UCP-HT). In order to substantially reduce the computational burden of solving the long-term bidding optimization as a heuristic procedure. At the first stage, plant activities are preselected to fulfill the ever-changing residual demand as well as spinning reserve requirements without any storage activities. Moreover, typical techno-economic parameters like power output specifications, minimum up/down-times, and time-dependent startups are included. Hereby, start solutions obtained by a multi-start greedy algorithm are repaired and enhanced by rule-based algorithms and local optimization routines. The second stage improves the solutions in consideration of energy storages. The best storage allocation is found by local adjustments of previous solutions releasing committed plant activities stepwise by storage operations to achieve further cost reductions. The final solution continuously dispatches the remaining storage capacity of each thermal and storage unit for, e.g., a yearly time horizon. Within a comprehensive performance analysis, we compare our approach to standard techniques using large-scale instances derived from the literature as well as a real-world case study of the electricity market in Germany.

3 - Locating fast-charging stations along the German Autobahn
Patrick Jochem, Melanie Reuter-Oppermann, Stefan Nickel, Wolf Fichtner

The roll-out of charging stations was seen as a necessary requirement for a successful market uptake of electric vehicles (EV). For long-distance trips, time is scarce, and therefore Mode 4 DC fast charging stations are currently high on the political agenda in Europe. The roll-out of the fast charging system is a severe investment for the future mobility system with EV and their optimal allocation is of high value for the society. The allocation of the first charging stations influences the profitability of all other fast charging stations and should therefore be perfectly arranged. In this talk we focus on the allocation of fast charging stations along the German Autobahn. In order to estimate the adequate number of charging points per fast charging location along the Autobahn in Southern Germany with respect to costs and waiting time of EV users, we first analyzed the workload of long distance trips over time in Germany. The data is taken from the most recent dataset "Mobilität in Deutschland". It is based on a survey in 2008 and 2009 on traffic information of over 100,000 people on the national level. Together with disaggregated traffic flow data for each intercept, the specific flows between each highway exit are estimated. We use a flow-refueling coverage model for the optimal allocation of charging stations and include future developments and possible scenarios, for example for the market penetration, costs and range of EV. A simulation is used to study the waiting times and utilization depending on the size of the charging stations and to test the influence of different charging behaviors (e.g. early charging due to range anxiety or longer charging times). Resulting cost estimates and average distances to the electricity grid are given, too.
storage costs for both the natural gas storage and the compressed air energy storage (CAES) unit exceed the discounted revenues in the base variant. Moreover, the value of intertemporal arbitrage of carbon dioxide is found to be insufficient to cover the marginal costs.

1 - Improved Balanced Flow Computation and Experiments on Combinatorial Algorithms for Linear Arrow-Debreu Markets

Omar Darwish

We present a new algorithm for computing balanced flows in equality networks arising in market equilibrium computations. The current best time bound for computing balanced flows in such networks requires \( O(n) \) maxflow computations, where \( n \) is the number of nodes in the network [Devanur et al. 2008]. Our algorithm requires only a single parametric flow computation. The best algorithm for computing parametric flows [Gallo et al. 1989] is only by a logarithmic factor slower than the best algorithms for computing maxflows. Hence, the running time of the algorithms in [Devanur et al. 2008] and [Du and Mehlhorn 2015] for computing market equilibria in linear Fisher and Arrow-Debreu markets improve by almost a factor of \( n \). Additionally, we report on some preliminary results and improvements discovered in our recent and ongoing implementation efforts of the combinatorial algorithms by Du and Mehlhorn for the linear Arrow-Debreu market model. Our observations on random instances show interesting behavior beyond what is predicted by the theoretical analysis of the running time and convergence properties. This is joint work with Kurt Mehlhorn.

2 - Amortized Analysis of Asynchronous Coordinate Descent and Tatonnement

Yun Kuen Cheung

This paper concerns asynchrony in iterative processes, focusing on gradient descent and tatonnement, a fundamental price dynamic. Gradient descent is an important class of iterative algorithms for minimizing convex functions. Classically, gradient descent has been a sequential and synchronous process, although distributed and asynchronous variants have been studied since the 1980s. Coordinate descent is a commonly studied version of gradient descent. In this paper, we focus on asynchronous coordinate descent on convex functions; \( F: \mathbb{R}^n \rightarrow \mathbb{R} \) of the form \( F(p) = f(p) + \sum_{k=1}^{n} \Psi_k(p_k) \), where \( f: \mathbb{R}^n \rightarrow \mathbb{R} \) is a smooth convex function, and each \( \Psi_k: \mathbb{R} \rightarrow \mathbb{R} \) is a univariate and possibly non-smooth convex function. Such functions occur in many data analysis and machine learning problems.

We consider a fairly general way to formulate asynchronous coordinate descent (ACD); it captures the standard synchronous coordinate descent, cyclic coordinate descent, and the version of stochastic coordinate descent that uses no-replacement sampling; a version which has not previously been analysed although it is used in practice.

We analyze this ACD process via an amortized analysis, the first such analysis for ACD. The bounds we obtain are worst case, even for stochastic coordinate descent! The amortization allows for bad updates (updates that increase the convex function value); in contrast, many prior works made the strong assumption that every update must be a (1+\( \varepsilon \))-approx. equilibrium in exchange markets with weak gross substitute (WGS) property. It runs in time polynomial in market parameters and \( \log(1/\varepsilon) \). Moreover, we show how to broaden our approach to markets with spending-constraint and budget-additive utilities, for which we obtain the first efficient algorithms to compute exact equilibria.

This is joint work with Xiaohui Bei and Jugal Garg.

1 - Cruise Line Revenue Management: Overview and Research Opportunities

Daniel Sturm, Kathrin Fischer

Cruise lines constitute an important and continuously growing sector of the worldwide leisure industry. With respect to revenue management, they share a variety of relevant attributes with airlines, hotels and especially casinos. However, revenue management practices and corresponding decision support systems which are suitable for other sectors of the leisure industry have to be adapted or extended in order to meet all requirements of cruise lines. Not only has a specific customer market segmentation to be applied, but also multiple capacity limitations have to be considered simultaneously. Additionally, individual customer values due to substantial on-board spending and individual customer choice behaviour patterns have to be incorporated into the revenue management process. Until now, decision support systems, optimization models, as well as pricing and allocation policies for cruise line revenue management have attracted little attention in the field of operations research. Based on a thorough review of the existing literature and by comparing it with revenue management models and practices in other areas, research gaps in cruise line revenue management are identified and possible approaches to close these gaps are discussed. These approaches include the extension of existing optimization models, the adaption of known revenue management policies, the verification of their effectiveness using appropriate simulations, as well as the validation of their practical applicability based on scenarios derived from real world data sets.

2 - Integer Linear Programming (ILP) Models for Price Recommendation for Online Retailers

Somnath Sikdar, Ralf Winkler, Berkan Erol, Maximilian Werk

We describe how one might use ILP models to recommend prices for online retailers with warehouses when there are multiple optimisation targets and where one is able to forecast the effect of prices for each article in the inventory. We consider the following scenario: customers buy articles online and are allowed to return them within a specified time window. The cost associated with an article has three components: a base cost (what the company pays to purchase the article); a fulfillment cost (the cost of storing the article in a warehouse and then delivering it to the customer); a return cost (the cost of sending the article back from the customer to a warehouse). We assume that we have a forecasting module that gives future prices of an article for the entire duration for which it will be sold, predicts how many will be sold and how many will be returned per week for the said duration. The design of such a forecasting module is independent of interest but we only provide a brief description of it in this paper due to space reasons. In such a situation, we show how one might construct ILP models that recommend prices under a variety of optimisation criteria: maximising profits, maximising the number of sold articles whilst respecting budgetary constraints, minimising the loss whilst achieving a certain number of sold items. The last two cases are useful for special sales offers such as mid-season or end-of-season sales, or targeted advertising campaigns. Often these optimisation objectives have interesting applications not related to pricing. We give an example where the warehouse outbound traffic is regulated by adjusting discounts whilst minimising the loss in profits.
1 - Analyzing the vulnerabilities of the German high-speed train network using quantitative graph theory
Zhonglin Wang, Martin Zsifkovits, Stefan Wolfgang Pickl

The German high-speed train system (ICE) as one of the critical infra-structures is mapped into a distance-weighted undirected network. The aim of the analysis is to make full use of quantitative graph theory in order to analyze the vulnerabilities of the network and to detect the centers and hubs of the system. When conducting network analysis of railways, traditionally the betweenness centrality measure and the efficiency measure are applied. Based on these two measures, a new vulnerability measure that we call betweenness-efficiency vulnerability measure is proposed, which can be used to detect the most vulnerable nodes. By analyzing and comparing the results of these three measures, highly vulnerable stations are identified, which therefore have more potential to harm the overall system in case of disruption. This can help decision-makers understanding the structure, behavior and vulner-abilities of the network more straightforwardly from the quantitative graph theory’s point of view. Based on the vulnerability index network resid-ual closeness, we found the proposed new measure being more suitable than the traditional betweenness and efficiency measures. Finally, the problem of adapting a new vulnerability measure to this kind of system is discussed.

2 - On the Convex Piecewise Linear Unsplittable Multi-commodity Flow Problem
Bernard Fortz, Luís Gouveia, Martin Joyce-Moniz

We consider the problem of finding the cheapest routing for a set of commodities over a directed graph, such that: i) each commodity flows through a single path, ii) the routing cost of each arc is given by a con- vex piecewise linear function of the load i.e. the total flow) traversing it. We propose a new mixed-integer programming formulation for this problem. This formulation gives a complete description of the asso-ciated polyhedron for the single commodity case, and produces very tight linear programming bounds for the multi-commodity case.

3 - A new Way to solve the Quickest Transshipment Problem
Miriam Schlöter, Martin Skutella

Flows over time are a generalization of classical network flows. As they add a time component to the flows they are better suited for real world applications, for example evacuation. In an evacuation situation it is usually the aim to evacuate a number of people from an endangered area to certain safe sites with possibly bounded capacities as quickly as possible. This situation is modelled in the Quickest Transshipment Problem. Given a network N with capacities and transit times and a set of terminals with supplies or demands, a quickest transshipment is a flow over time in N satisfying all supplies and demands within mini-mal time. Hoppe and Tardos describe the only known polynomial time algorithm to solve this problem (1995). At first they determine the min-imal feasible time horizon T for a given transshipment problem via one parametrized submodular function minimization. After that the actual transshipment needs to be computed. The main idea of the transship-ment computation is to reduce it to a lexicographically maximum flow over time problem by attaching new sources and sinks to the network via arcs with suitable chosen capacities and transit times. However, for each attached terminal another parametrized submodular function minimization problem has to be solved. We describe a new way to solve a quickest transshipment problem which only requires the one submodular function minimization to determine the minimal feasible time horizon T. At first we show a structural result, namely that each quickest transshipment problem can be solved by a convex combina- tion of at most number of terminals many lexicographically maximum flows over time. Then we show that a suitable convex combination can actually be computed while determining the minimal feasible time horizon T.

1 - Redistricting in Mexico
Eric Alfredo Rincón-García, Sergio de-los-Cobos-Silva, Miguel Ángel Gutiérrez, Antonín Ponsich, Roman Anselmo Mora-Gutiérrez, Pedro Lara-velázquez

Redistricting is the redrawing of the boundaries of legislative districts for electoral purposes in such a way that Federal or state requirements are fulfilled. In 2015 the National Electoral Institute of Mexico carried out the redistricting process of 15 states using a nonlinear program-ming model where population equality and compactness were consid-ered as conflicting objective functions, whereas other criteria, such as contiguity, travel times between municipalities, and indigenous pop-ulation were included as constraints. Besides, in order to find high quality redistricting plans in acceptable amounts of time, two auto-mated redistricting algorithms were designed: a Simulated Annealing based algorithm, and, for the first time in Mexico, a population based technique was used, an Artificial Bee Colony inspired algorithm. The primary purpose of this presentation is to describe the main character-istics of this redistricting process. To address this issue, we provide a description of the problem, and a brief overview of the inner working mode of both optimization algorithms. Finally we include computa-tional results that prove that the population based technique is more robust its counterpart for this kind of problems.

2 - Toll zone planning for road-based traffic
Martin Tschöke, Sven Müller, Sascha Ruja

In light of the increasing attention on economic, environmental and health impacts of road traffic, methods for controlling its volume and density gain more and more importance. Especially legislators look into ways of letting users of road traffic contribute to covering infra-structure and maintenance cost. One important instrument in this re-spect is the introduction of toll collection systems and toll zones. In this paper, we introduce a new approach for planning toll zones that maximizes operational income. Overall revenue is determined on the basis of the total number of trips, number of toll zones passed and the price for passing a toll zone. As in tariff zone planning for public transportation, we further consider that users of road traffic are price sensitive and adapt their behavior with respect to the price structure of the system. We develop a MIP model that constructs consistent toll zones on the basis of a set of transitivity constraints. The model’s ap-plicability to real world cases is demonstrated by a mathematical model where population equality and compactness were consid-ered as conflicting objective functions, whereas other criteria, such as contiguity, travel times between municipalities, and indigenous pop-ulation were included as constraints. Besides, in order to find high quality redistricting plans in acceptable amounts of time, two auto-mated redistricting algorithms were designed: a Simulated Annealing based algorithm, and, for the first time in Mexico, a population based technique was used, an Artificial Bee Colony inspired algorithm. The primary purpose of this presentation is to describe the main character-istics of this redistricting process. To address this issue, we provide a description of the problem, and a brief overview of the inner working mode of both optimization algorithms. Finally we include computa-tional results that prove that the population based technique is more robust its counterpart for this kind of problems.

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Disaster-prone areas, as e.g. the American southeast coast, have to face the disastrous consequences of hurricanes every year. Preparing strategies can help significantly in reducing fatalities, economic damage and response times in the aftermath of a disaster. In particular, the prepositioning of relief items before the landfall of a hurricane may accelerate the adequate supply to those affected by the hurricane, and hence can decrease the number of casualties. Prepositioning issues have received much attention from the research community in recent years, resulting in an increased number of publications. While the focus of these papers is mainly on model presentation, efficient solution methods as well as realistic case studies are still lacking. Usually, only relatively small scale examples or case studies are chosen to ensure the solvability of the proposed model by means of commercial solvers. In addition, the lack of adequate data impedes the design of genuine examples. However, large scale problems of prepositioning relief items become more and more relevant for practical applications and more realistic examples have to be considered to validate methodological developments in realistic settings. After presenting a short overview on modeling approaches, an overview of application cases given in the state-of-the-art literature is provided, highlighting the gap to more realistic problems. Based on this review, a more realistic large-scale case study on prepositioning relief items in the Gulf of Mexico area is designed. As the development of appropriate solution methods for large-scale problems is another important issue in this regard, this aspect is emphasized in the contribution as well.

2 - First Analytic System Dynamics Simulation Results for the Interplay of Airport Sectors
Gonzalo Barbeito, Martin Zsilkovits, Michael Rampetsreiter, Martin Weiderer

In 2001 security at airports became a very important topic. The recent terrorist attack on the Brussels airport showed that it did not lose any importance. Based on the quite probable assumption of a smart attacker, points with a high concentration of people need to be identified, as they will maximize the number of casualties. Due to the very different nature of the various sectors of an airport and their complex interplay, potential threats are hard to detect and predict analytically. In this paper we present first analytic simulation results with a system dynamics model, which focuses on a global risk management and shows the relevant sectors and their interconnection - keeping track of the number of people in each area as well. Even though the model is based on a generic airport, variation of the parameters allow for important conclusions to be drawn on bottle necks, potential points of attack and possible counter measures.
Carlo method. On the other hand, the sourcing problem consists of a portfolio optimization problem of different short- and long-term electricity contracts at minimizing a trade-off between electricity cost and Conditional Value-at-Risk. In this work we formulate the joint stochastic optimization problem of smelter operations and electricity sourcing. The combined model is benchmarked against settings where the electricity demand from the smelter is assumed to be constant when sourcing, or where sourcing and smelter operations are solved in a sequential manner, i.e. an operating policy for the smelter is used as basis for electricity demand in the sourcing problem. The comparison highlights that although the joint problem provides additional modelling and computational challenges, it might be important to integrate smelter operations and electricity sourcing, and an aluminium producer can reduce the risk without compromising the smelter value.

3 - Production Planning in Dairy Industry under Uncertainty

**Biľge Bilgen**

The dairy industry is a significant component of many economies, and is a major industry in the most developed and developing economies of the world. This study presents a novel mixed integer linear programming (MILP) model for the production planning of a multi-stage process within the dairy industry. The production process in the dairy industry consists of raw milk tanks, pasteurizers, processed milk tanks, sterilizers, aseptic tanks, and filling and packaging lines. Production stages are linked by intermediate storage tanks with limited capacities. This study has specifically focused on a number of industry specific characteristics (e.g. shelf life, intermediate storage, multi-stage processing, continuous flow, production bottlenecks, available connections, dedicated production lines, setup times, and costs). The key decision variables of this process are: the quantity of intermediate products, SKUs processed on resources in each time period, waiting times as raw milk and intermediate products on resources, quantity of SKUs sold; quantity of SKUs held in inventory, lost sales of SKUs, and time consumed by resources. The objective is to maximize the total profits based on sales revenue from the products against the costs, such as setup, inventory holdings, lost sales, and production costs. Since one of the distinct characteristics of the dairy supply chain is uncertainty, the deterministic model is extended to deal with an uncertain demand parameter and risk management issues are discussed using an illustrative example.

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**FC-11**
Friday, 11:45-13:15 - Seminarraum 110

**Stochastic Models in Operations**

**Stream: Production and Operations Management**

**Chair: Christoph Schwindt**

1 - **Markov model for system throughput analysis in warehouse design**

**Anja Heßler, Christoph Schwindt**

When designing a warehouse, an important decision consists in dimensioning the storage and retrieval system appropriately, which presupposes an accurate model of the system throughput under steady-state conditions. The expected maximum system throughput equals the reciprocal of the expected operation cycle time, which for given storage location strategy and layout is largely influenced by the storage and retrieval strategy. This strategy defines the way in which storage locations are assigned to orders and the order set is partitioned into operation cycles. Disregarding the time savings achieved by optimally assigning storage locations to orders may heavily bias the throughput analysis. We consider a continuous-time Markov chain to derive analytical results for the expected operation cycle time under optimized storage and retrieval strategy. In a first setting, we consider a rack storage under random storage location strategy serviced by one rack feeder performing single command cycles. We assume homogeneous stock keeping units and storage and retrieval orders released according to independent Poisson arrivals. A system state is identified with the occupancy of the storage locations with stock keeping units. The optimized assignment of storage locations to the orders is taken into account by sorting the storage locations with respect to the resulting cycle times and only considering the first feasible location in this sequence for state transitions. An analytical formula for the expected cycle time results from constructing aggregate birth-death processes where for fixed parameter n, a system state is identified with the number of occupied storage locations among the first n locations.

2 - **Heuristic Approximations for Closed Networks: A Case Study in Open-pit Mining**

**Ruslan Krenzler, Hans Daduna, Robert Kitter, Dietrich Stoyan**

We investigate a fundamental model from open-pit mining, which is a cyclic system consisting of a shovel, traveling loaded, unloading facility, and traveling back empty. The interaction of these subsystems determines the capacity of the shovel, which is the fundamental quantity of interest. To determine this capacity one needs the stationary probability that the shovel is idle. Because an exact analysis of the performance of the system is out of reach, besides of simulations there are various approximation algorithms proposed in the literature which stem from computer science and can be characterized as general purpose algorithms. We propose for solving the special problem under mining conditions an extremely simple algorithm. Comparison with several general purpose algorithms shows that for realistic situations the special algorithm outperforms the generic algorithms in this research paper. A new approach is proposed to handle combinatorial problems without needing to use an indirect representation mechanism along with opposition based learning is also incorporated into combinatoric WSA algorithm in order to further improve its diversification capability. The performance of the algorithm is tested on several resource constrained project scheduling problems. The preliminary results are promising; the best known solutions of many benchmark problems are improved.

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**FC-12**
Friday, 11:45-13:15 - Seminarraum 202

**Combinatorial Optimization: New Approaches**

**Stream: Metaheuristics**

**Chair: Silvia Schwarze**

1 - **Combinatorial Optimization via Weighted Superposition Attraction**

*Adil Baykasoğlu, Mümin Emre Şenol*

Weighted Superposition Attraction (WSA) is a swarm based metaheuristic algorithm which is recently proposed for solving continuous optimization problems by the first author. Performance of the WSA was extensively tested with many unconstrained and constrained optimization test problems. Due to its competitive performance on continuous optimization problems we motivated to develop a combinatoric version of WSA in this research paper. A new approach is proposed to handle combinatorial problems without needing to use an indirect representation mechanism like random keys. Additionally, random walk mechanism along with opposition based learning is also incorporated into combinatoric WSA algorithm in order to further improve its diversification capability. The performance of the algorithm is tested on several resource constrained project scheduling problems. The preliminary results are promising; the best known solutions of many benchmark problems are improved.

2 - **A Sequential Hyperheuristic for Optimizing The Parameters of A Generic Parameterised Dual Local Search with a TSP Application**

*Mona Hamid, Jamal Ouenniche*

Combinatorial optimization problems have been at the origin of the design of many optimal and heuristic solution frameworks such as branch-and-bound algorithms, branch-and-cut algorithms, classical local search methods, metaheuristics, and hyperheuristics. In this paper, we propose a sequential hyperheuristic to optimize the parameters of a generic and parameterised dual local search algorithm. We empirically assess the performance of the proposed framework using instances from the TSPLIB. Empirical results suggest that the proposed framework delivers outstanding performance.

3 - **An NSGA-III Approach for Multi-Objective Structural Optimization**

*Amir H. Gandomi*
This study describes the Reference point based Non-dominated Sorting Genetic Algorithm-II (r-NSGA-II) called as NSGA-III for solving multi-objective challenging structural engineering problems that involve complex constraints. The reference point method is employed in the NSGA-III to store non-dominated Pareto optimal solutions obtained so far. Solutions are chosen based on the reference point mechanism which provides the best coverage of solutions in a multi-objective search space. To prove the effectiveness of the NSGA-III algorithm, first a set of standard unconstrained and constrained test functions are solved. The NSGA-III algorithm is then applied to a variety multi-objective structural design optimization problems, including truss design and beam design problems. The results are verified by comparing NSGA-III against other well-known multi-objective optimization algorithms such as NSGA-II and MOPSO. The results of the NSGA-III algorithm on the test functions show that not only does the algorithm have high coverage, it also benefits from a quick convergence in comparison with other algorithms. The results of the algorithms on the structural optimization problems demonstrate its applicability and a high potential to solve real-world and challenging problems.

1 - Kuhn - Tucker optimality conditions in equilibrium optimization models for network industries markets
Michal Fendek, Eleonora Fendekova

Currently a significant attention in scholarly discussions on various levels is being paid to the subject of network industries. It is understandable as network industries in fact ensure the production and distribution of energy sources which play a key role in an effective operation of the developed economies. The discussions are usually focused on the question of a reasonable profit of the network industries companies and on the other hand on the question of prices which are determined by the reasonable and generally acceptable costs of their production. Naturally, equilibrium on the network industries market, as well as on any market, is being created based on the level of demand and supply on said market. For the network industries market equilibrium models a certain segregation of the market is characteristic, resulting in the network industries usually not being substitutable. Therefore a satisfaction gained from their consumption can be uniquely quantified. In principle, it is such a representation of utility function where a network industry product is considered to be a good with its own and exactly formulated utility function and the other goods are considered as a consumption of one calculated aggregated good with standardized unit price. In this paper we will discuss the analysis of microeconomic optimization models of consumers and producers behavior on the network industries market, i.e. the analysis of demand and supply phenomena on this specific market, as well as the general questions of network industries sector effectiveness. For the optimization problems we will formulate the Kuhn-Tucker optimality conditions and we will study their interpretation options.

2 - Fluctuating supply and learning by doing in a non-autonomous optimal control model of renewable energy production
Gernot Tragler, Elke Moser, Dieter Grass

The world-wide energy demand is still increasing implying an increase in greenhouse gas emissions, so an urgent task is to find a carbon-low energy supply through an optimal trade-off between energy security and sustainability. Energy security, however, turns out to be difficult for renewable energy generation because the supply of renewable sources underlies strong volatility. We address this issue by means of a non-autonomous optimal control model determining the optimal mix of fossil and renewable energy used to cover the energy demand of a small country. We assume that the supply of the renewable resource fluctuates seasonally and also include learning effects for the renewable energy technology.

2 - Integrated models for production-inventory systems with base stock policy
Sonja Otten, Ruslan Krenzler, Hans Daduna

Production processes are usually investigated using models and methods from queueing theory. Control of warehouses and their optimization rely on models and methods from inventory theory. Both areas are fields of Operations Research (OR), but they comprise quite different methodologies and techniques. In classical OR these theories are considered as disjoint research areas. Today’s emergence of complex supply chains (production-inventory networks) calls for integrated production-inventory models, which are focus of our present research.

We consider a two-echelon production-inventory system with a supplier connected to parallel production systems (servers) at several locations, each with a local inventory. Demand of customers arrives at each production system according to a Poisson process and is lost if the local inventory is depleted. To satisfy a customer’s demand each server needs exactly one unit of raw material from the associated local inventory. The supplier manufactures raw material to replenish the local inventories, which are controlled by a base stock policy, i.e. each unit taken from the associated local inventory results in a direct order sent to the supplier. The supplier can be of complex structure, e.g. a production network itself.

We develop a Markov process model for this production-inventory system and derive the steady state distribution of the system in explicit product form. This enables us to analyze the long term average costs with the aim to find the optimal base stock levels.


3 - Decomposition of open queueing networks with batch service
Wiebke Klünder

The decomposition method for non-product form networks with non-exponentially distributed interarrival and service times assumes that nodes within the network can be treated being stochastically independent and internal flows can be approximated by renewal processes. The method consists of three phases to calculate the interarrival times of a node: merging, flow, splitting. Some well-known approximation formulae for ordinary single class open queueing networks can be used to approximate the characteristics in each phase for each node as shown by Kuehn, Chylla, Whitt and Pujolle/Ia. Node performance measures such as mean queue length are determined by using approximation formulae for non-Markovian queues. 2011 the decomposition method was extended
Scheduling with MILPs

1. A multi-criteria MILP formulation for energy aware hybrid flow shop scheduling
   Sven Schulz

   The present paper introduces a multi-criteria parallel flow shop problem considering variable discrete production speeds. Managing energy consumption more sustainably and efficiently is one of the most significant challenges for a growing society in the twenty-first century. In recent years, consequently, the consideration of energy consumption has been gaining increasing importance in all industrial planning processes. Logically, there is also a limited set of papers dealing with different aspects of energy consumption as well as energy costs in scheduling. Overall, three different approaches can be identified. In detail, the energy consumption can be reduced by specific planning, time-dependent electricity cost might be exploited or the peak power may be decreased. In contrast to the majority of energy-aware scheduling models these ideas are adopted simultaneously in the proposed new extensive MILP formulation. In order to affect peak load and energy consumption variable discrete production rates as well as heterogeneous parallel machines with different levels of efficiency are considered. As a result, the interdependencies of different energy aware scheduling approaches can be shown. Furthermore, a multi-criteria objective function is proposed. Besides total completion time, time depending energy costs and the peak power are minimized. It can be shown that there is a dilemma between peak power minimization and demand charge reduction. A compromise proposal is given for this contrary effect. Since this problem is NP-hard, the numeric example is not only solved by classical solver software but also by using a heuristic approach. The results of the numeric example illustrate how the model operates.

2. Lower bounds for the two-machine flow shop problem with time delays
   Mohamed Amine Mkadem, Aziz Moukrim, Mehdi Serairi

   We address the flow shop scheduling problem with two machines and time delays. We dispose of a set \( J = 1, 2, \ldots, n \) of \( n \) jobs that must be executed without preemption on two machines \( M_1 \) and \( M_2 \), which can only handle one operation at a time. Each job \( j \) has two operations. The first operation must be executed during \( p(1,j) \) time units on \( M_1 \). Then, \( l_j \) time units are needed to transport job \( j \) to \( M_2 \), where the second operation has to be executed during \( p(2,j) \) time units. The objective is to find a feasible schedule on the two machines that minimizes the completion time of the last scheduled job on \( M_2 \). This problem is NP-hard in the strong sense even with unit-time operations. We present a comprehensive theoretical analysis of the different lower bounds of the literature and we propose new relaxation schemes. Then, we elucidate dominance relationships between them. Moreover, we investigate a linear programming-based lower bound that includes the implementation of a new dominance rule and a valid inequality. Finally, we present the result of an extensive computational study that was carried out on a set of 480 instances including new hard instances. Our new relaxation schemes outperform the state of the art lower bounds.

3. Machine scheduling for multi-product disassembly
   Franz Ehm

   In recent years, manufacturers of consumer goods have been faced with a substantial reflow of end-of-life products mainly due to increased ecological thinking among customers or legal directives. There are several strategies which have emerged under the topic of remanufacturing in order to exploit the remaining economic value from these products. The efficient disassembly plays a key role in enabling these potentials or limit the losses resulting from the duty of disposal. This study represents a novel approach to combine the problems of disassembly sequence planning and machine scheduling. In this context, we assume a shop of several non-identical stations which are available for the complete disassembly of a given set of heterogeneous products. The problem is to simultaneously determine the sequence of disassem-
NP-hard, and thus we do not expect a $(1+\varepsilon)$-approximation algorithm run on a time that depends polynomially on $1/\varepsilon$. Furthermore, Chen et al. recently showed that a running time of $2^{\Omega(1/\varepsilon)} + \text{poly}(n)$ for any $\delta > 0$ would imply that the Exponential Time Hypothesis (ETH) fails. A long sequence of algorithms have been developed that try to obtain low dependencies on $1/\varepsilon$, the better of which achieves a running time of $2^{\text{ideO}(1/\varepsilon)} + \text{O}(\text{poly}(n))$. In this paper we obtain an algorithm with a running time of $2^{\text{ideO}(1/\varepsilon)} + \text{O}(\text{poly}(n))$, which is tight under ETH up to logarithmic factors on the exponent.

Our main technical contribution is a new structural result on the configuration-ILP. More precisely, we show the existence of a highly symmetric and sparse optimal solution, in which all but a constant number of machines are assigned a configuration with small support. This structure can then be exploited by integer programming techniques and enumeration. We believe that our structural result is of independent interest and should find applications to other settings. In particular, we show how the structure can be applied to the minimum makespan problem on related machines and to a larger class of objective functions on parallel machines. For all these cases we obtain an efficient PTAS with running time $2^{\text{ideO}(1/\varepsilon)} + \text{poly}(n)$.

3 - Lower Bounds for Capacitated Lot-Sizing with Stochastic Demand and Service Level Constraints
Hartmut Stadtler, Malte Meistering

Recently, new approaches have been proposed in literature to model capacitated lot-sizing problems with stochastic demands given some service level constraints. In contrast to well-known stochastic or robust optimization approaches these new proposals do not require to model scenarios and thus have a much greater potential to be used for solving (large-scale) real world production planning problems. However, lower bounds showing the potential optimality gap associated with these new approaches are still missing in literature. To close this gap we present deterministic model formulations for the capacitated lot-sizing problem (CLSP) including given service level constraints. We will consider the periodic and cyclic service level as well as the 0- and 1-service level. Here, we assume that service levels for individual products are controlled over a given evaluation interval (e.g., one year).

Preliminary computational results will also be presented.

Key words: Capacitated lot-sizing, demand uncertainty, service levels, lower bounds

Efficient Neighborhood Search for Vehicle Routing Problems
Stream: Logistics, Routing and Location Planning
Chair: Timo Gschwind

1 - Large Neighborhood Search for the Clustered Vehicle Routing Problem
Timo Hintsch, Stefan Irmisch

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

2 - An Adaptive Large Neighborhood Search for the Dial-a-Ride Problem
Timo Gschwind, Michael Drexl

In the Dial-a-Ride Problem (DARP), user-specified transportation requests from origin to destination points have to be serviced by a fleet of homogeneous vehicles. The problem variant we consider aims at finding a set of minimum-cost routes satisfying pairing and precedence, capacity, time-window, maximum route-duration, and maximum user ride-time constraints. We propose an adaptive large neighborhood search (ALNS) for its solution. The key novelty of the approach is an exact constant-time algorithm for evaluating the feasibility of request insertions in the repair steps of the ALNS. Computational results indicate that the basic version of our ALNS is competitive to state-of-the-art methods for the DARP regarding both solution quality and computation times. To increase the solution quality, we propose two optional improvement techniques: A local-search based, intra-route improvement mechanism that each cluster must have been served in total before the next cluster can be served. This decomposes the problem into three subproblems, the assignment of clusters to tours, the routing inside a cluster, and the routing of the clusters in the tour. The second task requires the solution of several Hamiltonian path problems, one for each possibility to start and end the route through the cluster. These Hamiltonian paths are pre-computed for every pair of customers inside each cluster. The chosen start-end-pair of the clusters also affects the routing of clusters. We present a Large Neighborhood Search which makes use of the Balas-Simonetti heuristic. Computational results are compared to existing exact and heuristic approaches from the literature. In addition a second variant, the CluVRP with soft constraints, is considered. Customers of same clusters must still be part of same routes, but do not need to be served continguously any more. Adaptations of our approach are discussed.

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**OR 2016 - Hamburg**

**FC-19**
Friday, 11:45-13:15 - Seminarraum 403

**Polyhedral and Heuristic Methods for Railway Timetabling**

Stream: Traffic and Passenger Transportation  
Chair: Andreas Bärmann

1 - Rail rapid transit Timetabling Problem under dynamic passenger demand: Exact formulations  
David Canca, Eva Barrena, Gilbert Laporte, Leandro Coelho

The Railway planning process is a complex activity that is usually decomposed into several stages, namely network design, line planning, timetabling, rolling stock, and crew rostering and scheduling. In this work we study the design and optimization of non-periodic train timetables when passengers demand follows a dynamic behavior along certain planning horizon. We present four different formulations for this problem. All of them try to minimize the average passenger waiting time. The first one consists of a mixed integer non-linear programming model in which binary variables represent train launching times and the objective function contains a quadratic term. The remaining ones incorporate flow variables, allowing for a linear representation of the objective function. We compare the benefits and disadvantages of each formulation and present a branch-and-cut algorithm applicable to all of them. Finally, we perform experiments derived from real data and show the advantages of designing a timetable adapted to the demand pattern, as opposed to a regular timetable.

2 - Adaptive Large Neighborhood Search to solve the rail rapid transit timetabling under dynamic passenger demand  
Eva Barrena, David Canca, Gilbert Laporte, Leandro Coelho

We analyze the problem of designing train timetables for a rail rapid transit (RRT) line subject to a dynamic passenger demand pattern with the objective of minimizing the average passenger waiting time at the stations. We discuss two mathematical programming formulations that generalize the non-periodic train timetabling problem on a single line when a dynamic demand pattern is considered. Since exact methods have their limitations to deal with real size instances, we consider the use of heuristics or metaheuristics. By analyzing the properties of the problem, we suggest a fast adaptive large neighborhood search (ALNS) metaheuristic in order to solve large instances of the problem within short computation times. A set of extensive computational experiments allows us to demonstrate the ALNS computational superiority in comparison with a truncated branch-and-cut algorithm. We have succeeded in reducing the passenger AWT by 20% by using less than 1% of the computation time required by the latter algorithm.

3 - Compact Tight Optimization Models for Energy-Efficient Railway Timetables  
Andreas Bärmann, Alexander Martin, Oskar Schneider

In this talk, we present compact tight model formulations for the optimization of railway timetables. The goal is to minimize the energy costs of the railway operator which are incurred by high peaks in power-consumption by the circulating railway traffic. The models are validated on real-world instances by our industry partner Deutsche Bahn AG and show high potential for cost savings.

A large part of the energy cost of a railway operator does not depend on the total amount of energy used by the trains, but only on the temporal balancing of the consumption. Thus, an evenly distributed power consumption over time is much cheaper that having high peaks and low valleys, according to the typical electricity contracts of big consumers. Our approach consists in adapting a tentative timetable by changing the orders of trains is very likely to result in an impractical timetable, hence more reliable. Moreover, changing a lot of routes and switching solutions within a real time management system. Another major goal is to change as few as possible in comparison to the original timetable. This should minimize the disturbance of the ongoing timetable because fewer changes are easier to communicate, easier to apply, and hence more reliable. Moreover, changing a lot of routes and switching the orders of trains is very likely to result in an impractical timetable due to a significant amount of incertitude. We present an integrated modeling approach for this kind of re-optimization tasks using Mixed Integer Programming. Finally, we provide computational results for

**FC-20**
Friday, 11:45-13:15 - Seminarraum 404

**Advances in Railway Transportation (i)**

Stream: Traffic and Passenger Transportation  
Chair: Frank Fischer

1 - A Robust Approach to Integrating Energy Peak Loads in Operational Train Timetabling  
Anja Hähle, Christoph Heldmberg

Operational train timetabling asks for feasible schedules for trains that take into account time windows and prespecified routes as well as other constraints such as station capacities and headway times. Another significant factor is the overall energy consumption profile which mainly depends on when and how often trains accelerate. Indeed, within electricity costs the total energy consumption is just one contributor. The electricity bill also includes a significant component for the energy peak loads. Therefore the generation of energy-efficient train timetables is not only interesting from an environmental perspective but is also an important competitive factor for railway companies. We propose a model for including energy peak loads in train scheduling and present computational results on real world instances of Deutsche Bahn. Since energy peaks can be displaced by a variety of external influences and practical data are never completely certain, we discuss approaches to improve the robustness of the model by using robust optimization techniques.

2 - An integrated service-network design and hub location problem for intermodal traffic  
Thorsten Ramsauer, Andreas Bärmann, Alexander Martin

In this talk we present a case study on a real-world integrated service-network design and hub location problem for intermodal road/rail traffic. We consider a mixed-integer formulation which links three important decisions of bimodal traffic from an infrastructure and logistics provider’s point of view and resolves them simultaneously. On the first level the model solves the infrastructure provider’s hub location problem that is deciding where to build additional transshipment terminals. Since this decision depends on the structure of the transports usually performed in the network, the second decision is to determine the mode of transportation for each order in a given set of typical transport orders. Finally, to ensure efficient transportation, a railroad blocking problem needs to be solved for the orders picked for intermodal transportation. The overall objective is to minimize transportation costs and energy consumption. To solve this model we developed a bunch of preprocessing steps that are able to significantly shrink the problem size while maintaining the exactness of the approach. The remaining problem is then solved using a branch-and-bound algorithm. Computational studies with real-world data from a large railway-company in Germany show promising potential in cost and energy savings by shifting more traffic from road to rails.

3 - A Re-optimization Approach for Train Dispatching  
Torsten Klug, Frank Fischer, Thomas Schlechte, Boris Grimm

The Train Dispatching Problem (TDP) is to schedule trains through a network in a cost optimal way. Due to disturbances during operation existing track allocations often have to be re-scheduled and integrated into the timetable. There are various causes that can lead to a situation where the implemented timetable becomes unexpectedly infeasible. Predictable and unpredictable construction sites and breakdowns that block a track must be integrated shortly into a timetable. In addition, delayed trains and modifications of speed limits may require an adjustment of the timetable. Since an operator has only minutes or seconds for his decisions, a re-optimization algorithm has to calculate solutions within a real time management system. Another major goal is to change as few as possible in comparison to the original timetable. This should minimize the disturbance of the ongoing timetable because fewer changes are easier to communicate, easier to apply, and hence more reliable. Moreover, changing a lot of routes and switching the orders of trains is very likely to result in an impractical timetable due to a significant amount of incertitude. We present an integrated modelling approach for this kind of re-optimization tasks using Mixed Integer Programming. Finally, we provide computational results for
scenarios provided by the INFORMS RAS Problem Solving Competition 2012. The computational results indicates that the model and algorithmic approach produces high quality solutions in a very short time.

1. Closest and barrier distances in the presence of a finite size facility
   Masashi Miyagawa

   This work develops a bi-objective model for determining the location, size, and shape of a finite size facility. The objectives are to minimize both the closest and barrier distances. The closest distance represents the accessibility of customers, whereas the barrier distance represents the interference to travelers. The distributions of the closest and barrier distances are derived for a rectangular facility in a rectangular city where the distance is measured as the rectilinear distance. The analytical expressions for the distributions demonstrate how the location, size, and shape of the facility affect the closest and barrier distances. A numerical example shows that there exists a tradeoff between the closest and barrier distances.

2. Min-max fair emergency system with randomly occupied centers
   Jaroslav Janacek, Marek Kvet

   The contribution is focused on min-max fair emergency service system design under uncertain center ability of service providing caused by current occupation of the center by previously raised demand. Studied generalized system disutility follows the idea that the individual user’s disutility comes from more than one located service center and the contributions from relevant centers are weighted by some coefficients, which may express probability that the associated center is the nearest opened center from the located centers for the user. The main goal of this contribution is to present a fast approach to the min-max optimal emergency service system design. Within the paper, the generalized system disutility will be studied. The model of generalized disutility impacts the complexity of the problems, which must be solved by using solving techniques. The consequence of the generalized disutility model is that the suitability of common approaches considerably changes, when the min-max optimal emergency service system is designed. We introduce here an advanced approximate algorithm for the min-max location problem based on radial formulation and valid exposing structures. Furthermore, presented method enables its simple implementation within common optimization environment instead of the necessity of developing special software tool.

3. Allocating Capacity in Bikeshare-Systems
   Daniel Freund, Shane Henderson, David B. Shmoys

   Bikeshare-systems (BSSs) allow users to rent and return a bike at any station within the system. The last decade has witnessed not only a significant increase in the number of BSSs, but also a leap in the usage data these systems collect. We present data-driven methods to support New York City Bike Bikeshare’s (NYCBS) operations. In particular, in this talk we extend a model to allocate docks within the system so as to minimize out-of-stock events (OOS). We model demand for bikes and docks at individual bikeshare-stations using continuous-time Markov chains. At each station, customers arrive (independently) with Poisson-rates to return or rent a bike. An out-of-stock event occurs when a customer arrives to rent (return) a bike when the station is empty (full). Past work has shown that with constant exogenous rates our cost-function, the expected number of OOS, can be computed exactly. Using a stochastic dynamic program, we show that this extends when rates are time-dependent. Moreover with constant rates the cost-function is known to be jointly convex in the number of docks and bikes at each station, which allows the computation of optimal allocations of bikes and docks. We generalize this result for arbitrary demand-realizations. We then define a Markov chain on the start-of-day number of bikes at each station, enabling us to determine the allocation of docks that minimizes the cost-function in steady-state. Since the stochastic dynamic program is the computational bottleneck, we provide a greedy algorithm that provably finds the optimal allocation of docks (and bikes) in a fraction of the prior computation time. Our work is used by NYCBS beyond the allocation of docks, informing for example their redistribution of bikes.
Friday, 13:45-15:00

FD-01
Friday, 13:45-15:00 - Aula

Plenary Lecture and Closing Ceremony

Stream: Plenaries
Chair: Andreas Fink
Chair: Martin Josef Geiger

1 - Network Flow and Equilibrium Computation in the Linear Exchange Economy
Kurt Mehlhorn

Leon Walras introduced an economic market model in 1874. In this model, every agent participating in the market has an initial endowment of some goods and a utility function over sets of goods. Goods are assumed to be divisible. The market clears at a set of prices if each agent can spend its entire budget (= the total value of its goods at the set of prices) on a bundle of goods with maximum utility, and all goods are completely sold. Market clearing prices are also called equilibrium prices. In the linear version of the problem, all utility functions are linear. For the case of linear utility functions, Walras’ model is also known as the linear exchange economy. Walras argued the existence of equilibrium prices by describing an iterative improvement algorithm. However, his argument was incomplete. A convincing proof of existence was only given in the 1950 by Arrow and Debreu. The proof is non-constructive. Starting in the ’70s, the quest for algorithms arose. The first algorithms were exponential. Later, polynomial time algorithms were derived based on the formulation of the problem as a convex program and the use of the Ellipsoid or the interior point method. In the technical part of the talk, we describe a combinatorial polynomial-time algorithm for computing equilibrium prices. We formulate the problem as a network flow problem in which the prices are modeled as capacities. We show that the problem can be solved by an iterative algorithm. In each iteration, we first adjust the prices and then compute a maximum flow. The adjustment of the prices is based on a careful examination of the current maximum flow. We also report on an implementation of the algorithm. (joint work with Ran Duan, Jugal Garg, and Omar Darwish).
**Business Analytics and Forecasting**
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Thomas Setzer
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Track(s): 3 17

**Control Theory and Continuous Optimization**
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Christiane Tammer
Martin-Luther-University
Halle-Wittenberg
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Track(s): 13

**Decision Theory and Multiple Criteria Decision Making**
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Kathrin Klarmroth
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Track(s): 14

**Discrete and Integer Optimization**
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Marco Lübbecke
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Track(s): 2 3

**Energy and Environment**
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Dominik Möst
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Track(s): 3 4

**Finance**
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Michael H. Breitner
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Track(s): 9

**Game Theory and Experimental Economics**
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Guido Voigt
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Track(s): 5 7

**Graphs and Networks**
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Sven Krumke
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Track(s): 7

**Health Care Management**
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Teresa Melo
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Track(s): 16

**Logistics, Routing and Location Planning**
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Herbert Kopfer
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Track(s): 8 18 21

**Metaheuristics**
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Stefan Voss
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Track(s): 12

**Optimization under Uncertainty**
Achim Koberstein
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Anita Schöbel
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Track(s): 10

**Plenaries**
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Track(s): 1
<table>
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<tr>
<th>Conference Track</th>
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