Wednesday, 8:30-10:00

■ WA-01

Wednesday, 8:30-10:00 - AUDIMAX

Opening and EURO Plenary (Fischetti)

Stream: Plenaries
Chair: *Gerhard Wäscher*

1 - Thin models for big data
Matteo Fischetti

Relevance and importance of the mathematical modeling and optimization tools has been widely accepted by professionals working in the field of business analytics. Predictive and prescriptive data analytics are nowadays impossible without efficient optimization tools capable of dealing with large amount of data. These recent synergies between Operations Research and Business Analytics impose new challenges for the next generation of exact algorithms. Despite the huge success of general purpose solvers in the last decade, finding optimal solutions for Mixed-Integer Programming (MIP) models involving millions of variables still remains out of reach for many important optimization problems.

The talk will be mainly focused on the methodological (very challenging) issue of producing a highly scalable solution scheme for MIP models of very large size, as motivated by the nowadays applications. As a case study, we will address the development of an exact MIP-based approach for one of the most famous and most studied problems in the Operations Research literature: the Uncapacitated Facility Location (UFL) problem, with linear or quadratic costs. UFL with linear costs—together with its cardinality-constrained variant known as the p-median problem—plays a fundamental role in business analytics, and in particular in clustering and classification where it is used for unsupervised learning. UFL with quadratic allocation costs, on the other hand, appears as an important subproblem in the design of energy distribution networks where power loss is proportional to the square of the electric currents flowing in the system.

Our approach is based on the idea of working on a small subset of the decision variables, using a sound Benders decomposition scheme.

Wednesday, 10:30-12:30

■ WB-02

Wednesday, 10:30-12:30 - HS 7

Project Management and Scheduling I (i)

Stream: Scheduling and Project Management
Chair: *Richard Hartl*

1 - Resource-constrained project scheduling with overtime
Andre Schnabel, Carolin Kellenbrink

Jobs scheduled in the conventional resource-constrained project scheduling problem (RCPSP) consume renewable resources during their execution. Thereby, it is often assumed that each of these resources has a constant capacity throughout the planning horizon, which must not be exceeded. In practice, the usage of additional capacities can be part of the decision problem. For that reason, we extend the classical RCPSP by a decision on the usage of overtime with associated penalty costs (RCPSP-OC).

In order to solve problem instances of practically relevant size, we develop heuristic solution methods. To prevent examination of unnecessary schedules, a set containing optimal solutions for the RCPSP-OC is derived and contrasted with the corresponding sets from different scheduling objectives. We present genetic algorithms using different solution encodings and schedule generation schemes. Some of these genetic algorithms simultaneously minimize project duration and overtime costs. Others solve the RCPSP-OC by evaluating active schedules associated with different possible overtime patterns. Additionally, we suggest solution methods for the RCPSP-OC, which minimize overtime for promising deadlines. For medium-sized problem instances, a problem specific branch and bound procedure is developed in order to obtain exact solutions. We conclude by evaluating the effectiveness of solving the RCPSP-OC using the proposed heuristic and exact methods in a comparative study.

2 - Efficient CP-SAT approaches for the solution of the MRCPSP with GPRs
Alexander Schnell, Richard Hartl

Recent results from the literature have shown the power of exact approaches combining Constraint Programming (CP) and Boolean Satisfiability (SAT) Solving techniques for the solution of variants of the single-mode resource-constrained project scheduling problem (SR-CPSP). In our talk, we present extensions of these approaches to efficiently solve multi-mode RCPSP instances. Therefore, we introduce two constraint handlers gprecedencemm and cumulativemm which can be used within the optimization framework SCIP. With the above constraints one can model renewable resource constraints and generalized precedence relations (GPRs) in the context of multi-mode jobs. They both capture constraint propagation algorithms for the above problem characteristics. Moreover, the processed domain reductions are explained to the SCIP-internal SAT Solving mechanism which is able to deduce nogoods and backjumps. We compare two formulations of the MRCPSP with GPRs within SCIP, one with and one without gprecedencemm. Our computational results on instances from the literature show that the integration of gprecedencemm immensely strengthens the original formulation. Moreover, our SCIP-approach outperforms the state-of-the-art exact algorithm for the MRCPSP with GPRs on instances with 50 activities. In total, our results are highly promising, i.e. we can close 289 open instances with 30, 50 and 100 activities from the literature.

■ WB-03

Wednesday, 10:30-12:30 - HS 16

Scheduling Applications (i)

Stream: Scheduling and Project Management
Chair: *Jens Brunner*

1 - Integrated task planning and shift scheduling of logistics assistants in hospitals
Jonas Volland, Andreas Fügener, Jens Brunner

Effective and efficient logistics management in hospitals is of continuously increasing importance. Nurses usually spend a significant part of their time for logistics activities in the areas of material supply, food preparation and disposal, and cleaning. In order to release nurses from those non-patient-care related activities, a case hospital employs logistics assistants who take over the tasks. In this context, the case hospital is faced with two optimization problems, i.e., first how to schedule the logistics tasks and second, how to plan and design the shifts for the logistics assistants. We propose an integrated optimization model, which simultaneously performs both optimization problems. We therefore develop a model that combines resource-constrained project scheduling (RCPSP) and shift scheduling, and propose a column generation-based approach to solve the problem. Computational results are presented and we show that cost reductions can be achieved.

2 - Heuristics for the part inventory model sequencing problem
Martin Wirth, Florian Jaehn, Michael Schneider

Just-in-time supply for mixed-model assembly lines out of third-party consignment stocks is currently employed in several industries, like, e.g., car manufacturing. The manufacturer only keeps a small intermediate storage and replenishments are made from a consignment warehouse (closely aligned to the assembly line) whenever the inventory at the manufacturer's site is depleted. Boysen et al. (2007) described a short-term planning problem that aims at minimizing the inventory holding cost of the manufacturer depending on the model sequence of the assembly line and the consequential order release dates. The resulting part inventory model sequencing problem is NP-hard. In this paper, we present several construction heuristics and an adaptive large neighborhood search to address the problem. Furthermore, we compare the performance of the methods to existing results from the literature in numerical studies.

3 - Partially-Concurrent Open Shop Scheduling with Preemptions
Hagai Ilani, Elad Shufan, Tal Grinshpoun, Dvir Shabtay

Partially-Concurrent Open Shop Scheduling (PCOSS) was recently introduced as a common generalization of the well-known Open Shop Scheduling (OSS) model and the Concurrent Open Shop Scheduling (COSS) model. PCOSS was shown to be NP-HARD even when there is only one machine and all operations have unit processing time. In this research we investigate PCOSS with allowed preemptions. Our main goal is to determine conditions under which known results on OSS with preemptions can be extended to the PCOSS case. A PCOSS can be presented by a conflict graph that determines which pairs of operations cannot be processed concurrently. We show that if the conflict graph can be presented as the line graph of a bi-partite graph, then there is a natural extension of a polynomial algorithm for OSS with preemptions to the PCOSS case.

■ WB-04
Wednesday, 10:30-12:30 - HS 21

Robust flows and network design (i)

Stream: Discrete Optimization
Chair: *Britta Peis*

1 - Additive Stabilizers for Unstable Graphs
Corinna Gottschalk, Karthekeyan Chandrasekaran, Britta Peis, Daniel Schmand, Andreas Wierz

A graph is defined to be stable if the cardinality of a maximum matching equals the size of a minimum fractional vertex cover. Stable graphs play a significant role in combinatorial games. For example, stable graphs are exactly those graphs with non-empty core in the associated assignment games (introduced by Shapley and Shubik). The notion of stable graphs naturally extends to the weighted setting: a weighted graph is called stable if it admits an integral matching M and a fractional vertex cover (w.r.t. the weights) such that the weight of M is equal to the size of the vertex cover. We investigate the problem of stabilizing an unstable unit-weight graph by increasing (some of) the edge-weights. The goal is to minimize the total added weight. We give a combinatorial polynomial time algorithm to solve the problem in factor-critical graphs. For general graphs, we show the existence of a half-integral optimal stabilizer, and exploit the half-integrality to show that the problem is strongly NP-hard in general graphs. Moreover, we present an algorithm to compute an optimal additive stabilizer whose running time is exponential only in the size of the Tutte set in the Gallai-Edmonds decomposition.

2 - Robust flows in path-based interdiction models
Jannik Matuschke, Thomas S. McCormick, Gianpaolo Oriolo, Britta Peis, Martin Skutella

Due to the importance of robustness in many real-world optimization problems, the field of robust optimization has gained a lot of attention over the past decade. We concentrate on max flow problems and introduce a novel robust optimization model which, compared to known models from the literature, features several advantageous properties: (i) We consider a general class of path-based flow problems which can be used to model a large variety of network routing problems (and other packing problems). (ii) We aim at solutions that are robust against interdiction by a potent adversary who has the power to attack any flow path of his choice on any edge of the network. (iii) In contrast to previous robust max flow models, which are intractable, optimal robust flows for the most important basic variants of our model can be found efficiently in polynomial time. We also consider generalizations where the flow player can spend a budget to protect the network against the interdictor.

3 - k-Delete Recoverable Robust Combinatorial Optimization
Christina Büsing

We consider combinatorial optimization problems and their k-Delete recoverable robust (k-del RR) version. K-del RR is a two stage process to deal with cost-uncertainties. In the first stage, a solution of the underlying problem is fixed. In the second stage, depending on the revealed cost, at most k elements of this solution are deleted to reduce the cost. We prove that the k-del RR shortest path and MST problem are strongly NP-hard when considering Gamma scenarios. Furthermore, we provide polynomial solvable cases.

■ WB-05
Wednesday, 10:30-12:30 - HS 23

Hierarchical Planning

Stream: Production and Operations Management
Chair: *Leena Suhl*

1 - Towards An Integrated Approach to Service Process Design
Fabian Strohm

With the increased role services are playing in today's economy, research on service design has strongly advanced during the last decade. One important aspect when it comes to planning new services or optimizing existing ones is service process design. Providing tools to visualize, analyze and improve processes supports people both from marketing and operations departments. The most established method is Service Blueprinting presented by Shostack in 1982, whereas the most recent — PCN-analysis — has just been published by Sampson in 2012. Besides there is a variety of promising concepts that have been used mainly in a production or information context offering great potential when applied to services. Despite the tremendous amount of research in the different fields, an integrated analysis with regard to a service setting is still missing. Thus, this research first provides an overview of the most important or promising tools highlighting their characteristics, strength and limitations. In a second step the applicability of the whole concept or some of its aspects with regard to services is analyzed. Finally, the article discusses opportunities for future research in this field and offers a preview how some of the identified gaps can be closed.

2 - Combining different lot sizing and scheduling models for production control

Florian Isenberg, Leena Suhl

A model will be presented that combines three different lot sizing and scheduling models to cope with the various requirements and challenges given by the metalworking industry. Each of the three models has its own planning scope and fulfills a different task regarding the entire production plan. Therefore, it has to deal with its own subset of these requirements. The three models are selected to provide an adequate level of detail. Combining these models can easily result in inconsistencies, leading to infeasible models or production plans which cannot be realized. Many aspects have to be taken into account, to guarantee the correct functionality of the integrated model. The idea is to divide the planning horizon into three different planning scopes, one for the short term model, one for the medium term model and one for the long term model. It is important to choose the length of each planning scope and the level of detail according to the requirements, the order situation and the shop floor. This is analyzed based on some instances originating from a medium-sized enterprise in the metalworking industry. The commonalities and differences of the three models will be discussed and some first results of how to adjust and combine these models best, will be given in the talk.

3 - Order acceptance in production planning with demand uncertainty

Tarik Aouam, Kobe Geryl

We consider the integration of order accptance decisions in production planning problems when the quantity ordered is uncertain. Two tactical planning problems are formulated and solved. The objective of these models is to determine simultaneously an optimal production plan and a set of customer orders to accept in order to maximize expected profit while limiting the risk from accepted orders. The two models result from two possible reasons for rejecting an order, even if the unit price the customer is willing to pay exceeds the variable production cost and there is enough capacity to avoid shortage. The first model, the lot sizing model, is related to economies of scale. In fact, in the case of high fixed costs it might not be economical to satisfy a single order of a small quantity. The second model, the load-dependent lead time model, is related to the workload of the production stage. Indeed, the revenue from an additional order should at least offset the variable production cost plus the shadow prices of the capacity constraints that take into account workload. A robust optimization (RO) approach is adapted to model quantity ordered uncertainty and the resulting robust models give the planner the choice of selecting among the highly profitable yet risky orders or less profitable but possibly more stable orders. The formulated models are mixed integer linear programs, which we solve using relax-and-fix heuristics. Numerical results show that the proposed relax-and-fix heuristics outperform a state-of-the-art solver, in terms of solution quality (gap) and CPU time. The value of the two intergations is studied and the effects of various uncertainty budgets and parameters on economical and coputational performances are analyzed.

■ WB-06

Wednesday, 10:30-12:30 - HS 24

Data Envelopment Analysis I

Stream: Production and Operations Management
Chair: *Josef Jablonsky*

1 - Successful Strategic Outcome Improvement Of Sugarcane Industry Performance Management Through DEA: The Case Khuzestan Province Of Iran

Mohamad Reza Rasol Roveicy

Some authors have argued that waste is technically an output and hence should be modeled as such ;as an alternative properly weak disposability of outputs should be incorporated to avoid modeling it as a conventional ,while others believe that waste is merely an input.Today bagasse derived from sugarcane converted into a biofuel known as ethanol is also called a clean energy. By using DEA approach we can prove the feasibility of conventional inputs which can be substitute for gasoline.This is in fact a burning issue of many economists today .This paper focuses on evaluating performance of sugarcane industry as a DMU's based on evaluation of relative efficiency of comparable DMU's.Based on information about existing data on the performance of the units, DEA forms an empirical efficient surface.Thus,the study is of two folds firstly to reach sufficiency level in sugar consumption in Iran,and secondly,reducing high dependency on gasoline consumption in the province of Khuzestan. Successful Strategic Outcome Improvement Of Sugarcane Industry Performance Management Through DEA: The Case Khuzestan Province Of Iran

2 - Treating scale-efficiency gaps in peer-based DEA

Andreas Dellnitz

Data envelopment analysis (DEA) is a method for calculating relative efficiency as a ratio of weighted outputs to weighted inputs of decision making units (DMUs). It is well-known that DEA can be done under the assumption of constant returns to scale (CRS) or variable returns to scale (VRS), however. One major disadvantage of the classical approach is that each DMU optimizes its individual weighting scheme–often called self-appraisal. To overcome this flaw cross-efficiency evaluation has been developed as an alternative way of efficiency evaluation and ranking of DMUs, cf. Sexton (1986) or Doyle and Green (1994). Here all individual weighting schemes–called price systems–are applied to the activities of all DMUs. The derived cross-efficiency matrix forms the basis for seeking a consensual price system–a peer–, and hence this price system can be used for a peer-based activity planning, cf. Rödder and Reucher (2012). In this contribution we show that a scale-efficiency gap can occur when peer-based activity planning under VRS is applied, i.e. there is no feasible point in which self-appraisal efficiency under CRS, VRS and peer-appraisal efficiency coincide. As a consequence, we propose a mixed integer linear problem to find a compromise. Moreover, some numerical examples are provided to complement our theoretical results.

3 - Efficiency of Investment banks during the financial crisis: a conditional frontier analysis

Anamaria Aldea, Luiza Badin, Carmen Lipara

The bankruptcy of Lehman Brothers in September 2008 marked a turning point for banking system structure in United States, as well as everywhere else in the world. Analyzed in the next year following the outbreak of the financial crisis in the United States, the listed local investment banks from FactSet database have lower efficiency scores, showing what given that most banks were forced to abandon the complex financial products they promoted up till that moment in order to focus on providing loans and accepting deposits. In the European Union (EU), on the other hand, the crisis has been called the 'sovereign debt crisis', which peaked in 2012, but the indebtedness of EU states had signed an upward trend for several years before. In this paper we study the efficiency of listed investment banks and the impact of stock volatility on investment banks' performances. Our approach is based on the latest methodology developed in conditional nonparametric frontier models, accounting for external factors which are not under the control of the decision-making unit, but may influence the efficiency and the production process. We use balance sheet items as inputs and outputs, as well as two variables as the environmental factors. The results of this study reveal the effects of the changes in regulations made by national regulatory authorities from almost every country to save banks and protect banking system from future disruptions.

4 - Efficiency measurement in multi-period production systems

Josef Jablonsky

The paper aims at efficiency measurement in multi-period production systems. A common approach how to analyze efficiency in multi-period systems in Malmquist index, window analysis, and the Park and Park model (PP model) that attempts to measure the aggregative efficiency within multiple periods. The disadvantage of this model consists in its orientation to the best period of the decision making unit (DMU) under evaluation, i.e. the aggregative efficiency is given as the "best' efficiency score across all periods. The paper formulates original modifications of the PP model — the model that is oriented on the "worse' period of the DMU under evaluation, and the model that computes average efficiency across all periods. In addition, we propose a multi-period SBM and super-efficiency SBM models that measure inefficiencies using relative slacks, i.e. negative relative deviations in the input space and positive ones in the output space. The results of all models are illustrated and compared on the three-period example taken from the paper that introduced the PP model. The differences in results are discussed.

■ WB-07

Wednesday, 10:30-12:30 - HS 26

Dynamic, stochastic and fuzzy Routing (c)

Stream: Logistics and Transportation
Chair: *Stefan Minner*

1 - Strategy learning of route choice under different information reliabilities

Tai-yu Ma, Roberta di Pace, Gennaro Nicola Bifulco

In recent years, the enhancement and progress in communication technologies make traffic information services more dynamic, personalized and diffused, which are expected to increase traffic efficiency and reduce urban traffic congestion. To understand the role and model the effect of their introduction, a key issue is to simulate the reactions of travelers to the received information and the influence it has on route choices. In this perspective, the study aims to model the travelers' day-to-day route choice in case of Advanced Traveler Information System (ATIS). The main focus is related to modeling travelers' route choice learning process. The comparison among different approaches is proposed, in particular, the considered approaches are divided into two main groups: the reinforcement learning (RL) based, including extended RL (ERL), and the belief-learning based, such as Joint Strategy Fictitious Play (JSFP) and Bayesian learning (BL). All analyses have been carried out considering data collected by a web-based Stated Preference experiment, where the respondents are provided with information at different levels of accuracy in order to investigate the effect of information reliability. The result shows that in case of intermediate and high accurate levels, JSFP best predicts the respondents' route choice behavior under information provision, reflecting a best-reply strategy is used by the travelers for their route choice decisions. However, in case of low information accuracy, the result shows a no-learning behavior due to the payoff variability effect. The finding can provide useful insight for supporting effective ATIS design.

2 - Dynamic Routing in Time-dependent Traffic Networks

Shao Chieh Lin, Chung-Shou Liao

This study investigates the dynamic routing problem with time-dependent trac data. Given a road network, the objective of this problem is to find a shortest route plan from a source to a destination in a dynamic manner. From a theoretical point of view, the problem discusses a new shortest-path query problem with dynamic changes that are subject to trac conditions. On the other hand, this paper considers this problem with practical high-density time-series data and exploits advanced data structures to reduce computation loads. The experimental result demonstrates the eectiveness of the proposed adaptive strategy and its immediate responses to trac changes. Moreover, we also provide several heuristics, including traffic prediction techniques, which may suggest alternate routes to quickly avoid congestion, when traffic jams happen. These heuristics can speed up computation in large-scale trac networks and derive near-shortest routes.

3 - A Constrained Fuzzy Arithmetic Based Approach to Transshipment Problem with Fuzzy Decision Variables

Kemal Subulan, Adil Baykasoğlu

In the literature, there is an increasing attention to solve fully fuzzy linear programming problems in which all of the parameters as well as the decision variables are stated as fuzzy. However, most of the existing approaches for solving fuzzy mathematical programs are depend on the standard fuzzy arithmetic or extension principle. These approaches may produce questionable results for many real world engineering applications. In other words, standard fuzzy arithmetic may cause information deficient results and overestimation in the solutions since ignoring the known constraints in fuzzy arithmetic. Based on this observation, a new approach which is based on constrained fuzzy arithmetic operations is proposed. The proposed approach also incorporates the decision maker's attitudes toward risk. In the proposed approach, fuzzy arithmetic operations are performed with the help of additional information presented by the decision maker. Actually, this information presents the requisite crisp or fuzzy constraints/relations between the base variables of the fuzzy components in a fully fuzzy mathematical program. In order to illustrate the validity of the proposed approach, various types of fuzzy transshipment problems with fuzzy decision variables are solved and the obtained solutions are also compared with other methods available in the literature. The computational results show that more reliable and information efficient solutions can be generated for fuzzy transshipment problems by making use of the proposed approach. It was also shown that overly imprecise solutions can be avoided by the proposed approach for risk-averse decision makers (This work is supported by Scientific Research Projects Governing Unit (BAPYB) of Dokuz Eylül University, project No: 2015.KB.FEN.003)

4 - Vehicle Routing with Stochastic and Dependent Demands: a Bayesian Approach

Alexandre Florio, Richard Hartl, Stefan Minner

The Vehicle Routing Problem (VRP) is a well-known optimization problem in the area of transportation and logistics. The Stochastic Vehicle Routing Problem (SVRP) is a variant of the VRP in which some of the problem input is probabilistic. When only the customers' demands are uncertain we have the SVRP with Stochastic Demands (SVRPSD).

Most research done on the SVRPSD assume the demands to be statistically independent. The independence assumption greatly simplifies the probabilistic models used to describe the demands. However, such assumption does not hold in many practical scenarios where correlated demands are not only possible but also expected.

This study presents an algorithm for the SVRPSD in which the demands may be positively correlated and thus dependent. We develop a demand model where the demands are influenced by an external factor, which is uncertain at planning time but on which a prior knowledge exists. Such knowledge is updated in a Bayesian fashion each time a customer is visited and its actual demand observed. The accumulated knowledge over the external factor is then used to better estimate the demands of the remaining customers in a route. We use such information in a dynamic programming algorithm, which prescribes preventive returns to the depot for replenishment before the route is resumed.

We combine the restocking policy from the dynamic programming algorithm with a heuristic for generating a priori routes. The final algorithm is then used to solve several SVRPSD instances. We compare the solutions with the ones obtained by treating the problem as deterministic and using a simple restocking policy. We also compare our solutions with the optimal a posteriori (wait and see) solutions.

■ WB-08

Wednesday, 10:30-12:30 - HS 27

Forecasting with Neural Networks & Computational Intelligence

Stream: Forecasting
Chair: *Michael H. Breitner*

1 - Residual Values of Utility Vehicles: An Application of Neural Networks

Hans-Jörg von Mettenheim, Christoph Gleue, Dennis Eilers, Michael H. Breitner

It is quite common nowadays that new utility vehicles are not sold but leased. In the case of leasing an accurate estimation of the residual value after the lease time is necessary for planning purposes. The problem involves forecasting a resell value of a vehicle three to five years in advance and through market cycles. The specific challenge of the utility vehicle industry is, additionally, that data is comparatively more sparse than in the automotive industry in general. Also a multitude of diverse use-cases causes the condition of the returned vehicles to vary significantly. We present a real-world application and show how a relatively sparse dataset can still lead to satisfying forecast results. Our base artificial neural network model only uses two inputs: vehicle age and kilometers driven. It still manages to beat the relevant benchmarks.

2 - Forecasting Wheat Production by Artificial Neural Networks and Linear Regression Models

Mehmet Aktan

Meteorological factors such as minimum, average and maximum temperatures and amount of precipitation have strong effects on agricultural production. In this work, wheat production in five provinces of Turkey (Konya, Ankara, Adana, Erzurum and Çorum) was modeled by

artificial neural networks (ANN) and linear regression models. Daily data of minimum, average and maximum temperatures and precipitation amounts between years 1999 and 2010 were related with the wheat production amounts for each of the five provinces. ANN models can be used in assessing the dynamics of complex non-linear systems. Statistical significance of both ANN and linear regression models were compared. Such models can be beneficial in estimating the amount of wheat production by using the data collected during the planting season.

3 - Forecasting energy consumption using ensemble ARIMA-ANFIS hybrid algorithm

Sasan Barak

Energy consumption is increasing in developing countries like Iran. In order to improve energy condition and plan future demands for these countries, forecasting energy consumption is essential. Therefore, the use of accurate forecast models that can provide suitable solution in unstable situation with low data is important. In this paper, the annual energy consumption is forecasted using 3 patterns of ARIMA-ANFIS model. In the first pattern, ARIMA (Auto Regressive Integrated Moving Average) model is implemented on 4 input features, where its nonlinear residuals are forecasted by 6 different ANFIS (Adaptive Neuro Fuzzy Inference System) structure including grid partitioning, sub clustering and fuzzy c means clustering (each with 2 training algorithms). In the second pattern, the forecasting of ARIMA in addition to 4 input features are assumed as input variables for ANFIS prediction. Therefore, ARIMA's output as one of ANFIS inputs is used in energy prediction with 6 different ANFIS structures. In the third pattern, due to solve the lack of prediction data, the second pattern is applied with AdaBoost (Adaptive Boosting) data diversification model and a novel ensemble methodology is presented. The results indicate that proposed hybrid patterns improve the accuracy of single ARIMA and ANFIS models in forecasting energy consumption, though third pattern, used diversification model, acts better than others. Finally, a comprehensive comparison between different hybrid prediction models is done.

4 - Integration of Demand Forecasting in the Design of Option Bundles

Radu Constantin Popa, Martin Grunow

In option bundling several options are sold as a package. The existing methods for designing option bundles focus only on maximizing the revenues or minimizing the costs resulting from offering them to the customers instead of standalone options. None of the methods found in the literature incorporate operational aspects into their objective, even though option bundling has been identified as an important variety mitigation strategy. One of the operational advantages mentioned in the literature is the capability of option bundling to reduce forecasting errors. However, this conclusion is based only on a few observations in empirical studies. Thus far, no numerical experiments were undertaken to evaluate its validity. In our current work we are addressing these gaps by integrating the reduction of option demand forecasting errors in an option bundles design method. We focus on striking a balance between the maximization of the revenues and the minimization of the variability of the option demand resulting from offering bundles instead of options. These objectives are incorporated in a clustering algorithm. A numerical study based on real-life data from Mercedes is undertaken.

■ WB-09

Wednesday, 10:30-12:30 - HS 30

Games and Production Management (c)

Stream: Game Theory
Chair: *Xuan Vinh Doan*

1 - Game theory and Purchasing Management: an empirical study of extensive-form games in harbour cranes sector

Sandra Martínez, Carolina Bernardos, Miguel Mediavilla

The purchasing function is assuming an increasingly relevant role within companies in the last decades, taking over the main responsibility for the costs of goods purchased as well as for supplier management. Its relevancy is due to the fact that purchasing can contribute to develop competitive advantages by aligning its strategy to the business strategy. Purchasing strategy is usually deployed per (purchasing) category and operationally executed in the so called tactical purchasing process. One key step is the negotiation/bidding where there is a lack of empirical research regarding the application of game theory. This paper contributes by discussing how game theory can be systematically utilised for designing negotiations (i.e. games) and getting more efficient results —by presenting an empirical study on harbour cranes sector with two players: one of the biggest German corporation and a leading harbour cranes engineering company. The research is based on a literature review and a case study following the constructive research (CR) methodology. CR is an approach that aims to produce solutions to explicit problems and is closely related to the concept of innovative constructivism. This approach develops an innovative solution, which is theoretically grounded, to a relevant practical problem. An essential component of CR is the generation of new learning and knowledge in the process of constructing the solution. The case study as such is exploratory in nature. Two of the main researchers have been actively involved in the project transition of the case company. Thus, facets of action research (AR) have also been deployed.

2 - Newsvendor Games with Ambiguity in Demand Distributions

Xuan Vinh Doan, Tri-Dung Nguyen

We investigate newsvendor games whose payoff function is uncertain due to ambiguity in demand distributions. We discuss the concept of stability under uncertainty and introduce the concepts for robust payoff distribution when the payoff function is uncertain. Properties and numerical schemes for finding the robust solutions are presented.

■ WB-10

Wednesday, 10:30-12:30 - HS 31

Multi-objective optimization in transport and logistics I

Stream: Logistics and Transportation
Chair: *Sophie Parragh*

1 - A multi-objective Location Routing Problem with pickups, deliveries and transshipments including aspects of prospective German truck driver shortage

Sebastian Jäger, Rainer Leisten

The acquisition of professional truck drivers is one of the greatest challenges for the transportation and logistics sector in Germany. Approximately 350,000 drivers will retire within the next ten to fifteen years and cannot be replaced adequately. Especially the drivers' job within the full truckload (FTL) industry is suffering from poor attractiveness due to long absences as a result of extensive tours, low wages and societal undervaluation.

The topic itself is mentioned in many scientific contributions of different disciplines. However, only a limited number of publications focus on necessary changes in operations for long distance truckload transports. A large number of these are simulation-based approaches developing a more structured way of dealing with full truckloads by using relay networks. At such relays, loads between different trucks can be exchanged, giving most drivers the opportunity to remain within closer proximity to their domiciles.

As the German FTL industry consists of many small companies that cannot afford to develop a complete relay network with a cost minimization approach, a Location-Routing approach is introduced that helps companies to design a network that satisfies drivers needs most. Therefore, a new objective function is defined that minimizes the number of nights spent on the road by drivers. As first experiments have shown, competing behavior between typical KPI of trucking companies, the function is extended to a multi-objective approach, also considering travelled distances and lead times for goods.

2 - Multi-objective optimization of a pharmaceutical distribution case in consideration of fairness and consistency

Andreas Krawinkler, Fabien Tricoire, Karl Doerner

Consistent and fair delivery strategies within urban areas can bring several advantages for freight forwarder. Due to the constantly rising requirements for urban freight distribution, it is obligatory to provide applicable long term solutions which not only focus on minimization in terms of costs or driver time. Certain tasks, like finding a parking

place or delivering to certain customers, as well as massive differentiations between working hours, can affect productivity to a crucial extent. Therefore we want to investigate different trade-off solutions considering such aspects for supporting long- and mid-term decisions in the context of determining which vehicle to buy and which driver to employ.

We consider costs in terms of vehicle and overtime costs, fairness in deviation of overtime hours, as well as driver consistency. The aim is to find different applicable trade-off solutions among these three objectives over a specific time horizon. Additionally we want to examine different scenarios in terms of applying consistency for differently sized subsets of premium customers. The problem considered is a multi-period vehicle routing problem, including customer demands with different frequencies. Said frequencies and demand quantities are based on a real world pharmaceutical distribution case in Vienna.

We describe the problem in a multi-objective mathematical model to evaluate the trade-off among the different solutions and to determine the cost of fairness and consistency. In order to solve instance sizes of the real world case, our heuristic splits the problem into two echelons. We first try to find a bound for the vehicle costs on the strategic or tactical level; based on this we try solve the operational daily routing problem.

3 - Evaluating the trade-off between cost and service-oriented objectives in routing and scheduling problems

Sophie Parragh, Kris Braekers, Attila Kovacs, Fabien Tricoire, Richard Hartl

In many routing and scheduling problems besides cost also service-oriented objectives are of concern. In order to shed some light on their trade-off relationship, instead of using a weighted sum objective function, we introduce separate service-oriented objectives into the generalized consistent vehicle routing problem (GenConVRP) and into the home care routing and scheduling problem (HCRSP). In the multi-objective GenConVRP, in addition to routing costs, we optimize the maximum number of different drivers per customer (driver consistency) and the maximum arrival time difference on two different days in the planning horizon (arrival time consistency). In the bi-objective HCRSP, besides minimizing routing and overtime costs, we maximize the service level with respect to preferred visit times and nurses. Overtime costs in combination with interval preferences on preferred visit times results in a scheduling problem for each route that is a bi-objective problem in itself, which is a distinctive characteristic of the bi-objective HCRSP. For both problems we solve small instances to optimality using the epsilon-constraint scheme. To solve larger instances we devise algorithms combining large neighborhood search and multi-directional local search. We can show that a considerable trade-off between cost and client-oriented objectives exists. However, our results also reveal that, using the minimum cost solution as a basis, the considered visit time-oriented service levels may be improved drastically with only small additional costs. In the GenConVRP, visiting each customer by the same driver each time is significantly more expensive than allowing at least two drivers and, in several cases, arrival time consistency and driver consistency can be improved simultaneously.

■ WB-11

Wednesday, 10:30-12:30 - HS 32

Recent Advances in Public Transportation

Stream: Logistics and Transportation
Chair: *Jan Fabian Ehmke*
Chair: *Natalia Kliewer*

1 - The Vehicle Scheduling Problem with Electric Vehicles — Solution Methods and Extensions

Nils Olsen, Natalia Kliewer, Josephine Reuer, Lena Wolbeck

From the use of electric busses in public transport companies, there arise additional restrictions, which need to be considered in the vehicle scheduling. We present two vehicle scheduling problems regarding electric vehicles (EVs) by considering the limited battery capacity restriction as well as the vehicles' possibility to recharge their batteries.

First, we develop heuristics to solve the electric vehicle scheduling problem (EVSP) which aim at obtaining feasible vehicle schedules using only EVs and finding upper bounds on the costs. Second, we extend a time-space network based solution method for the VSP in order to solve the multi-vehicle type vehicle scheduling problem with EVs (MVT-(E)VSP). Our approach enhances the method by different flow decomposition strategies and an algorithm that inserts chargings into the schedule when possible, generating feasible blocks for electric vehicles. This way, we receive a vehicle schedule using a limited percentage of EVs as well as standard internal combustion engine vehicles.

In addition, we propose different extensions of those models, such as capacities for charging stations and multi-depot scheduling with EVs. Furthermore, we use heuristics modifying the solutions of the MVT-(E)VSP in order to fit the EVSP. By this means, we are able to compare the results with those of the EVSP solution methods. We test our approaches on ten real-world instances with up to 10000 service trips.

2 - Robust Efficiency in Public Bus Transport and Airline Resource Scheduling

Bastian Amberg, Lucian Ionescu, Natalia Kliewer

In this work we compare resource scheduling in public bus transport and airline traffic in the context of robustness and cost-efficiency.

The main task in resource scheduling is the assignment of aircrafts/ vehicles and crews for operating tasks. Traditionally, the goal is to minimize planned costs. However, in operations one frequently has to deal with disruptions which may lead to delays implying expensive recovery actions. This problem is addressed by robust resource scheduling when both planned cost-efficiency and robustness of schedules are considered as competing objectives. A set of scheduling approaches can be used to compute pareto-optimal solutions representing this trade-off.

In order to incorporate robustness into resource schedules we consider both stability and flexibility aspects during scheduling. Stability describes the ability of a system to work properly without changes and adjustments in case of disruptions. In contrast, flexibility means the ability to be adapted to changing environments by manageable and mostly cost-neutral actions.

Generalizing the findings from two research projects we discuss the following influential factors on the robustness of the computed resource schedules: Firstly, problem characteristics in public transport and air traffic network topologies are examined and their influence on the consideration of flexibility and stability issues in robust resource scheduling is discussed. Secondly, we present several strategies that lead to an improvement of the pareto-front by improving the trade-off between robustness and cost-efficiency. These strategies include the improvement of scheduling and optimization techniques as well as a refinement of delay prediction models enabling a robustness evaluation closer to reality.

3 - Integrated timetabling and vehicle scheduling with balanced departure times

Jan Fabian Ehmke, Verena Schmid

Extending the vehicle scheduling problem with time windows (VSP-TW), we propose the vehicle scheduling problem with time windows and balanced timetables (VSP-TW-BT). In addition to the cost-efficiency objective of the VSP-TW, our objective function considers the quality of a timetable from a passenger's point of view. Timetables are generated by balancing consecutive departures on a line according to predefined departure time intervals. We use a weighted sum approach to combine both objectives, namely costs of operation and quality of timetables. Our mathematical model and solution approach are based on efficient techniques known from the area of vehicle routing. A hybrid metaheuristic framework is proposed, which decomposes the problem into a scheduling and a balancing component. Real-world inspired instances allow for the evaluation of quality and performance of the solution approach. The proposed solution approach is able to outperform a commercial solver in terms of run time and solution quality.

4 - OD matrix estimation using smart card transactions data and its usage for the tariff zones partitioning problem

Michal Kohani

OD matrix is an important input parameter for a large number of optimization problem especially in the public passenger transportation. Obtaining the OD matrix is often very difficult task. Traditional approaches, such as surveys, could not enable us to obtain comprehensive and complex data on passengers and their journeys and are also quite expensive. In cases where passengers in transportation use the smart cards, we can obtain more accurate data about the passengers' journeys also in cases where these data are incomplete. In this contribution we present a trip-chaining method to obtain passenger journeys from smart card transactions data. Using these transactions data and

their combination with data from other sources such as street maps, timetable and bus line routes, we are able to obtain origins and destinations of passenger journeys and also information about the changes between the lines on the passenger's journey. Designed approach is verified on the case of the Zilina municipality, where we have a data set with passengers' smart card transactions for a period of one week (approx. 110 000 transaction records). Obtained OD matrix is later used as the input for the solving of the tariff zone partitioning problem in the Zilina municipality area and these results are also presented in this contribution.

■ WB-12

Wednesday, 10:30-12:30 - HS 33

Maritime Logistics I

Stream: Logistics and Transportation
Chair: *Hans-Dietrich Haasis*

1 - Horizontal Cooperation in Maritime Supply Chains

Dirk Sackmann, Alexandra Rittmann

Structural changes in international trade and the evolution of maritime transport have directly influenced maritime supply chains. Successfully implemented cooperation development strategies lead to cooperation benefits between the supply chain actors. In the course of horizontal cooperation, companies share their existing resources in order to gain competitive advantages. Those have to be distributed fairly among the coalition members. Cooperative game theory approaches are considered to be adequate in this context. In this paper we analyze maritime supply chains from both a resource based view and a transaction cost economics point of view. We identify promising cooperation objects with respect to their specifity and uncertainty. Based on this data, the core, the Shapley value and the -value are compared and evaluated with respect to the distribution of cooperation benefits. Sometimes the Shapley value suffers from the problem of not being inside the core even when the core is a non-empty set. However, it is shown that its application is adequate in the context of horizontal cooperation in maritime supply chains.

2 - Systems Dynamics Approach for Analyzing Benefits for Port Coopetition

Hans-Dietrich Haasis

More and more port coopetition plays an important role for increasing trade facilitation, supply chain integration as well as regional connectivity and welfare. Focusing selected strategic and operative issues coopetition gives the chance for balancing cooperation and competition according to the political and organizational environment of ports. Within this paper a systems dynamics approach is presented analyzing the benefits for port coopetition. The approach can be used for the design of systematic competition strategies in practice. The benefits are related to green sus-tainability, strategic flexibility, economic operations, and security as well as logistics clusters development and trade facilitation. Related examples for port coopetition are outlined.

■ WB-13

Wednesday, 10:30-12:30 - HS 41

Sustainable Design and Operations of Supply Chains (i)

Stream: Supply Chain Management
Chair: *Gerd J. Hahn*
Chair: *Marcus Brandenburg*

1 - Life-Cycle Planning in Closed-Loop Supply Chains: A Study of Refurbished Laptops

Thomas Nowak, Gernot Lechner

In practical reverse logistics decision making, adequate pricing decisions for new and reprocessed products are of crucial importance to companies, since sales prices determine to a high extent the willingness of consumers to buy products or not. In this article, we present a newsvendor model with price effects, representing an original equipment manufacturer (OEM) that is able to make reverse channel choice of her products at the end of their usage phase. This means that the OEM has the choice between conducting product recovery operations on her own, as often done by manufacturers in the USA, or delegate product recovery operations to some third party provider, as imposed by the EU's waste electrical and electronic equipment legislation. Based on an empirical study on the prices of new and refurbished laptops, we are able to apply a realistic parameterization of our model. Therefore, the analysis of our model allows us to derive insights on the relationships between consumer awareness towards refurbished products, their return behavior as well as optimal reverse logistics decision making of an OEM.

2 - Planning of Sustainable Operations in Chemical Process Industries

Gerd J. Hahn, Marcus Brandenburg

Process industries typically involve complex manufacturing operations and thus require adequate decision support. In this paper, we focus on two relevant features in aggregate production planning of process industry operations: (i) sustainable planning given alternative product routings and production modes in the manufacturing process, (ii) integrated planning with the operational level anticipating product mix decisions on lead times and WIP inventories. We focus on the issue of multi-level chemical production processes and highlight the trade-off between capacity utilization and lead times in a stochastic manufacturing environment. A novel hierarchical decision support tool is presented that combines a deterministic linear programming model and an aggregate stochastic queuing model. The model is exemplified at a case example from the chemical industry to illustrate managerial insights and methodological benefits of our approach.

3 - Simulation and optimization to configure eco-efficient supply chains under consideration of performance and risk aspects

Marcus Brandenburg

Formal models that support multi-criteria decision making represent a strongly growing area in sustainable supply chain management research. However, uncertainties and risks in formal models for green supply chain (SC) design are seldom considered. The paper at hand suggests a hybrid simulation and optimization approach to configure an eco-efficient SC for a new product under consideration of economic and environmental risks. Discrete-event simulation is applied to assess the financial, operational and environmental performance and risk of different SC configuration options. The analytic hierarchy process is employed to solve the resulting multi-criteria decision problem of choosing exactly one option. The approach is illustrated at a case example of a fast moving consumer goods manufacturer.

■ WB-14

Wednesday, 10:30-12:30 - HS 42

Integer Programming for Graph Optimization Problems

Stream: Graphs and Networks
Chair: *Fabio Furini*
Chair: *Enrico Malaguti*

1 - Formulation and solution of Coloring problems as Maximum Weighted Stable Set problems

Enrico Malaguti, Denis Cornaz, Fabio Furini

In Vertex Coloring Problems, one is required to assign a color to each vertex of an undirected graph in such a way that adjacent vertices receive different colors, and the objective is to minimize the cost of the used colors. In this work we solve four different coloring problems formulated as Maximum Weighted Stable Set Problems on an associated graph. We exploit the transformation proposed by Cornaz and Jost [Operations Research Letters, 2008], where given a graph G, an auxiliary graph G' is constructed, such that the family of all stable sets of G' is in one-to-one correspondence with the family of all feasible colorings of G. The transformation was originally proposed for the classical Vertex Coloring and the Max-Coloring problems; we extend it to the Equitable Coloring problem and the Bin Packing Problem with Conflicts. We report extensive computational experiments on benchmark

instances of the four problems, and compare the solution method with the state-of-the-art algorithms. By exploiting the proposed method, we largely outperform the state-of-the-art algorithm for the Max-coloring problem, and we are able to solve, for the first time to proven optimality, 14 Max-coloring and 2 Equitable Coloring instances.

2 - Equilibrated Vertex k-Separator Problem

Enrico Malaguti, Fabio Furini, Denis Cornaz, Mathieu Lacroix, A. Ridha Mahjoub, Sébastian Martin

Given an undirected graph, a Vertex k-Separator (VKS) is a subset of the vertex set such that, when the VKS is removed from the graph, the remaining vertices can be partitioned into k subsets that are pairwise edge-disconnected. The problem of finding the minimum size VKS is called Vertex k-Separator Problem (VKSP), without any additional constraints, necessary in real-world applications, the VKSP is trivial. In this paper we focus on the two real-world and challenging constrained versions of the VKSP. The first one is the Cardinality VKSP, i.e., the problem of finding a minimum cardinality separator such that the sizes of the resulting disconnected subsets are bounded. The second one is the Balanced VKSP, i.e., the problem of finding a minimum cardinality VKS such that the sizes of the resulting disconnected subsets are balanced. We present a compact Integer Linear Programming formulation for the problems and investigate the associated polytopes. We also present Exponential-Size formulations, for which we derive a column generation and a branching scheme. Extensive computational results prove the effectiveness of the proposed methods and of the theoretical analysis. The formulations are compared using a set of benchmark instances from the literature and a set of real-world instances from a simulation physical models.

3 - Lower Bounding Techniques for DSATUR-based Branch and Bound

Ian-Christopher Ternier, Fabio Furini, Virginie Gabrel

Given an undirected graph, the Vertex Coloring Problem (VCP) consists of assigning a color to each vertex of the graph such that two adjacent vertices do not share the same color and the total number of colors is minimized. DSATUR-based Branch- and-Bound is a well-known exact algorithm for the VCP. It can be successfully applied to different VCP variants as well. One of its main drawbacks is that a lower bound (equal to the size of a maximal clique) is computed once at the root of the branching scheme and it is never updated during the execution of the algorithm. In this article, we show how to update the lower bound and we compare the efficiency of several lower bounding techniques.

■ WB-15

Wednesday, 10:30-12:30 - HS 45

Simulation in the Automotive Sector

Stream: Simulation and Decision Support
Chair: *Kai Gutenschwager*

1 - Is today's paint shop structure still up-to-date? - The virtual model of a modular manufacturing structure

Dirk Wortmann

The simulation of production and logistics processes is a well-established part of the process design and re-design in the automotive industry and allows to evaluate completely new production concepts on a very detailed level. In this presentation the analysis of a manufacturing concept is described which was originally launched as a project by Audi. The aim was to develop an innovative manufacturing structure for body, paint shop and assembly. The new structure is based on a concept developed by SimPlan, the so called "modular manufacturing structure'. With the help of a simulation model the paint shop of the Ingolstadt plant was virtually transferred to this new structure and compared to the existing process. The results disclosed significant benefits. Consequentially Audi and SimPlan decided to apply for a patent. The general concept was also applied for the evaluation of a taxi paint shop in a Chinese plant. The analysis of the existing structure showed substantial inefficiencies caused by a complex buffer structure and a sophisticated material flow control strategy. A simulation study was set up to analyze if the modular structure would be more suitable. Therefore, a simulation model was created, which was based on exactly the same premises, such as cycle times, availabilities and repair rates as the original model. Only the complex conveyor system was replaced by the modular structure. The results comparing the throughput of the two design alternatives are just as convincing as for the formerly analyzed manufacturing system of Audi in Ingolstadt.

2 - Dimension of a central de-coupling module and evaluation of the impact of different scheduling strategies by simulation studies

Mareike Mueller

In order to fulfill the demand of mass customization, the OEM usually produces several car types with customized configurations on one highly flexible assembly line. By using a make-to-order strategy and by fixing the assembly sequence at an early stage it is possible to affirm a scheduled delivery date. The fixed sequence also enables the implementation of JIT and JIS supplying approaches and therefore has a major impact on the lean production. The alignment of the supply chain on the scheduled assembly date requires a steadiness of the whole production process. Random processing times caused by machine breakdowns, rework and withhold of certain scheduled orders (due to quality reasons, missing parts or failure in the supply chain) cause blocking and starving within the production process. This has an effect on the stability of the process and therewith decreases either the steadiness of the scheduled assembly sequence or the total output of the production line. A central de-coupling buffer between the three assembly sections body shop, paint shop and final assembly reduces this impact. In this lecture we show a practical example of dimensioning a central decoupling buffer. With a simulation study we outline the advantages of central buffer with an automated storage and retrieval system and show the trade-off between steadiness of the fixed production sequence and scheduled output.

3 - Simulation-based modelling and analysis of schedule instability in automotive supply chains

Tim Gruchmann, Thomas Gollmann

Within automotive supply chains, instability of OEM's order schedule creates inefficiencies in production processes and bears the risk of supply disruptions. Due to the market power of the OEM, 1st tier suppliers are not always able to influence the scheduling behavior of their customers. Addressing however the root causes of schedule instability, in particular the unreliability of the supplier network, this can help to curtail short-term demand variations and increase the overall supply chain efficiency. To this end, a stylized assembly supply chain model is simulated with two 1st tier suppliers and a single OEM. This supply chain can be disrupted by a shortage occurring at one of the two suppliers due to random machine breakdowns, what consequently creates schedule instability affecting both the buyer and the other supplier. At first the theory-based model containing the said mechanism causing schedule instability is developed in AnyLogic. As second step a simulation study is carried out to derive managerial and theoretical implications accordingly.

4 - Supply chain simulation in the cloud: Shared model building and result analysis with respect to requirements for concealing individual input data

Kai Gutenschwager, Till Fechteler

The simulation of supply networks has drawn considerable research activities in the last decades. For setting up models integrating more than one company, data usually needs to be revealed concerning, e.g., available production resources, order policies and cost rates. A straight forward approach implies that one company, usually the OEM, sets up the simulation model and needs to receive all data from the other participants within the supply chain. However, participants often do not want to reveal data concerning internal processes and cost structures, such that inter-organizational studies are rather uncommon.

Here, cloud computing comes into play. Some simulation tools offer a data-driven modeling approach, which allows to specify different scenarios concerning the design and configuration of supply chains. The actual simulation model is then generated based on the given input data. SimChain is a first simulation tool which offers model building and the execution of simulation experiments as a cloud service. However, it is based on a single user concept for a simulation project. In this presentation we focus on possible approaches for shared model building and evaluation in order to overcome the problems which result from requirements of concealing individual data. Our approach is based on a complex authentication concept which allows participants to hide internal data from other participants, but to simultaneously allow the usage of the data for detailed simulation models and the presentation of (limited) statistics for the entire supply chain. A three-level concept for data usage and the respective level of detail of publishing results is presented on the basis of the data model of SimChain.

■ WB-16

Wednesday, 10:30-12:30 - HS 46

Hierarchical and Complementarity Models in Energy Systems

Stream: Energy and Environment
Chair: *S. Jalal Kazempour*

1 - Generator Maintenance Scheduling in Competitive Environment

Hrvoje Pandzic

Each producer schedules its units' maintenance periods to maximize its revenue using a bilevel approach. The upper-level problem of this bilevel model seeks maximum revenue and contains unit scheduling constraints, while the lower-level problems represent the market clearing process under different operating conditions. This single producer maintenance problem can be recast as a mathematical program with equilibrium constraints (MPEC). Since the MPECs of all producers have to be considered simultaneously and the market clearing process is common to all of them, the proposed formulation for maintenance scheduling is an equilibrium problem with equilibrium constraints (EPEC) corresponding to a multiple-leader-common-follower game. The solution of this EPEC is a set of equilibria, in which none of the producers is able to increase its revenue unilaterally by changing the maintenance periods of its generating units.

2 - Bilevel model for retail electricity pricing

Georgia Asimakopoulou, Andreas Vlachos, Nikos Hatziargyriou

The electricity distribution is currently undergoing significant changes both in its mode of operation and in its form. New types of loads (shiftable, curtailable), as well as the existence of distributed generation units pose new challenges, while advances in the Information and Communication Technologies provide new opportunities for the network and its users (Operator, retailers, prosumers). Smart meters are seen as a means for enabling customers having a better control over their electricity bills and for helping the retailer in the process of data gathering. More importantly, they constitute an invaluable ally for facilitating the pricing task of the retailer, reflecting more efficiently the true cost of electricity. Price signals made available through in-home displays are expected to affect the behavior of the distribution network users in a way difficult to predict using existing tools (e.g. load forecasting). In attempting to participate in the retail market cost-efficiently, the electricity retailer needs to incorporate such a complex environment in its operations. The question that arises is: at what level should the retail price be set and what form the pricing scheme should have in order to induce the consumers in a behavior optimal both for them and for the retailer? In order to answer this question we first identify the hierarchical decision-making process underlying the aforementioned interaction between electricity retailer and consumer. We, then, formulate a bilevel programming problem (BLPP) that enables testing a variety of pricing schemes. The BLPP is transformed into a Mixed-Integer Linear Programming Problem and is solved using CPLEX solver under GAMS. The results are compared in terms of profitability for the retailer and cost for the customer.

3 - Stochastic Market Clearing: An Adequate Pricing Scheme Per Scenario

S. Jalal Kazempour, Pierre Pinson

The available stochastic market clearing tools in the literature guarantee revenue adequacy in the market and non-negative profit for all producers (conventional and renewable) in expectation only. This has been criticized since those criteria are not guaranteed per scenario. We propose an equilibrium model rendering a MILP that is revenue adequate per scenario and for which each producer's profit is also non-negative per scenario.

■ WB-17

Wednesday, 10:30-12:30 - HS 47

Dissertation Prizes

Stream: Prize awards
Chair: *Anita Schöbel*

1 - From structures to heuristics to global solvers

Timo Berthold

In the literature for mixed integer programming, primal heuristics are often considered as stand-alone procedures; in that context, heuristics are treated as an alternative to solving a problem to proven optimality. This conceals the fact that heuristics are a fundamental component of state-of-the-art global solvers for mixed integer linear programming (MIP) and mixed integer nonlinear programming (MINLP). We focus on this latter aspect and study heuristics that are tightly integrated within an MINLP solver and analyze their impact on the overall solution process.

In this presentation, we introduce two large-neighborhood search heuristics, Undercover and RENS, that are designed to be employed as start heuristics inside a global solver. Undercover explores a mixed integer *linear* subproblem of a given MINLP. Therefore, an auxiliary vertex covering problem is solved to identify a smallest set of variables to fix such that each constraint is linearized. RENS uses a sub-MINLP to exploit the set of feasible roundings of a given solution of a relaxation.

We give theoretic motivations and discuss implementation details of both approaches. Computational results assess the ability of these heuristics to find feasible solutions and their impact on the overall performance of the MINLP solver SCIP. To this end, we introduce a new performance measure, the primal integral, that depends on the quality of solutions as well as on the points in time when they are found.

2 - Models and Methods for Optimizing Baggage Handling at Airports

Markus Frey

The dissertation treats the optimization potentials of baggage handling processes at airports. From an operational research perspective, the baggage flow from the Check-in to the departing airplane and from the arriving airplane to the baggage claim are described. For the planning of outbound and inbound baggage handling mixed-integer programs are derived. The objectives of the models include reducing the workload peaks at the handling facilities. Due to the complexity of both problems, efficient solution procedures are developed. Computational studies show the improvements in comparison to the current solution procedures.

3 - Robust Quantitative Comparative Statics for a Multimarket Paradox

Philipp von Falkenhausen

We introduce a quantitative approach to comparative statics that allows to bound the maximum effect of an exogenous parameter change on a system's equilibrium. The motivation for this approach is a well known paradox in multimarket Cournot competition, where a positive price shock on a monopoly market may actually reduce the monopolist's profit. We use our approach to quantify for the first time the worst case profit reduction for multimarket oligopolies exposed to arbitrary positive price shocks. For markets with affine price functions and firms with convex cost technologies, we show that the relative profit loss of any firm is at most 25% no matter how many firms compete in the oligopoly. Our results further extend to the impact of positive price shocks on total profit of all firms as well as on social welfare, which decrease by at most 25% and 16.6%, respectively. Finally, we show that in our model, mixed, correlated and coarse correlated equilibria are essentially unique, thus, all our bounds apply to these game solutions as well.

4 - Robust Desing of Single-Commodity Networks

Daniel Schmidt

Designing networks that are both reliable and cost-efficient in a large number of scenarios is a difficult task. A standard tool for these robustness problems is integer programming (IP). Here, a challenge is to find compact or efficiently separable linear programming relaxations. In this talk, we develop a Branch-and-Cut algorithm for a robust single-commodity network design problem: We are looking for minimum cost integer capacities that allow us to send a single-commodity flow through a network while being uncertain about the nodeâ EUR ^{TM}s true supplies and demands.

In particular, we consider the case where the supply and demand scenarios are given as a small finite list or, that instead of knowing the exact supply or demand at each node, we only know a lower and an upper bound for the true value. For both cases, we provide a capacity based IP formulation along with a practical cutting plane algorithm and evaluates it on a large set of problem instances. Besides the practical algorithm, we identify facet inducing cut-set and 3-partition inequalities and adapt a facet lifting theorem by Agarwal.

■ WB-18

Wednesday, 10:30-12:30 - HS 48

Control Energy Markets

Stream: Energy and Environment
Chair: *Gerold Petritsch*
Chair: *Elke Moser*

1 - Inter hour power output changes and technical ranges of power plants for ancillary markets

Ingo Spiegelberg

Activation of reserve power is on short call, hence power plants have to change their power output in short time periods to provide reserve power. Thus, it has to be noted while modeling power generation units providing ancillary power. Here, we show the technical requirements for the compliance of power output changes between two trading hours. We will give a short approach of two types of inter hour power output changes. Changes can be understood as changing the power output or changing the power generating unit. In addition we will add technical ranges for power plants and show how they interact with the inter hour power output changes.

2 - Short term optimization of control energy decisions for combined power and district heating portfolios

Jan Hofmann

Optimal decisions on the contribution of every specific asset in a portfolio to control energy markets are generally not easy to obtain. This gets even more complex when considering a district heating network and several heat demands. In this case the flexibility of all assets is constrained by the fulfillment of those heat demands. Economic profit is only a secondary objective. Not only may uncertainties of energy prices reduce the economic profit of the decision for the control energy market, but also uncertainties of heat demands may narrow the flexibility of the portfolio as well. To fulfill both heat demands and control energy obligations from previous decisions at the same time may lead to difficult or even infeasible problems under these uncertainties. Another crucial point to consider is the general uncertainty of control energy calls and therefore an uncertain surplus or shortfall in heat generation. This has to be taken into account for every contribution to the control energy market. These problems can be tackled by a variety of approaches, ranging from detailed deterministic short term models able to respond quickly to changes to more general stochastic models to come up with more robust control energy offer decisions in the first place.

3 - Optimization of Hydro Storage Plants Combined With Control Energy Optimization

Elke Moser

Optimal management of hydro storage power stations requires profound models considering both, mid-term planning on the one hand and short-term planning for week-ahead, day-ahead and intraday activities on the other hand. Further on, the market segment of control energy gets increasingly interesting for power trading. Here, however, the submission of an optimal offer coming along with the calculation of its opportunity costs, the estimation of the risks as well as the cost-effective implementation in case of an award are challenging issues for schedule optimization. Taking a chain of hydro storage power stations as example, we first present a method to link optimization models with different planning horizons together in order to guarantee consistence in their solution. We then also show what the practical consequences of submitting control energy offers are, how strong the impact of stochastic quantities is and how one can possibly deal with such uncertainties.

4 - Exact solutions to binary equilibrium problems with compensation and the power market uplift problem

Daniel Huppmann, Sauleh Siddiqui

We propose a novel method to find Nash equilibria in games with binary decision variables by including compensation payments and incentive-compatibility constraints from non-cooperative game theory directly into an optimization framework in lieu of using first order conditions of a linearization, or relaxation of integrality conditions. The reformulation offers a new approach to obtain and interpret dual variables to binary constraints using the benefit or loss from deviation rather than marginal relaxations. The method endogenizes the trade-off between overall (societal) efficiency and compensation payments necessary to align incentives of individual players. We provide existence results and conditions under which this problem can be solved as a mixed-binary linear program.

We apply the solution approach to a stylized nodal power-market equilibrium problem with binary on-off decisions. This illustrative example shows that our approach yields an exact solution to the binary Nash game with compensation. We compare different implementations of actual market rules within our model, in particular constraints ensuring non-negative profits (no-loss rule) and restrictions on the compensation payments to non-dispatched generators. We discuss the resulting equilibria in terms of overall welfare, efficiency, and allocational equity.

■ WB-19

Wednesday, 10:30-12:30 - HS 50

Optimization in Energy

Stream: Energy and Environment
Chair: *Maria Teresa Vespucci*

1 - Portfolio Management and Stochastic Optimization in Discrete Time: An Application to Intraday Electricity Trading and Water Values for Hydroassets

Luisa Tibiletti, Simone Farinelli

A stochastic multiperiod optimization problem in discrete time for a generic utility function is discretized in the space dimensions by means of a 'bushy' recombining tree (i.e. a k » 1-lattice), so that we do not deal with the dimensionality curse nor are we annoyed by heuristic arguments concerning the choice of representative branches in a non recombining tree. Inequality constraints are packed into the objective function by the logarithmic barrier approach and the utility function is approximated by its second order Taylor polynomial. The optimal solution for the original problem is obtained as a diagonal sequence where the rst diagonal dimension is the parameter controlling the logarithmic penalty and the second is the parameter for the Newton step in the construction of the approximated solution. The obtained algorithm is implemented in Mathematica and applied to optimize intraday electricity trading and model at the same time water values for hydroassets.

2 - Optimal operation of power distribution networks

Paolo Pisciella, Maria Teresa Vespucci, Diana Moneta, Giacomo Viganò

A Distribution System Operator (DSO) will be in charge of operating power distribution networks, in order to compensate generation-load imbalances with respect to a previously determined scheduling, while guaranteeing constraints on currents in lines for security and voltages at nodes for power quality. Internal (i.e. owned by DSO) regulation resources will be electricity storage devices and on-load tap changers. DSO's external regulation resources (i.e. owned by third parties) will be the dispatch of active and reactive power of generation plants and the exchange of active and reactive power with the high voltage transmission network. Costs associated to the use of internal regulation resources reflect device deterioration; costs associated to the use of external regulation resources are to be defined by the Regulator, so as to allow a technically efficient operation of the network. The optimal redispatch minimizes the total costs for using internal and external resources, constrained by power flow equations, balance equation for the batteries and local control constraints. Active losses are also considered and penalized in the objective function. The problem is modeled by using a non linear sparse formulation and solved using a primal-dual interior point method. The procedure allows finding efficient configurations of the network and can be used as a simulation tool by the Regulator to analyze the impact of different costs associated to external regulation resources.

3 - An application of PCA based approach to large area wind and solar power forecast

Federica Davò

This work is concerned with predicting the overall wind power production from several wind farms located over Sicily (one of the Italian market regions), whose total installed power is 1746 MW, and the overall observed solar irradiance measured by several solar stations that are part of the Oklahoma Mesonet sites. In the case of Sicily the study has been conducted over a 2-year long period, with hourly data of the aggregated wind power output of the island. The 0-72 hour wind predictions are generated with the limited-area meteorological model RAMS, with boundary conditions provided by the ECMWF determinist forecast. For the Oklahoma case, the study has been conducted over

a 3-year period, considering daily data of the aggregated solar radiation output . Numerical weather prediction data for the contest come from the NOAA/ESRL Global Ensemble Forecast System Reforecast Version 2. A Principal Component Analysis (PCA) has been applied to reduce the datasets dimension. These data sets include the wind speed data extracted at 50 m above the ground from the RAMS grid points available over Sicily, and on the downward short-wave radiative flux average at the surface over Oklahoma Mesonet sites. A Neural Network (NN) and the analog ensemble (AnEn) are then used as post processing technique of the PCA output to obtain the final wind and solar power forecast. The NN and AnEn have been trained with the PCA output and the power measurements on the first year for the wind case and on the first two years for the solar case of the analyzed period. The PCA implementation is shown to lead to a reduction of RMSE, MAE and BIAS and computational cost and an increase in correlation, than using the data without the PCA reduction.

4 - Transmission switching in electricity networks via nonlinear stochastic programming
Maria Teresa Vespucci, Francesco Piu, Alois Pichler, Asgeir Tomasgard

Switching off selected transmission lines of an electricity network can reduce the total power generation cost. New lines, needed to link power production places not exploited in the past (e.g. off-shore wind parks), offer the opportunity to incorporate new switching possibilities. We focus on an investment decisions problem solved for creating remote, automatic switches required to implement lines switching actions. The problem solution permits to locate lines which are promising for future switching possibilities. However, switching actions optimal under some operational conditions may cause economic inefficiencies under other conditions. The problem is to identify the lines whose switching off provides the statistically highest savings that are robust under several different scenarios. Switches investment under uncertainty must consider a large set of optimal transmission switching (OTS) instances. We analyze switches investments and real-time operations as interacting aspects of a more general problem. The first part of our research is focused on the heuristic solution of the computationally demanding OTS problem under several scenarios. We study the performance of different heuristics, with the aim of integrating a selected heuristic in the nonlinear stochastic programming model of the switches investment problem.

■ WB-20

Wednesday, 10:30-12:30 - ÜR Germanistik 1

Stochastic programming - big data and applications (i)

Stream: Stochastic Optimization
Chair: *Milos Kopa*

1 - Applications of stochastic programming - a challenging source of big data
Vaclav Kozmik, Jitka Dupacova

We shall give examples of various sources and uses of big data: Huge data coming from the boom of information technologies (e.g. telecommunications) in contrast to big data related with an approximation of a probability distribution and/or a suitable time discretization. We shall characterize them according to their purpose - extraction of information, evaluation of prescribed performance criteria including descriptive statistics and finally, in the context of stochastic programming, screening studies, support for managerial decisions, on line tracking or optimization with high frequency data. Suitable numerical techniques including preprocessing and analysis of results will be reported with emphasis on two-stage multiperiod and multistage stochastic programs.

2 - Non-life insurance rate-making based on data-mining techniques and stochastic programming
Martin Branda

We focus on rating of non-life insurance contracts. We employ multiplicative models with basic premium levels and specific surcharge coefficients for various levels of selected risk factors. We use generalized linear models (GLM) to describe the probability distribution of total losses for a contract during one year. The models are based on large datasets of historical observations of claims on large number of policies. We propose optimization problems which reduce the problem significantly to lower number of tariff cells. We introduce stochastic programming problems with reliability type constraints which take into account individual risk of each rate cell or collective risk. In the numerical study, we apply the approaches to Motor Third Party Liability (MTPL) policies.

3 - Optimal Investment Policy in Pension Fund
Sebastiano Vitali, Milos Kopa, Vittorio Moriggia

We present the definition of an optimal policy decision for a pension fund. Starting from the analysis of the existing members of the fund in order to identify a set of representative contributors, we focus on an individual optimal portfolio allocation in a Pension Plan prospective. In particular, for each representative member, we propose a multistage stochastic program (MSP) which includes a multi-criteria objective function. The optimal choice is the portfolio allocation that minimizes the Average Value at Risk Deviation of the final wealth and satisfies a set of wealth targets in the final stage and in an intermediate stage. Stochasticity arises from investor's salary process and assets return. The stochastic processes are assumed to be correlated. Numerical results show optimal dynamic portfolios with respect to investor's preferences.

4 - Optimal time to reposition inventories in multi-location centralized networks
Olga Rusyaeva, Joern Meissner

Repositioning of inventories between locations aims to decrease the impact of inventory imbalance in multi-location centralized networks, caused by e.g. imperfect demand information or delayed delivery. In practice, it is often done via lateral transshipments that are performed either reactively, when the stockout occurs, or proactively in an anticipation of future stockouts. The last approach calls an additional managerial decision, namely when to reposition inventories. As each location has two demand types, one from customers and another from other locations, the transshipment time should be chosen accurately to avoid transfers back and forth between locations, and, as a result, additional costs.

The objective of our study is to find an optimal time for proactive transshipments and optimal transshipment quantities in order to maximise the profit of a multi-location network of nonidentical locations. To this end, we decompose the problem on dynamic program to find a transshipment time and on the linear program to derive transshipments between locations. Due to the large state space of the problem, known as the curse of dimensionality of the dynamic programming, a myopic policy and a policy based on the simulation are suggested for real-size problems. We present our numerical results obtained by dynamic programming and heuristic methods, and discuss their performance. Besides that, we compare the dynamic and static solutions, and describe the situations when it pays off to apply the dynamic policy.

■ WB-21

Wednesday, 10:30-12:30 - ÜR Germanistik 2

Robust Optimization (i)

Stream: Stochastic Optimization
Chair: *Wolfram Wiesemann*

1 - A dynamic programming approach for a class of robust optimization problems
Michael Poss, Agostinho Agra, Marcio Costa Santps, Dritan Nace

Common approaches to solve a robust optimization problem decompose the problem into a master problem (MP) and adversarial separation problems (APs). MP contains the original robust constraints, however written only for finite numbers of scenarios. Additional scenarios are generated on the fly by solving the APs. We consider in this work the budgeted uncertainty polytope from Bertsimas and Sim, widely used in the literature, and propose new dynamic programming algorithms to solve the APs that are based on the maximum number of deviations allowed and on the size of the deviations. Our algorithms can be applied to robust constraints that occur in various applications such as lot-sizing, TSP with time-windows, scheduling problems, and inventory routing problems, among many others. We show how the

simple version of the algorithms leads to a FPTAS when the deterministic problem is convex. We assess numerically our approach on a lot-sizing problem, showing a comparison with the classical MIP reformulation of the AP traditionally used in the literature.

2 - A Multi-Scale Decision Rule Approach for Multi-Market Multi-Reservoir Management

Napat Rujeerapaiboon, Daniel Kuhn, Wolfram Wiesemann

Peak/off-peak spreads on European electricity spot markets are eroding due to the nuclear phaseout and the recent growth in photovoltaic capacity in Germany. The reduced profitability of peak/off-peak arbitrage thus forces hydropower producers to participate in the balancing markets. We propose a two-layer stochastic programming model for the optimal operation of a cascade of hydropower plants selling energy on both spot and balancing markets. The master problem optimizes the reservoir management over a yearly horizon with weekly granularity, and the slave problems optimize the market transactions over a weekly horizon with hourly granularity. We solve both the master and slave problems in linear decision rules, and we exploit the inherent parallelism of the slave problems to achieve computational tractability.

3 - A Bicriteria Approach to Robust Optimization

André Chassein, Marc Goerigk

The classic approach in robust optimization is to optimize the solution with respect to the worst case scenario. This pessimistic approach yields solutions that perform best if the worst-case scenario happens, but also usually perform bad for an average case scenario. On the other hand, a solution that optimizes the performance of this average case scenario may lack in the worst-case performance guarantee.

In practice it is important to find a good compromise between these two solutions. We present an approach that resolves this problem by considering it as a bicriteria optimization problem. The Pareto curve of the bicriteria problem visualizes exactly how costly it is to ensure robustness and helps to choose the solution with the best balance between expected and guaranteed performance.

We focus in this talk on linear programming problems with uncertain objective functions. Building upon a theoretical observation on the structure of Pareto solutions for these problems, we present a column generation approach that requires no direct solution of the computationally expensive worst-case problem. In computational experiments we demonstrate the effectiveness of both the proposed algorithm, and the bicriteria perspective in general.

4 - K-Adaptability in Two-Stage Robust Binary Programming

Wolfram Wiesemann, Grani Hanasusanto, Daniel Kuhn

Over the last two decades, robust optimization has emerged as a computationally attractive approach to formulate and solve single-stage decision problems affected by uncertainty. More recently, robust optimization has been successfully applied to multi-stage problems with continuous recourse. This talk takes a step towards extending the robust optimization methodology to problems with integer recourse, which have largely resisted solution so far. To this end, we approximate two-stage robust binary programs by their corresponding K-adaptability problems, in which the decision maker pre-commits to K second-stage policies here-and-now and implements the best of these policies once the uncertain parameters are observed. We study the approximation quality and the computational complexity of the K-adaptability problem, and we propose two mixed-integer linear programming reformulations that can be solved with off-the-shelf software.

■ WB-22

Wednesday, 10:30-12:30 - ÜR Germanistik 3

Market Design & Optimization I (i)

Stream: Accounting and Revenue Management
Chair: *Martin Bichler*

1 - Pricing Combinatorial Auctions by a Set of Linear Price Vectors

Dirk Briskorn, Jenny Nossack, Kurt Jörnsten

We consider the situation where the optimum allocation (according to the winner determination problem) in a combinatorial auction with OR bids is given. We are left with the question how much to charge the winning bidders. Moreover, it would be convenient to have prices for each bundle (even those corresponding to losing bids) at hand in order to justify the allocation. Prices for bundles should fulfill the following requirements. For winning bids the bundle's price should not exceed the bid's value. Otherwise, winning bidders are not willing to pay the price. For losing bids the bundle's price should be at least the bid's value. Otherwise, losing bidders will complain since they would have been willing to pay more than the price. Moreover, prices should be anonymous.

We present a pricing scheme which induces a price for each bundle of items based on a set of linear price vectors. We define a market clearing in this setting and prove existence for an arbitrary auction and the optimum allocation. We then consider objectives aiming at market clearings with little diversity among the difference price vectors used.

2 - Vickrey-based Pricing in Iterative First-Price Auctions

Oleg Baranov, Lawrence Ausubel

Auction literature provides us with two prescriptions for achieving efficient outcomes in practical auction settings. First, an auction design should use the opportunity cost pricing principle to the extent possible to promote truthful revelation of bidder preferences. Second, the pricing mechanism should be implemented via an iterative "first-price' process where all bidders are fully informed about their current price at each iteration. For the heterogeneous environment with substitutes, we develop an auction design that adheres to both principles. We also show that the same approach can be used to address major problems of SMRA and CCA designs — two leading auction formats used for spectrum auctions.

3 - Allocation and payment rules in combinatorial double auction markets

Vladimir Fux, Martin Bichler

The design of efficient multi-item auctions, in particular single-sided combinatorial auctions, has received considerable attention in the recent years. Only a small part of the literature deals with double auctions, although many applications can be organized as double-sided combinatorial auctions. The VCG mechanism is strategy-proof, but payments are not always in the core and they might not be budget balanced. Resulting payments are also non-anonymous and non-linear. We analyze alternatives and explore the trade-offs between different payment rules.

■ WB-23

Wednesday, 10:30-12:30 - ÜR Germanistik 4

Discrete Methods for Gas Network Optimization Problems

Stream: Integer Programming
Chair: *Lars Schewe*

1 - Infeasibility in Flow and Stationary Gas Networks

Imke Joormann, Marc Pfetsch

Infeasibilities in the mathematical description of networks can arise for different reasons, including defective data, modeling issues and physical impracticability. For infeasible linear systems, there are two concept for the isolation of the cause of the infeasibility: irreducible infeasible subsystems (IISs) and IIS covers. IISs are infeasible subsystems such that each proper subsystem is feasible, while IIS covers consist of constraints that must be dropped to obtain a feasible system. We begin by investigating the theoretical foundation for the basic form of networks, flow problems with supplies and demands, and derive structural information for IISs and IIS covers.

For a stationary gas transportation network, modeled as a mixed-integer (non-)linear program (MI(N)LP), a further aspect of infeasibility arises in the context of branch-and-bound approaches to solve the model, where an analysis of infeasible discrete decisions can help to speed up the solution process. We show how generalizations of our basic results can be applied in this case.

2 - Computational studies on solving Mixed-Integer Nonlinear Programs by Mixed-Integer Linear Program relaxations
Robert Burlacu, Bjoern Geissler, Antonio Morsi, Lars Schewe

We present computational studies on some variants of a known method for solving Mixed-Integer Nonlinear Programs (MINLPs) by Discretization Techniques. The main idea of the method is based on using Piecewise Linear Functions to construct Mixed-Integer Linear Program (MILP) relaxations of the underlying MINLP. In order to find a global optimum of the given MINLP an iterative algorithm is developed which solves MIP relaxations that are adaptively refined. Moreover we show some numerical results for the Gas Network Nomination Validation Problem, where one has to determine if the controllable elements of a given gas network can be adjusted in a way that the demands of all customers are satisfied.

3 - Decomposition methods for mixed-integer programs combined with differential equations
Mathias Sirvent, Alexander Martin

Real world applications are often faced with a search for an optimal solution for mixed-integer programs with additional constraints given as differential equations. Our real world application is a gas network, where we have to consider the Euler equations, which model the gas dynamics and bring in differential equations to our network.

We propose a decomposition approach based on Generalized Benders Decomposition, where the masterproblem considers integer variables and a relaxation of the feasible set by ignoring the differential equations. The subproblem deals with the continuous variables and uses numerical methods to handle the differential equations. The master improves its relaxation during the algorithm by receiving additional cuts and disjunctions from the subproblem, whereas the subproblem itself evaluates the integer decisions of the masterproblem to generate these cuts and disjunctions. In comparison to Spatial Branching, we don't need explicitly given analytic functions. On the other hand additional requirements are necessary for the decomposition approach to ensure the correctness of the algorithm. We are testing small networks and present numerical results for the abovementioned algorithm.

4 - A network flow theory based model for natural gas networks
Martin Groß, Marc Pfetsch, Martin Skutella

We present a model for natural gas networks based on network flow theory. Usually, natural gas has to be transported over a great distance from its well to its point of use. This transportation is mainly done by using a network of pipelines and active components, which allow to direct the gas flow to accommodate diverse usage scenarios. Determining feasible usage scenarios and corresponding settings for the active components requires a good model for the natural gas network. Network flow theory is well suited to handle large scale transportation problems arising in logistics, a fact that our model carries over to natural gas networks.

■ WB-24

Wednesday, 10:30-12:30 - ÜR Germanistik 5

Inference and Problem Solving

Stream: Analytics
Chair: *Claus Gwiggner*

1 - Why It Needs More Than Statistics For Successful Data Based Decision Making
Katharina Schüller

In March 2015, Fraport AG in Frankfurt carried out an experimental Smart Data Lab (SDL). For the first time, experts from a variety of departments worked together in a laboratory situation. They defined four problems to be solved with analytics, using a huge collection of data from different sources within the company: • Effects of airplane positioning on retail turnover • Early warning system for sales forecast • Analysis of special freight potentials • Optimization of intraday delay prediction I was asked to conduct an initial workshop on statistical inference, multivariate methods, data mining and the use of SAS, and also to accompany the team as a statistical consultant during the 6 SDL weeks. Soon it turned out that my role would change due to my experience in leading a statistical consulting firm over the past 12 years. One of the key lessons learned was that problem solving with big data and analytics needs a lot more than statistical expert knowledge. Incorporating practical expertise into nearly every single phase of the analytics process was crucial, in order to correctly interpret the results and to identify pitfalls which would have led to severely misleading conclusions. The effective communication of statistical problems and statistical results helped promote the acceptance of SDL's data based recommendations. In this talk I will present examples of how statistical analysis and inference helped correct established decision rules and also how the cooperation with experts let us avoid analytical fallacies. Results from SDL were widely noticed and accepted by Fraport's executive board, which in turn has decided to make SDL a permanent institution.

2 - Partial Modeling Mismatch: Origin, Consequences, and Solutions for Customer Targeting
Stefan Lessmann, Kristof Coussement, Koen W. De Bock

Business analytics advocates formal, data-driven models to inform managerial decision making. This study concentrates on empirical prediction models that support business decisions through generating forecasts of future events. The key proposition of the paper is that such models are not perfectly aligned with business requirements. There is some mismatch between the internal objective of a prediction model and the economic objective that characterizes the environment to which the model is deployed. We call this misspecification partial modeling mismatch (PMM). The main contributions of the paper are twofold. First, we estimate the degree to which PMM diminishes the performance of predictive decision support models in the scope of an important business application: the selection of appropriate customers for direct marketing actions. Second, using the principles of ensemble selection, we propose a modeling framework that mitigates PMM. Our framework mimics the way in which managers make decisions and balances statistical and economic considerations during prediction model development. The results of a comprehensive empirical study confirm the effectiveness of the proposed framework. In comparison to challenging benchmarks, it predicts customer behavior more accurately and recommends substantially more profitable target groups for marketing actions. The implications of our study are that i) PMM seriously harms purely statistical prediction models, that ii) an integration of statistical and economic considerations is a suitable remedy, and that iii) the integrated approach is also much more appropriate than a development of predictive decision support models that maximizes business objectives directly.

3 - The Influence of Weather in Online Retailing - An Empirical Analysis
Kai Hoberg, Sebastian Steinker

Efficient logistics operations in e-commerce require that resources in warehousing and transportation be aligned with widely fluctuating demands. Customer orders must be fulfilled within short lead times to ensure high customer satisfaction while costly under-utilization of workers must be avoided. Accordingly, high forecasting accuracy of aggregate order quantities is essential. Many drivers of online sales, including seasonality, promotions or public holidays, are well known and have been frequently incorporated into forecasting approaches. However, the impact of weather on e-commerce consumer behavior has not been studied in depth. In this paper, we incorporate weather data into the sales forecasting of the largest European fashion online retailer. Based on actual weather data we find that sunshine, temperature and rain have a highly significant impact on sales, particularly in the summer, on weekends and on days with extreme weather. Our analysis indicates that daily fluctuations of online sales that are attributable to the weather effect can be as high as 18.8%. Using weather forecasts we are able to improve the sales forecasting accuracy by an incremental 63.6% on summer weekends. These considerable improvements in forecast accuracy may have an important impact on logistics and warehousing operations; particularly on high-volume weekends, which are sales periods that require special attention from a logistics perspective.

4 - Clustering Distributional Data: Case-Studies
Claus Gwiggner

Cluster analysis has the potential to reveal mechanisms that underly observed data or properties of the data sampling scheme. Examples are market segmentations or large, but possibly biased, data sets. Distributional data provides an additional abstraction level of the observations, enabling also significant dimension reduction. In this talk, we present results from distributional data analysis of real and simulated data. The methods are deterministic, probabilistic and geometric clustering techniques.

■ WB-26

Wednesday, 10:30-12:30 - SR Geschichte 1

Randomized Optimization Methods for Machine Learning

Stream: Continuous Optimization
Chair: *Peter Richtarik*

1 - Addaptive sum randomization technique in network-applications

Ilnura Usmanova, Ekaterina Krymova, Alexander Gasnikov

In many applications (searching equilibrium in transport networks, matrix correspondence calculation, web-page ranking etc) it is necessary to solve huge-scale convex optimization problems. The main ingredient of these problems is a sum-type functional. We combine different approaches (T. Zhang, S. Shalev-Shwartz, P. Richtarik etc.) for the concrete applications. In real applications the typical problem is the lack of information about the Lipschitz constants and the size of the solution. We propose some new ideas to adaptation of well known approaches to tackling such problems.

2 - Stochastic Dual Coordinate Ascent with Adaptive Probabilities

Dominik Csiba, Zheng Qu, Peter Richtarik

This paper introduces AdaSDCA: an adaptive variant of stochastic dual coordinate ascent (SDCA) for solving the regularized empirical risk minimization problems. Our modification consists in allowing the method adaptively change the probability distribution over the dual variables throughout the iterative process. AdaSDCA achieves provably better complexity bound than SDCA with the best fixed probability distribution, known as importance sampling. However, it is of a theoretical character as it is expensive to implement. We also propose AdaSDCA+: a practical variant which in our experiments outperforms existing non-adaptive methods.

3 - Stochastic Dual Newton Ascent for Empirical Risk Minimization

Peter Richtarik, Zheng Qu, Martin Takac, Olivier Fercoq

We propose a new algorithm for minimizing regularized empirical loss: Stochastic Dual Newton Ascent (SDNA). Our method is dual in nature: in each iteration we update a random subset of the dual variables. However, unlike existing methods such as stochastic dual coordinate ascent, SDNA is capable of utilizing all curvature information contained in the examples, which leads to striking improvements in both theory and practice - sometimes by orders of magnitude.

In the special case when an L2-regularizer is used in the primal, the dual problem is a concave quadratic maximization problem plus a separable term. In this regime, SDNA in each step solves a proximal subproblem involving a random principal submatrix of the Hessian of the quadratic function; whence the name of the method. If, in addition, the loss functions are quadratic, our method can be interpreted as a novel variant of the recently introduced Iterative Hessian Sketch.

■ WB-27

Wednesday, 10:30-12:30 - SR Geschichte 2

Portfolio Optimization I (c)

Stream: Financial Modelling
Chair: *David Wozabal*

1 - Optimizing donation portfolios with transaction costs for institutions of higher education

Sandra Ifrim

Decisions of optimal investment in fundraising activities need to be carefully considered by institutions for which donation portfolios represent important sources of revenue. This particularly is the case for U.S. institutions of higher education. If undertaking investments in fundraising activities represents a precondition to receive contributions, portfolio planning models are necessary. This paper analyses whether the inclusion of beliefs about donor withdrawal in the modelling of the distribution of expected returns for the donation portfolio can improve the efficiency of investment decisions. Copula methods are used to this end. Of primary concern are the effects on expected return and risk for the donation portfolio before and after accounting for transaction costs. A simulation study based on donations reported by U.S. institutions of higher education reveals that portfolio returns will not be improved for donation portfolios subject to donor withdrawals. There is some evidence that accounting for donor withdrawal in the portfolio construction process will result in lower risk donation portfolios, but findings are mixed across institutions.

2 - New result on replicating portfolios

Ralf Werner

We consider the most popular approaches for the construction of replicating portfolios for life insurance liabilities known as cash flow matching and terminal value matching. Solutions to these problems are derived analytically and a detailed comparison is provided. It is shown that the (unique) solutions have fair value equal to the fair value of liabilities. Then, the problems are generalized by relaxing the requirement of static replication to allow for dynamic investment strategies in a numeraire asset with zero present value. A relationship between the solutions to these generalized problems is established, which sheds new light on the relation of the original problems. Finally, it is proved that the fair values of the optimal solutions to the generalized problems remain equal to the fair value of liabilities. Based on numerical examples it is shown that the dynamic investment strategies can be reasonably approximated by linear regression, such that an out-of-sample implementation, as e.g. needed for MCEV and Solvency II calculations, is possible,

3 - Optimal investment decision under two sources of uncertainty

Rita Pimentel, Cláudia Nunes

We derive the optimal investment decision in a project where both demand and investment costs are stochastic processes, eventually subject to shocks. We extend the approach used in Dixit and Pindyk (1994), chapter 6.5, to deal with two sources of uncertainty, but assuming that the underlying processes are no longer geometric Brownian diffusion but rather jump diffusion processes. Under certain assumptions it is still possible to derive a closed expression for the value of the firm, and we prove formally that the result that we get is indeed the solution of the optimization problem. We also apply the derived results to the high-speed rail (HSR) transport valuation model, extending Couto et al.(2012), in order to embrace random investment. Numerical results are shown, as well as comparative statistics, where we discuss in particular the influence of the jump process in the investment decision.

4 - TEDAS - Tail Event ASset Allocation

Sergey Nasekin, Alla Petukhina

In this study, we develop a two-step asset allocation strategy which identifies the tail risk of a benchmark asset and uses multi-moment dynamic portfolio selection to account for possible conditional non-normality of portfolio returns. The TEDAS - Tail Event ASset Allocation strategy is based on the non-negative/non-positive Lasso adaptive quantile regression method which captures left- and right-"tail events" for the selected benchmark asset. Dynamic conditional multi-moment investor risk/utility measures are developed and used to perform portfolio selection. This procedure assumes neither joint nor marginal normality of assets' returns and incorporates dynamic multivariate portfolio skewness and kurtosis statistics into portfolio optimization. The TEDAS strategy is tested for major international markets and demonstrates superior out-of-sample performance compared to conventional asset allocation approaches such as mean-variance or Choquet portfolio selection which are not robust to the problem of high dimensionality in the case when the number of covariates exceeds the number of observations.

■ WB-28

Wednesday, 10:30-12:30 - HS 34

OR in Defense

Stream: OR for Security
Chair: *Gustav Feichtinger*

1 - When is Information Sufficient for Action? Search with Unreliable Yet Informative Intelligence
Moshe Kress

We analyze a variant of the whereabouts search problem, in which a searcher looks for a target hiding in one of n possible locations. Unlike in the classic version, our searcher does not pursue the target by actively moving from one location to the next. Instead, the searcher receives a stream of intelligence about the location of the target. At any time, the searcher can engage the location he thinks contains the target or wait for more intelligence. The searcher incurs costs when he engages the wrong location, based on insufficient intelligence, or waits too long in the hopes of gaining better situational awareness, which allows the target to either execute his plot or disappear. We formulate the searcher's decision as an optimal stopping problem and establish conditions for optimally executing this search-and-interdict mission.

2 - Optimizing counter-insurgency measures by asymmetric Lanchester models
Andreas Novak, Gustav Feichtinger

Combat between governmental forces and insurgents is modeled in an asymmetric Lanchester-type setting. Since the authorities often have little and unreliable information about the insurgents 'shots in the dark' have undesirable side-effects as collateral damages may increase the insurgency. Therefore the governmental forces have to identify the location and the strength of the insurgents to fight them more efficiently. In a simplified model in which the effort to gather intelligence is the only control variable and its interaction with the insurgents based on information is modeled in a non-linear way, it can be shown that persistent oscillations (stable limit cycles) may be an optimal solution. We also present a more general model in which, additionally, the recruitment rate of governmental troops as well as the attrition rate of the insurgents caused by the regime's forces are considered as control variables.

3 - Intelligence and Firepower in Counterinsurgencies
Andrea Seidl, Gustav Feichtinger, Dieter Grass, Moshe Kress, Stefan Wrzaczek

Efficient counterinsurgency operations require good intelligence. Absent such information, government forces have only limited situational awareness regarding the insurgents, and therefore engage them with largely unaimed fire. Such an engagement has two drawbacks. First, insurgents may escape unharmed and continue their violent actions against the governemnt and civilians. Secondly, poor targeting will create collateral damage — hitting innocent bystanders.

In the present paper we use an optimal control approach to study within a Lanchester type model to which extent a government should optimally apply hard counter-insurgency measures and to which extent it should use intelligence measures. We assume it is the objective of the government to minimize costs and to end the insurgency within a certain time frame. We analyse the impact of initial state values, i.e. the size of the governmental forces and the insurgents, as well as the impact of certain key parameters on the optimal solution.

4 - Managing Public Opinion While Fighting Terrorism
Gustav Feichtinger, Jonathan Caulkins, Dieter Grass

The key innovation in this two-state optimal control model is to presume that the outflow from the stock of terrorists is increasing in the level of public sympathy for those operations, as well as in the level of counter-terror efforts. The reason for this is that public support encourages the civilian population, within which the terrorists are embedded, to provide information or otherwise assist the counter-terror forces, or at least to refrain from actively helping the terrorists.

The analysis yields interesting results, both mathematically and substantially. We find a Skiba curve separating different regions in state space, for which it is optimal to drive the system to steady states with either a lower or a higher number of terrorists. There are places in the state space where a slight increase in the initial number of terrorists can tip the optimal strategy, from approaching the lower-level to approaching the higher-level of terrorists.

In the second part of the paper the existence of persistent oscillations is shown. Hopf and Bautin bifurcations occur. The latter generates a phase portrait in which a stable limit cycle coexists with a stable fixed point providing a nice interpretation of the solution. The unstable cycle in between acts as separatrix between two basins of attraction.

■ WB-29

Wednesday, 10:30-12:30 - SR IÖGF

Multiobjective Metaheuristics (c)

Stream: Multiple Criteria Decision Making
Chair: *Martin Josef Geiger*
Chair: *Fabien Tricoire*

1 - A multiple criteria decision making model for scheduling tasks in cloud computing environment
Khaled Sellami, Rabah Kassa, Djamal Dris

Resources allocation and scheduling of service workflows is an important challenge in distributed computing. This is particularly true in a cloud computing environment, where many computer resources may be available at specified locations, as and when required. Quality-of-service (QoS) issues such as execution time and running costs must also be considered. Meeting this challenge requires that two classic computational problems be tackled. The first problem is allocating resources to each of the tasks in the composite web services or workflow. The second problem involves scheduling resources when each resource may be used by more than one task, and may be needed at different times. Existing approaches to scheduling workflows or composite web services in cloud computing focus only on reducing the constraint problem - such as the deadline constraint, or the cost constraint (bi-objective optimisation). This paper proposes a multiple criteria decision making mode that solves a scheduling problem by considering more than two constraints (multi-objective optimisation). Experimental results demonstrate the effectiveness and scalability of the proposed algorithm.

2 - On properties and the complexity of multi-criteria sorting algorithms
Thibaut Barthelemy, Sophie Parragh, Fabien Tricoire, Richard Hartl

Multi-criteria sort consists in ranking points lying in a d-dimensional space with d > 1. It plays an important role in metaheuristics for multi-objective optimization. Whereas the evolutionary algorithm SPEA sorts solutions, represented by points in objective space, with respect to a dominance count, NSGA sorts with respect to dominance relations. Other metaheuristics assess the point coordinates through a scalar indicator and they rank the points using standard single-criterion sorting. From a generalized point of view, we categorize ranking approaches with respect to properties inherited from voting theory. Then, we study lower bounds on the complexity of sorting algorithms in each category. At last, we give ideas for implementing a non-dominated sort whose average complexity in practice is expected to be close to O(n log n) even for high dimensions while the best worst case complexity known so far is O(n (log n)(d-1)).

■ WB-30

Wednesday, 10:30-12:30 - Visitor Center

Stochastic Models for Supply-Chain Management (i)

Stream: Stochastic Models
Chair: *Michael Manitz*

1 - Stochastic Dynamic Capacitated Lot-Sizing with uncertain production times
Michael Kirste

We present a dynamic multi-item capacitated lot-sizing problem with stochastic production times. A new strategy which uses time slots instead of lot sizes is proposed to control the production output. We develop a mathematical model, where uncertain production times are modelled by renewal theory. Uncertainty in production is controlled by a fill rate constraint. A numerical experiment emphazises the importance to consider uncertain production times in production planning problems.

2 - Applying postponement as a risk management strategy in globally operating supply chains
Christoph Weskamp, Leena Suhl

In the course of globalization, applying mass-customizing strategies has led to a diversity of variants in many economic sectors (e.g. apparel industry or printer industry) Thus, getting accurate customer demand forecasts becomes increasingly challenging and strategies are required that decrease inventory stocks and simultaneously avoid shortfalls. For this purpose, several types of postponement strategies have been discussed in literature and are considered as an appropriate approach for risk-pooling. This work focuses on the identification of optimal strategies for production and distribution under demand uncertainty and considers an integrated view of manufacturing and logistics postponement. It aims to identify the optimal geographical location of the production processes as well as the logistical operations within the supply chain. Based on former research, we extended our two-stage stochastic mixed-integer model formulation by a risk measurement in the model, which addresses the decision maker's level of risk aversion within the uncertain environment. In this work, we analyze the impact of the additional model component on postponement decisions and illustrate the results based on a case study.

3 - Performance evaluation of a lost sales, push - pull production-inventory system under supply and demand uncertainty
Georgios Varlas, Michael Vidalis

A three stages, linear, push-pull production-inventory system is investigated. The system consists of a production station, a finished goods buffer, and a retailer following continuous review (R, Q) policy. Exponentially distributed production and transportation times are assumed. External demand is modeled as a compound Poisson process, and a lost sales regime is assumed. The system is modeled as a continuous time - discreet space Markov process using Matrix Analytic methods. An algorithm is developed in MatLab to construct the transition matrix that describes the system for different structural and operational parameters. The resulting system of linear equations provides the vector of the stationary probabilities. Then key performance measures such as customer service levels, average inventories etc. are computed. The proposed model can be used as a descriptive model to explore the dynamics of the system via different scenarios concerning structural characteristics. Also, it may be used as an optimization tool in the context of a prescriptive model.

■ WB-31

Wednesday, 10:30-12:30 - Marietta Blau Saal

Health Care Operations Management I

Stream: Health and Disaster Aid
Chair: *Katja Schimmelpfeng*

1 - Segmenting departments and wards to increase bed occupancy levels
Manuel Walther, Alexander Hübner, Heinrich Kuhn

To uphold quality of patient care in hospitals under cost pressures it is important to use resources as efficiently as possible. A key driver in this context is the bed occupancy level, where the goal is to keep it as high as possible while avoiding overload situations. We propose a stochastic IP model to segment departments and wards into groups, i.e. allocating departments and wards to clusters. This allows pooling resources and at the same time leveling out the associated overall bed occupancy levels including seasonality effects. The objective function is cost-based and minimizes the additional management and personnel qualification costs due to patient pooling effects as well as all costs associated to holding the required bed capacity available. The segmentation constraints include medical feasibility, patient compatibility, personnel qualification synergies, and walking distance within a pool of wards and to relevant fixed facilities. We formulate the model as a set partitioning approach to reduce computational complexity. The model was implemented with a real-life case study at a large German hospital as well as simulated data to show general applicability even for very large hospitals. It contributes to current literature on three distinct aspects. First, our approach allows for time-efficient and exact solutions of the department-ward-allocation problem considering the above-mentioned constraints. Second, we take seasonal effects and differing occupancy distributions per department into account, which for our application proves more robust than the Erlang-Loss approach commonly used in literature. Last but not least, we provide a solution that is highly customizable in terms of department-specific constraints and service levels.

2 - Estimating the impact of economies and diseconomies of scale on hospital case mix planning
Sebastian Hof, Jens Brunner

The problem of choosing the composition and volume of patients in a hospital is called the case mix planning problem. Many countries recently changed to reimbursement systems where hospitals are recompensed for patients according to their diagnosis. In those systems, selecting patients has a significant impact on hospital profit. We design a methodology to analyze effects of economies and diseconomies of scale on case mix planning in single and multiple site hospitals. We formulate a non-linear program, introduce a linear approximation scheme using sophisticated preprocessing methods, and improve standard solution methods by branching on special ordered set constraints. We evaluate data from different hospitals to quantify the impact of scale effects and show preliminary results. The conclusions have important implications on strategic hospital planning ranging from the specification of supplied services to local clustering of departments.

3 - Physician Scheduling Including Flexible Day, Shift and Break Patterns
Melanie Erhard, Jens Brunner

In hospitals, personnel generates the biggest and most important cost. This research focuses on physicians scheduling in hospitals and considers different characteristics of the workforce. The main objective is to investigate different kinds of flexibility. In particular, we vary the number of consecutive working days and consider shifts having distinct starting and ending periods including flexible break assignment. Our objective is to minimize the number of assigned physicians subject to demand coverage and labor regulations. We formulate the problem as a mixed-integer program and test different scenarios with standard software (like CPLEX). Preliminary results show that flexibility has a huge impact on the workforce size.

4 - Improving Platelet Supply through Coordinating Collection and Appointment Scheduling Operations
Ali Ekici, Azadeh Mobasher, Okan Ozener

According to the regulations, in order to extract platelets, donated blood units have to be processed at a central processing center within six hours of donation time. In this paper, considering this processing time requirement of donated blood units for platelet production we study collection and appointment scheduling operations at the blood donation sites. Specifically, given the blood donation network of a blood collection organization, we try to coordinate pickup and appointment schedules at the blood donation sites to maximize platelet production. We call the problem under consideration Integrated Collection and Appointment Scheduling Problem. We first provide a mixed integer linear programming model for the problem. Then, we propose a heuristic algorithm called Integer Programming Based Algorithm. We perform a computational study to test the performance of the proposed model and algorithm in terms of solution quality and computational efficiency on the instances from Gulf Coast Regional Blood Center located in Houston, TX.

Wednesday, 14:00-15:30

■ WC-02

Wednesday, 14:00-15:30 - HS 7

Project Management and Scheduling II (i)

Stream: Scheduling and Project Management
Chair: *Norbert Trautmann*

1 - Appointment scheduling in hospitals: sequencing and scheduling using timeaggregation
Sarah Kirchner, Marco Lübbecke

In Germany as well as in many other countries, hospital services provided for admitted patients are settled using diagnosis-related groups (DRGs). That is, patients are grouped according to their diagnosis, received services and demographic characteristics into a DRG. The hospital receives a fixed reimbursement dependent on this DRG. This payment scheme provides incentives for hospitals to aim for a short hospitalization of patients. Almost all patients receive more than one medical service during their hospital stay and there may be dependencies between these services. To facilitate the requirements of these multiple dependent services, coordinated appointment calendars for the different resources of a hospital are needed. At the moment, it is common practice that medical staff at a resource sequentially assigns appointment times to incoming requests disregarding all other services the patient may need and often without considering the impact the decision has on the length of the patients stay. Additional to the admitted patients, many hospital units also provide ambulatory services to patients. Often they also need to consider walk-in patients that arrive at the hospital without prior notice. We assume that accurate information about the exact execution time for a request is only needed on the day of execution itself. Before that, it is sufficient to know the day the request is scheduled to be processed. A time-indexed IP formulation for the problem is proposed in which timeslots are aggregated for the time after the next day. To cope with the requirements of walk-in patients additional heuristics are proposed.

2 - An MILP-based heuristic for staff scheduling problems with acceptance levels
Tom Rihm, Philipp Baumann

We present a real-world staff-assignment problem that was reported to us by a provider of an online workforce scheduling software. The problem consists of assigning employees to work shifts subject to a large variety of requirements related to work laws, work shift compatibility, workload balancing, and personal preferences of employees. A target value is given for each requirement, and all possible deviations from these values are associated with acceptance levels. The objective is to minimize the total number of deviations in ascending order of the acceptance levels.

We present an exact lexicographic goal programming MILP formulation and an MILP-based heuristic. The heuristic consists of two phases: in the first phase a feasible schedule is built and in the second phase parts of the schedule are iteratively re-optimized by applying an exact MILP model. A major advantage of such MILP-based approaches is the flexibility to account for additional constraints or modified planning objectives, which is important as the requirements may vary depending on the company or planning period.

The applicability of the heuristic is demonstrated for a test set derived from real-world data. Our computational results indicate that the heuristic is able to devise optimal solutions to non-trivial problem instances, and outperforms the exact lexicographic goal programming formulation on medium- and large-sized problem instances.

3 - Efficient list-generation techniques for scheduling assessment centers
Adrian Zimmermann, Norbert Trautmann

Human resources managers often conduct assessment centers to evaluate candidates for a job position. During an assessment center, the candidates perform a series of tasks. The tasks require one or two assessors (e.g., managers or psychologists) that observe and evaluate the candidates. If an exercise is designed as a role-play, an actor is required who plays, e.g., an unhappy customer with whom the candidate has to deal with. Besides performing the tasks, each candidate has a lunch break within a prescribed time window. Each candidate should be observed by approximately half the number of the assessors; however, an assessor may not observe a candidate if they personally know each other. The planning problem consists of determining (1) resource-feasible start times of all tasks and lunch breaks and (2) a feasible assignment of assessors to candidates, such that the assessment center duration is minimized. We present a list-scheduling heuristic that generates feasible schedules for such assessment centers. We propose several novel techniques to generate the respective task lists. Our computational results indicate that our approach is capable of devising optimal or near-optimal schedules for real-world instances within short CPU time.

■ WC-03

Wednesday, 14:00-15:30 - HS 16

Scheduling in Freight Rail Transport (i)

Stream: Scheduling and Project Management
Chair: *Erwin Pesch*

1 - A New Hierarchical Approach for Optimized Train Path Assignment with Traffic Days
Daniel Pöhle, Matthias Feil

German Railways Infrastructure division DB Netz has started to gradually introduce a new process for its rail freight timetabling. This process contains two main stages: at first a pre-planning of standardized train paths (called "slots') and afterwards the assignment of train path applications to the pre-planned slots. The current implemented train path assignment optimization model (Nachtigall 2014) has a model scope of one single traffic day. However, current train path applications for the network timetable have multiple and diverse traffic days (e.g. Monday till Friday or Tuesday and Thursday) and cannot be assigned appropriately today. At first it will be illustrated by what a "good' train path assignment with multiple traffic days is characterized from the point of view of an infrastructure manager and its customers. Subsequently, a new hierarchical approach for train path assignment with different traffic days will be presented which is derived from the analysis of present train path applications. The analyses of a German long term timetable scenario indicate that this new approach generates promising results.

2 - Modelling and Solving a Train Path Assignment Model With Traffic Day Restriction
Karl Nachtigall

The German Railway Company (DB Netz) schedules freight trains by connecting pre-constructed slots to a full train path. We consider this problem with special attention to traffic day restrictions and model it by a binary linear decision model. For each train request a train path has to be constructed from a set of pre-defined path parts within a time-space network. Those train requests should be realized only at certain days of the week. Each customer request has a specific traffic day pattern, which is a difficult challenge for the allocation process. Infrastructure capacity managers intend to achieve an efficient utilization of the capacity, whereas customers are interested in homogeneous train paths over all requested traffic days. We discuss those partly contradictory requirements within the context of our binary linear decision model. The problem is solved by using column generation within a branch and price approach. We give some modeling and implementation details and present computational results from real world instances.

3 - Two-way bounded dynamic programming approach for operations planning in transshipment yards
Alena Otto, Xiyu Li, Erwin Pesch

We propose a two-way bounded dynamic programming (TBDP) approach to deal with situations, when it takes long to evaluate the value function in the state graph of dynamic programming. TBDP provides sharp bounds early in the solution process and identifies critical subproblems, i.e. states and transition arcs, for which the value function has to be estimated. Based on the TBDP framework, we develop a heuristic and an exact algorithm for the static crane scheduling problem (SCSP). The SCSP refers to simultaneous yard partitioning into single crane areas and job sequencing at railway container transshipment yards, where both rail-rail and rail-road transshipments are present.

■ WC-04

Wednesday, 14:00-15:30 - HS 21

Special cases of the TSP (i)

Stream: Discrete Optimization
Chair: *Isabella Hoffmann*
Chair: *Anja Fischer*

1 - The Traveling Salesman Problem on Grids with Forbidden Neighborhoods

Anja Fischer, Philipp Hungerländer

We consider special Euclidean Traveling Salesman Problems with additional constraints. Given points in the Euclidean plane we look for a shortest tour over all points such that the distances between neighboring points in the tour are not smaller than a given value. This problem is motivated by an application in beam melting. Indeed, one hopes to reduce the internal stress of the workpiece by such orders. In this talk we restrict to point sets that correspond to regular grids. For different values of the minimal distance between neighboring points we present optimal Hamiltonian cycles and paths depending on the size of the grid. In a special case we derive exactly the so called knight's tours as optimal tours. Furthermore, we present some results if the distances are measured via the Manhattan metric. At the end we give some suggestions for future work that are related to the application in beam melting, too. Indeed, it might be preferable to restrict not only the distance of neighboring points in the tour but also of points that are close in the tour, for instance for two nodes with exactly one other node between them.

2 - Approximation of the Maximum Scatter TSP on an Equidistant Grid

Isabella Hoffmann, Sascha Kurz, Jörg Rambau

In the maximum scatter traveling salesman problem the objective is to find a tour that maximizes the shortest distance between any two consecutive nodes. This model can be applied to manufacturing processes, particularly laser melting processes. We extend an algorithm by Arkin et al. that yields optimal solutions for nodes on a line to an equidistant grid. The algorithm takes linear time to produce a feasible tour. For special cases, which cover more than half of all possible grid sizes, the algorithm produces an optimal solution. In all other cases we get a good primal bound on the objective value. The gap between the optimal solution and the computed solution is less than the distance between two neighbor nodes. Moreover, we get a feasible tour. This tour can be taken as an initial tour for further approximation, e.g., an adaptation of the Lin-Kernighan heuristic, or a binary search solving a Hamiltonian problem with a set of edges restricted in length. Similar considerations for the 2-Neighbor TSP are in progress.

■ WC-05

Wednesday, 14:00-15:30 - HS 23

POM applications I

Stream: Production and Operations Management
Chair: *Sonja Kalkowski*

1 - A multi criteria schedule construction heuristic for energy efficiency aware detailed production planning in a SIEMENS rail production factory

Rafael Fink

Depending on the range and the complexity of the goods produced, production planning can be a difficult task. Presumably that is one of the reasons why most contributions from scientific literature and scheduling rules applied in practice just focus on single economic aspects like the adherence to delivery dates or the minimization of the make-span. Yet, production planning is a highly multi-objective task, in general. If, for instance, production planning does not explicitly account for potentials to improve energy efficiency, these potentials will probably not be tapped in the production execution phase, either. Yet, the importance of such secondary objectives is constantly increasing in real life applications. Therefore, within the European Union funded project 'Eco Manufactured transportation means from Clean and Competitive Factory' (EMC2-Factory) we developed an approach for operational production planning that not only addresses the earliness-tardiness problem in a make-to-order production environment but also integrates several measures to account for an improved energy efficiency of the production process. The algorithmic concept relies on a priority rule based schedule construction heuristic which we implemented in a software tool for a SIEMENS rail production facility. Today, production planners of the facility utilize that software tool to do a daily or weekly rolling horizon planning that simultaneously optimizes the production process with respect to different KPI's like the adherence to delivery dates, the needed transportation and setup effort or the overall energy demand. Trade-offs between these KPI's can be quantified by calculating and evaluating not just one single solution but a set of alternative non-dominated schedules.

2 - Mixed integer linear programming model for the multi-stage production planning problem in dairy industry

Bilge Bilgen

The dairy processing industry has a specific set of product and process characteristics such as high number of SKUs, divergent product structures, seasonal product demand, high demand variability, multiple intermediate products feeding many finished goods with limited storage capacity for intermediate products, high consumer driven demand variability, long lead-times for some packaging material, and a high level of complexity in the manufacturing process. This study introduces a novel model formulation for the continuous process, multi-stage, production planning problem that arises in the dairy industry. This problem addresses the issue of determining the production quantities of various intermediate products, and SKUs appearing in consecutive stages in a dairy production facility over a planning horizon. The models aims to maximize profit, while considering production, inventory holdings, lost sales, and setup costs. The problem we consider has multiple stages where raw milk or intermediate products serve as an input in the production of one or more intermediate products or end products. The production process uses parallel pasteurizers, sterilizers, and filling and packaging machines. The synchronization of production stages is difficult due to the difference between processing and packaging rates, and the limitations on the intermediate storage. The problem incorporates production characteristics particular to the dairy industry, including shelf lives, production speed, intermediate storage, multi-stage processing, and the availability of resources at each stage. Although this research is illustrated with an application in dairy industry, it encompasses the main characteristics of many food production systems.

3 - Reliable order promising with multidimensional anticipation of customer response

Sonja Kalkowski, Ralf Gössinger

Submitting offers to customers successfully is a major concern in make-to-order production. In a long-term perspective order promising does not only aim at short-term profit maximization but simultaneously at reaching an appropriate level of reliability. In the literature capable-to-promise (CTP) approaches are proposed to submit offers based on the present order and resource situation. A broad spectrum of measures to cover order- and resource-related uncertainty is considered in the CTP literature, but so far proposing alternative order specifications has not been focused in research. In particular, customer response to monetary as well as to non-monetary order specifications is not adequately taken into account. Therefore, the intension of the planned paper is to develop a CTP approach which aims at obtaining reliable planning results by proposing alternative order specifications that differ from customer requirements in price and delivery date. For this purpose a two-stage planning approach is derived: At the first planning stage orders are accepted if they can be fulfilled according to customer specifications in a profitable way. All other orders are provisionally rejected and re-planning is done at the second stage. Thereby deviating order specifications are determined which increase the profitability of provisionally rejected orders and may be acceptable for the customers. For this reason customer response to later delivery dates and reduced prices is anticipated by an estimated acceptance probability. In order to investigate the impacts of adjusting delivery dates and prices on generated profits as well as the reliability of planning results the planning approach is numerically analyzed based on real-world data.

■ WC-06

Wednesday, 14:00-15:30 - HS 24

Data Envelopment Analysis II

Stream: Production and Operations Management
Chair: *Bernhard Mahlberg*

1 - Data Envelopment Analysis for Panel Data
Oleg Badunenko

CCR and BCC models for the nonparametric efficiency measurement are developed to accommodate cross-section data. In the recent survey, Cook and Seiford (EJOR, 2009) summarize established models and conclude that if panel data is available the best one can do is to assume all observations of the same unit as separate units and proceed as if a cross-section data is at hand. There are at least two big drawbacks associated with such conduct. First, the panel structure is lost and second, all the units are assumed to operate under common frontier. This paper aims at dealing with these two issues. It proposes a new method for panel data nonparametric efficiency measurement. The basic idea comes from the production theory and the conjecture of orientation on the long-term performance (a la Farrell, 1957). The new method leaves it the data to reveal separate frontiers for different time periods and simultaneously takes panel structure of the data into account. The efficiencies in different time periods are then estimated relative to the corresponding frontier. The new method will also allow assuming different returns to scale and build-in previously developed extensions. Moreover, the new method is invariant if the panel data is unbalanced, it will anyway use all observations.

2 - Frontier Metatechnologies and Convexity: A Restatement
Kristiaan Kerstens, Christopher O'Donnell, Ignace Van de Woestyne

This contribution reconsiders the construction of metafrontiers based on underlying group frontiers using non-parametric technology specifications. We argue that the large majority of articles applying this popular methodology in fact assesses efficiency measures relative to a potentially poor approximation of the metafrontier. We develop a refined methodology for non-parametric specifications of technology yielding a proper non-convex metafrontier. Furthermore, this methodology is empirically applied on a secondary data set to verify the estimation of metatechnology ratios (as defined in O'Donnell, Rao, and Battese (2008)) as well as to illustrate the potential bias of using the currently established methods.

3 - Measuring input-specific productivity change through a Luenberger indicator based on the Principle of Least Action
Bernhard Mahlberg, Juan Aparicio, Magdalena Kapelko

In for-profit organizations efficiency and productivity measurement with reference to the potential for input-specific reductions is particularly important and has been the focus of interest in the recent literature. Different approaches can be formulated to measure and decompose input-specific productivity change over time. In this paper, we highlight some problems within existing approaches and propose a new methodology based on the Principle of Least Action, which is related to the notion of least distance and the determination of closest strongly efficient targets. This model is operationalized in the form of a non-radial Luenberger productivity indicator based on data envelopment analysis. In our approach overall productivity change is the sum of input-specific productivity changes. Overall productivity change and input-specific changes are broken up into indicators of efficiency change and technical change. This decomposition enables the researcher to quantify the contributions of each production factor to productivity change and its components. In this manner, the drivers of productivity development are revealed. For illustration purposes the new approach is applied to a recent dataset of Polish dairy processing firms.

■ WC-07

Wednesday, 14:00-15:30 - HS 26

Probabilistic Transportation Planning

Stream: Logistics and Transportation
Chair: *Marlin Wolf Ulmer*

1 - Single vehicle routing problem with a predefined customer sequence, stochastic demands and partial satisfaction of demands
Epaminondas Kyriakidis, Theodosis Dimitrakos

We consider the problem of finding the optimal routing of a single vehicle that starts its route from a depot and delivers a product to N customers that are served according to a particular order. The vehicle during its route can return to the depot for restocking. The demands of the customers are random variables with known distributions. The actual demand of each customer is revealed as soon as the vehicle visits the customer's site. It is permissible to satisfy fully or to satisfy partially or not to satisfy the demand of a customer. The cost structure includes travel costs between consecutive customers, travel costs between the customers and the depot and penalty costs if a customer's demand is not satisfied or if it is satisfied partially. A dynamic programming algorithm is developed for the determination of the optimal routing policy. It is shown that the optimal routing policy has a specific threshold-type structure.

2 - Multi-objective Transportation Problem with Fuzzy Decision Variable using Multi-choice Goal Programming
Sankar Kumar Roy

This paper presents the study of multi-objective transportation problem (MOTP) under the environment of fuzzy and multi-choice goal programming. Generally, the decision variables (which are unknown) of transportation problem (TP) are considered as real variables. Here, we have described the situation where the decision variables of each node are chosen from a set of multi-fuzzy numbers. TP with fuzzy decision variables under multiple objectives produces as a multi-objective fuzzy transportation problem (MOFTP). After that, a new way of mathematical model of MOFTP having with goal of each objective function has been incorporated and also the solution procedure has been shown using multi-choice goal programming. At last, an example is introduced to show the applicability and feasibility of the proposed model in this paper.

Index Terms: Transportation problem, Multi-objective decision making, Goal programming, Multi-choice programming, Fuzzy programming.

■ WC-08

Wednesday, 14:00-15:30 - HS 27

Forecasting for TV audiences - Methods & Applications

Stream: Forecasting
Chair: *Sven F. Crone*

1 - Model for the audience forecasting in TV advertisement
Grzegorz Pawlak, Maciej Drozdowski, Malgorzata Sterna

The goal of the work is to construct optimization tools for advertisement buyers of TV commercial slots in the multi-channel environment. A model of the daily audience prediction on the basis of the historical data for a real market and for the electronic telemetric measures of the audience will be presented. Taking into account the compound data from the telemetric measurements and the individual viewer characteristic, a model of the audience behavior in the multi-channel TV advertisement will be proposed. On the one hand the model consists of the integrated data structures designed for representing the audience data, organized on the data base architecture. On the other hand it includes the methods of analyzing these data for the audience forecasting. It contains viewing statements, weights and demographic data for all individuals derived from the telemetric panel. As a result the audience prediction model can be proposed for a given time period. As a consequence the communication and media plan in the advertising breaks could be constructed. The developed model will be calibrated on the particular time period of the historical data and the validation of the forecast accuracy will be estimated for the subsequent time periods of these data.

2 - Identification of patterns in TV consumption
Igor Rotin

The prognosis of TV consumption of target groups related to program genres is the planning and steering basis for many continuative applications for a TV station. This includes content topics for programming as well as the seasonal placement of specific programs. In addition the changing media usage due to the rapid increase of internet distribution has also influenced TV consumption. As a TV supplier it's important to analyze the influence of program-genre-development on TV consumption and station preferences. In the present case a data mining analysis was carried out to answer this specific question and in his presentation Dr. Igor Rotin will show how data mining and analytical methods for prediction, pattern identification and clustering are used in program research. Based on a mathematical cluster model TV consumption per viewer and genre dimension were used as input data. In the clustering process different distance functions were evaluated to determine appropriate similarity measures.

3 - Forecasting TV audiences with multivariate k-Nearest Neighbours - an empirical Evaluation
Sven F. Crone

Television impacts our daily lives. It provides news, entertainment and education. And, with minute-by-minute information on TV ratings and multi-billion-euro income streams from advertising, it represents an important forecasting application of high-frequency time series data that warrants sophisticated forecasting algorithms. In order to schedule each advertisement to the most suitable target audience, the number of TV viewers must be predicted for each 5 minute timeslot for multiple days in advance. However, viewership patterns vary by demographic of target audiences, from young adults to elderly couples and the affluent to the unemployed, across geo-regions from rainy North to sunny South, with TV programme schedules and weather driving viewership patterns over time. Consequently the forecasting task requires multivariate forecasting methods which are capable of handling high-frequency time series data in very large time series data. We propose to apply a multivariate k-Nearest Neighbour (k-NN) algorithm to TV viewership time series data. The algorithm is evaluated against a series of benchmark algorithms using UK data from a leading private UK TV channel using fixed-horizon multiple rolling origin evaluation, applying robust error measures in a valid and reliable experimental design. The results show the value of k-NN in improved accuracy, robustness, and efficiency over established statistical approaches.

■ WC-09

Wednesday, 14:00-15:30 - HS 30

Combinatorial Auctions

Stream: Game Theory
Chair: *Martin Hoefer*

1 - The Performance of Deferred-Acceptance Auctions
Paul Duetting, Vasilis Gkatzelis, Tim Roughgarden

Deferred-acceptance auctions are auctions for binary single-parameter mechanism design problems whose allocation rule can be implemented using an adaptive reverse greedy algorithm. Milgrom and Segal (2014) recently introduced these auctions and proved that they satisfy a remarkable list of incentive guarantees: in addition to being dominant-strategy incentive-compatible, they are weakly group-strategyproof, can be implemented by ascending-clock auctions, and admit outcome-equivalent full-information pay-as-bid versions. Neither forward greedy mechanisms nor the VCG mechanism generally possess any of these additional incentive properties. The goal of this paper is to initiate the study of deferred-acceptance auctions from an approximation standpoint. We study these auctions through the lens of two canonical welfare-maximization problems, in knapsack auctions and in combinatorial auctions with single-minded bidders.

For knapsack auctions, we prove a separation between deferred-acceptance auctions and arbitrary dominant-strategy incentive-compatible mechanisms. While the more general class can achieve an arbitrarily good approximation in polynomial time, and a constant-factor approximation via forward greedy algorithms, the former class cannot obtain an approximation guarantee sub-logarithmic in the number of items m, even with unbounded computation. We also give a polynomial-time deferred-acceptance auction that achieves an approximation guarantee of O(log m) for knapsack auctions.

For combinatorial auctions with single-minded bidders, we design novel polynomial-time mechanisms that achieve the best of both worlds: the incentive guarantees of a deferred-acceptance auction, and approximation guarantees close to the best possible.

2 - Combinatorial Auctions with Conflict-Based Externalities
Martin Starnberger, Yun Kuen Cheung, Monika Henzinger, Martin Hoefer

Combinatorial auctions (CA) are a well-studied area in algorithmic mechanism design. However, contrary to the standard model, empirical studies suggest that a bidder's valuation often does not depend solely on the goods assigned to him. For instance, in adwords auctions an advertiser might not want his ads to be displayed next to his competitors' ads. In this paper, we propose and analyze several natural graph-theoretic models that incorporate such negative externalities, in which bidders form a directed conflict graph with maximum out-degree D. We design algorithms and truthful mechanisms for social welfare maximization that attain approximation ratios depending on D.

For CA, our results are twofold: (1) A lottery that eliminates conflicts by discarding bidders/items independent of the bids. It allows to apply any truthful alpha-approximation mechanism for conflict-free valuations and yields an O(alpha D)-approximation mechanism. (2) For fractionally sub-additive valuations, we design a rounding algorithm via a novel combination of a semi-definite program and a linear program, resulting in a cone program; the approximation ratio is O((D log log D)/log D). The ratios are almost optimal given existing hardness results.

For adwords auctions, we present several algorithms for the most relevant scenario when the number of items is small. In particular, we design a truthful mechanism with approximation ratio o(D) when the number of items is only logarithmic in the number of bidders.

3 - Algorithms as Mechanisms: The Price of Anarchy of Relax-and-Round
Thomas Kesselheim, Paul Duetting, Eva Tardos

Many algorithms, that are originally designed without explicitly considering incentive properties, are later combined with simple pricing rules and used as mechanisms. The resulting mechanisms are often natural and simple to understand. But how good are these algorithms as mechanisms? Truthful reporting of valuations is typically not a dominant strategy (certainly not with a pay-your-bid, first-price rule, but it is likely not a good strategy even with a critical value, or second-price style rule either). Our goal is to show that a wide class of approximation algorithms yields this way mechanisms with low Price of Anarchy.

The seminal result of Lucier and Borodin [SODA 2010] shows that combining a greedy algorithm that is an -approximation algorithm with a pay-your-bid payment rule yields a mechanism whose Price of Anarchy is O(). In this paper we significantly extend the class of algorithms for which such a result is available by showing that this close connection between approximation ratio on the one hand and Price of Anarchy on the other also holds for the design principle of relaxation and rounding provided that the relaxation is smooth and the rounding is oblivious.

We demonstrate the far-reaching consequences of our result by showing its implications for sparse packing integer programs, such as multi-unit auctions and generalized matching, for the maximum traveling salesman problem, for combinatorial auctions, and for single source unsplittable flow problems. In all these problems our approach leads to novel simple, near-optimal mechanisms whose Price of Anarchy either matches or beats the performance guarantees of known mechanisms.

■ WC-10

Wednesday, 14:00-15:30 - HS 31

Multi-objective optimization in transport and logistics II

Stream: Logistics and Transportation
Chair: *Sophie Parragh*

1 - Bi-objective stochastic facility location
Fabien Tricoire, Sophie Parragh, Walter Gutjahr

We investigate facility location for service facilities in the broad sense. This includes for instance public service such as post offices, or other kinds of service-based businesses that require to locate facilities. In that context, the ability to provide service to a large part of the population is highly relevant, and typically comes at the cost of opening more facilities. Demand emanates from regions, each region representing a certain population, for instance a village in a rural context. Additionally, it is not always possible to assume that demand data are deterministic, as the decision maker has limited control over where people actually decide to go. For the same reason, demand from a given region can be split and service can be provided to this region concurrently by several facilities.

We consider a bi-objective stochastic optimization problem where the two objectives are the minimization of uncovered demand and the minimization of cost. The demand is stochastic. There are several methods to solve bi-objective optimization problems. We compare the well-known epsilon-constraint framework and a more recent bi-objective branch-and-bound algorithm which we previously introduced. Both methods rely on iteratively solving modified linear programs (LPs), so we consider that the stochastic LP is solved by a black box algorithm.

Stochasticity is modeled using samples. We then incorporate these samples in the model, transforming the stochastic LP into a deterministic one. However this results in a much bigger LP. We also investigate using the L-shaped method to solve the stochastic LP without creating as many variables and constraints. All four combinations of bi-objective framework and stochasticity treatment are tested and compared using existing data.

2 - Multi-objective synchronized transportation for inner city freight deliveries
Alexandra Anderluh, Vera Hemmelmayr, Pamela Nolz

The undeniable fact of increasing urbanization combined with the looming threats of climate change constitute the current challenges in city logistics. Supplying citizens with all necessary goods without deteriorating the quality of life in a city is difficult to accomplish. Therefore, we investigate the use of a more sustainable mode of transport, cargo bikes, in inner city delivery. We develop a two echelon routing scheme with synchronization of vans and cargo bikes. In our model we do not only focus on the mere economic objective to minimize monetary costs. Besides this economic objective we take into account the environmental objective expressed by emission costs and the social objective which is included for example by costs for traffic accidents and health risks induced by traffic. So we can include factors of all three pillars of sustainability in our optimization model. A combination of heuristic and exact methods is used to solve this NP-hard problem. We are going to present preliminary results for a test instance from Vienna. These results illustrate the influence of these types of costs and can therefore give planners a decision support in using such a more sustainable kind of freight distribution in a city.

3 - Freshness vs. cost for an integrated lot sizing and vehicle routing model with perishable products
Christian Almeder, Pamela Nolz, Tom Vogel

We formulate a multi-objective production-distribution model for products loosing quality within several hours after production. There is a single production plant which produces goods on a single production line. After production goods are transported to several shops within a close neighborhood of the plant. There are two criteria to be optimized: (i) a combination of production costs and distribution costs, (ii) a measure of product freshness when the products arrive in the shops. The production process of perishable products is captured by a general lot sizing problem (GLSP). Through its flexible time structure it allows to capture production times for different production lots and sublots. This GLSP is combined with aspects of an inventory routing problem (IRP) reflecting the delivery to the shops through multiple tours per day. We investigate and compare different solution approaches: production first - distribution second, iteration between production and distribution, integration of production and distribution, and asses the trade-off between freshness and cost using an Epsilon Constraint Method.

■ WC-11

Wednesday, 14:00-15:30 - HS 32

Electric and Green Vehicle Routing

Stream: Logistics and Transportation

Chair: *Jakob Puchinger*

1 - Location, allocation, and routing decisions in an electric car sharing system
Hatice Calik, Bernard Fortz

We focus on an electric car sharing system where we have a set of customers, each of which wishes to travel from an origin point to a destination point by starting at a certain time slot of the day. The customers are allowed to leave the cars to a station different than the one that they are taken. The location of the stations, the customer trips to be served and their routes need to be decided. The objective of the problem is to maximize the profit of the car sharing organization. The profit function considers the revenue obtained by serving the customers and fixed location cost of the stations. We provide new mathematical formulations for different variations of the problem and conduct computational experiments on newly generated problem instances.

2 - Effects of City Center Restriction Policies on the Tour Planning of Hybrid Heterogeneous Fleets
Gerhard Hiermann, Richard Hartl, Jakob Puchinger, Thibaut Vidal

The research in urban transportation has increased in the last years as a consequence of the growing population of cities and the subsequent increase of transportation demand. Increased traffic in cities leads to a rise in air and noise pollution due to increasing fleet sizes, which in turn effects the overall satisfaction of its citizens. City managers are thus actively searching for concepts to tackle this problem. One such concept uses city-center restrictions, as implemented in practice in several European cities, such as Bologna, Milan and Paris. Such restrictions penalize the use of conventional fossil fuelled vehicles inside a predefined area with the aim of decreasing the pollution generated by local emissions.

In this work we study the impact of such spatial restriction on tour planning solutions, considering alternative pricing models, or a general ban of fossil-fuelled engines. The planning problem, a hybrid heterogeneous electric vehicle routing problem with time windows and city center restrictions is solved using a hybrid genetic search metaheuristic developed in previous work. The experiments are performed on several classes of artificial instances as well as on a case study using the street map of the city of Vienna. Results of these experiments will be presented at the conference.

3 - Location Planning of Charging Stations for Electric City Buses
Brita Rohrbeck, Peter Förster, Kilian Berthold

Fuel prices on the rise and ambitious goals in environment protection make it more and more necessary to change for modern and more sustainable technologies. This trend also affects the public transportation sector. Electric buses with stationary charging technology fit this trend perfectly since they unburden cities from carbon dioxide and noise emissions. However, their acquisition is still costly, and an optimal choice of the charging stations' locations is mandatory.

In our talk we first present a mixed integer model that gives an optimal solution concerning the investment costs for a single bus route. This model is then extended to a network of routes. It is mainly constrained by an energy balance. Hence, energy consumption on the driven paths and of auxiliary consumers have to be considered as well as holding times at bus stops and thus the potentially recharged amount of electric energy. Additionally, we take account of different charging and battery technologies, service life preservation of the batteries as well as beneficial existing infrastructure and constructional restrictions.

We give an overview of our results obtained from real world data of the bus network of Mannheim. In our tests we consider different scenarios regarding passenger volume, traffic density and further factors.

■ WC-12

Wednesday, 14:00-15:30 - HS 33

Maritime Logistics II

Stream: Logistics and Transportation

Chair: *Joachim R. Daduna*

1 - Shift Preview — Improve day to day operation with the means of simulation

Holger Schuett

Terminal operation becomes more and more complex due to the high demands of shipping lines caused by the increase in vessel and package size per visit. Thus the control staff has to be supported by IT systems to find the optimal planning for next shift's operation.

Simulation and emulation for container terminals Simulation of container terminal operation is state of the art for planning purposes on the strategic level to secure the investment in a new terminal (layout configuration, number of equipment, rough overall strategies, etc.) for some 15 years already. Connecting the simulation models to the control systems (TOS) is becoming more and more commonly used for huge projects and automated processes. This technology —called emulation or virtual terminal- is used for training purposes as well as for testing the functionality of new releases and for fine-tuning the planning parameters in the tactical planning phase.

Shift Preview — the new approach This paper describes a new technical approach which combines the advantages of simulation (high speed) and emulation (high level of detail, application of real strategies). Shift Preview imports the current planning state out of the real time TOS. Besides the work queues and the equipment allocations all planning parameters (e.g. yard strategy adjustments) are directly taken from the TOS. The main topic to achieve high speed simulation responses is the paradigm change from time-based (needed in virtual terminals) to event-based simulation.

As a result the occurrence of bottlenecks as well as overutilization of equipment pools will be shown to the planner. Thus the planner will be set in the position to become pro-active instead of re-acting to the situation on the yard during the operation.

2 - Maritime Logistics Strategies in Offshore Wind Energy

Holger Schuett, Kerstin Lange, Hans-Dietrich Haasis

Aim of Research: The wind industry is facing new, great challenges due to the planned construction of thousands of offshore wind energy power plants in the Northern and Baltic Sea. With increasing distances from the coast and rising sizes of the plants the industry has to face the challenge to implement projects in the planned cost and time frame. However, up to now the most offshore research projects are focusing on technical aspects and not on logistics.

Methodology/approach: A simulation tool was developed, which considers various logistical specifications of maritime supply chain networks in offshore wind energy such as weather dependant transport and construction of power plants at sea. Port processes and different network configurations can be analyzed.

Findings: Different network configurations and transportation and assembly strategies affect the installation time and the utilization of resources for transport, transshipment and installation. The crucial challenge is to integrate port and sea processes to use the restricted time windows at sea due to weather constraints in an optimal way for planning the whole supply chain. The wind industry has to adapt its production and logistics concepts to the special offshore requirements at sea. Therefore, different logistics scenarios and their consequences for logistics costs and installation time will be discussed.

Practical implications: Different supply chain designs and logistical strategies have an essential impact on the competitiveness and the logistics costs of a wind park. With the aid of the simulation different scenarios can already be analyzed in the planning process.

3 - The Baltic Sea as a maritime highway in international multimodal transport

Joachim R. Daduna, Gunnar Prause

International multi-modal container flows between Western and Central Eastern Europe can be arranged via Mediterranean Sea as well as via the Baltic Sea. An important impact on the decision of the shippers are related to the available hinter-land links due to high importance for realizing the economic and ecologic effi-ciency gains of maritime transport. In this context transportation links via the Bal-tic Sea by using Short Sea Shippings, revealed significant advantages due to manifold reasons. But this situation may change since the SECA regulations for reduction of emissions in the Baltic Sea (Sulphur Emission Control Area) are in force since January 2015. By considering examples it will be shown how the new frame conditions will in-fluence the transport mode selection in container business. The focus will be laid on the analysis of the impact of increasing bunker costs since they seem to be the main reason for vanishing costs advantages of the traditional transport links in Baltic Sea Region. Consequently, the research tries to point out to which extend the costs for container transport will change and how this will influence the deci-sions of modal choice. The critical point represents the question how big changes in the modal split may appear, i.e. which increases for the shares of rail and road transport can be expected, and how the objectives of transport policy are foiled by applying the new emission regulations.

■ WC-13

Wednesday, 14:00-15:30 - HS 41

Supply Chain Risk (i)

Stream: Supply Chain Management

Chair: *Kamil Mizgier*

1 - Sourcing Strategies and Supply Chain Risk Management

Preetam Basu

Modern supply chains are complex networks made up of multiple entities spanning the entire globe. In these complex supply chain networks risks exist in every link and managing these risks have become extremely critical in the context of today's globalized supply networks. There have been numerous instances where supply chains have been adversely affected because of unforeseen supply disruptions leading to irreparable damages. The selection of a sourcing strategy plays a vital role in managing supply disruptions in global supply chains. The choice regarding the number of suppliers is one of the most important decisions in mitigating supply-side risks. In the recent past, the emergence of supply chain risk mitigation as a key issue has caused many procurement managers to reassess their reliance on single sourcing strategies. Despite the benefits cited in the literature for single sourcing there is enough evidence that provides justification in using dual-sourcing as a risk mitigating policy. Supplier rating based on performance measures is an important component for shaping supplier selection decisions and sourcing strategies of a firm. Selecting the right supplier is a complicated task as it involves considering different criteria. In this paper we analyze single versus dual-sourcing strategies of a buying organization in a multi-period setting where each supplier is exposed to disruption risks. We integrate the supplier rating mechanisms in our supplier selection and sourcing choice problem. We develop a stochastic dynamic programming model to formulate the sourcing problem and derive various managerial insights under different scenarios of supply disruptions.

2 - Optimization of Collaborative Planing and Decision Making in the Tourism Supply Chains

Pairach Piboonrungroj

In the tourism industry, planing and decision making are complex operations. Mutual operations and activities are required across tiers in the supply chain including suppliers, service providers, intermediaries (travel agents and tour operators) and customer (tourists). Such interdependent processes are also vary across various stages in the supply chain starting from planning, procurement, purchasing, productions, transports, inventory/storage, sales and proportion as well as customer services. By making decisions in these stages, the objective of all parties should be to maximize the overall profit of the supply chain as a whole, not for individual. By making a decision with collaborations across the supply chain, the collaborative firms could gain a better outcome. Such collaborations can be done in every stage especially forecasting, planning and execution. To support such collaborative decision making, a tourism supply chain optimization model was modeled. The model includes main supply chain players such as suppliers, hotels, travel agents and tourist attractions. The model was developed to maximize the profit of the whole supply chain. In comparison, the model was also compared to the scenarios where individual profit is the objective. The actual data from the tourism supply chain in Thailand was used to validate the model. The optimization found that the supply chain profitability can be reached when the decision making is made under collaborations in the supply chain. The outcome can be greater when the collaborations are supported by information sharing and team work.

3 - On the Association Between Economic Cycles and Operational Disruptions
Kamil Mizgier, Stephan Wagner, Stylianos Papageorgiou

In the aftermath of the financial crisis, companies have advanced models for measuring and managing operational disruptions. However, the measurement and management approaches neglect the existence of economic cycles. In this exploratory research, we investigate the relationship between economic cycles and operational risk in the US industry. We find that a positive relationship between economic cycles and the severity of operational disruptions exists. Moreover, we identify and model the dynamics of that relationship which follows a varied pattern when operational risk is categorized according to the industry sector. Our findings have implications for improved forecasting of operational risk and the development of an effective policy design.

■ WC-14

Wednesday, 14:00-15:30 - HS 42

Multi-Objective Shortest Path Problems

Stream: Graphs and Networks
Chair: *Stefan Ruzika*

1 - Flood Mitigation Problems on Directed Graphs
Clemens Thielen

We study flood mitigation problems on directed graphs. In the basic version of the problem, we are given a nonempty subset of the nodes of the graph (the initially flooded nodes), a nonnegative flooding cost for each node that is not initially flooded, and a nonnegative removal cost for each arc. The objective is to choose a subset of the arcs to remove from the graph such that the sum of the removal cost of the removed arcs and the flooding cost of the flooded nodes is minimized. Here, a node will be flooded if it is reachable by a directed path from some initially flooded node after the arc removal. In the budget constrained version of the problem, we are additionally given a budget and the objective is to choose a subset of the arcs to remove such that the total removal cost does not exceed the budget and the flooding cost of the flooded nodes is minimized. We provide several complexity results on different versions of flood mitigation problems. In particular, we show that the basic version of the problem can be solved efficiently by transforming it into a minimum cut problem, but the budget constrained version is strongly NP-hard.

2 - Labeling algorithms for multi-objective robust shortest path problems
Lisa Thom, Andrea Raith, Marie Schmidt, Anita Schöbel

In multi-objective optimization several objective functions are considered, e.g. searching for a route on which financial costs and travel time are minimized at the same time. Robust optimization is one possibility to handle uncertainties, that often occur in applications, e.g. travel times can depend on congestion. Only recently have concepts of those two fields been combined to multi-objective robust optimization. In our talk we consider a shortest path problem with several objective functions which are all scenario-dependent or uncertain. Our purpose is to identify robust Pareto solutions to this problem. We investigate if and how labeling algorithms for the multi-objective shortest path problem can be transfered to robust multi-objective path problems based on different robustness definitions. In particular we consider highly, flimsily and strictly robust efficiency. We distinguish between finding all robust efficient solutions and finding only a representative set.

3 - Shortest paths with shortest detours: A biobjective routing problem
Stefan Ruzika, Carolin Torchiani, Jan Peter Ohst, David Willems

We study a biobjective routing problem: the shortest path with shortest detour problem (SPSDP) in which the length of a chosen route is minimized as one criterion and, as second, the maximal length of a detour route if the chosen route happens to blocked is minimized. The choice of the second objective function is motivated by applications, and we present a new polynomial time algorithm that determines a minimal complete set of efficient solutions for SPSDP. Moreover, we show that the number of nondominated points is bounded by the number of arcs.

■ WC-15

Wednesday, 14:00-15:30 - HS 45

Decision Making Models

Stream: Simulation and Decision Support
Chair: *Fatima Dargam*

1 - A decision support model for evaluating a B2B partnership
Mehdi Piltan, Taraneh Sowlati

A decision support model for evaluating a B2B partnership Partnership is one of the strategies that could help companies increase their competitiveness in a global market. However, previous studies report a high failure rate for partnerships. The lack of a comprehensive partnership evaluation approach has been identified as one of the main reasons for partnership failure. This study presents a decision support model to evaluate a B2B partnership in different periods based on the performance measures associated with the drivers of each partner for entering into the partnership. Different Multi-Criteria Decision-Making (MCDM) methods are used in the model in order to address the interdependency, the importance of, and the uncertainty in performance measures. MCDM methods address human memory and cognitive limits and biases that lead to defects in an environment of increasing complexity and information overload such as those in B2B partnerships. The proposed model has two outputs: 1) the overall importance of each performance measure, 2) a single multidimensional index for the overall partnership performance in each period, named as Partnership Performance Index (PPI). PPI is different from either mere financial or operational performance measures. It includes multiple measures associated with the partnership drivers as well as their importance and interdependencies. The model is applied to a partnership between two companies in forest industry in Greater Vancouver, Canada. PPI is used to evaluate this partnership at three different periods and the results were validated by the managers.

2 - Appraising a Portfolio of Interdependent Physical and Digital Urban Infrastructure Investments: A Real Options Approach
Sebastian Maier, John Polak, David Gann

Investment decisions in urban infrastructure systems such as in energy, transport, ICT and waste are frequently made in the context of multiple interdependencies among urban systems and enormous uncertainty surrounding both the investments' intrinsic risks and the highly volatile supply and demand patterns encouraged by digital technologies. Traditional investment appraisal techniques are widely regarded as inadequate since they do not correctly take into account the multiple interdependencies among investment projects nor the various sources of uncertainty influencing the investments' performances. This paper presents a new real options-based appraisal framework for selecting a portfolio of interdependent physical and digital urban infrastructure investments. Representing the decision maker's flexibilities through an influence diagram, we have used this framework to formulate a multistage stochastic optimisation model that combines the Least Squares Monte Carlo algorithm for real options valuation with a mathematical modelling approach of infrastructure interdependencies considering physical, cyber, geographical, and logical interdependencies. Using the examples of district heating investment projects, we investigate the sensitivity of the optimised portfolio composition and corresponding real option exercise strategies to changes in demand and supply patterns and to the decision maker's budget constraints. The numerical results demonstrate that our approach has enormous potential to enhance and support long-term investment decisions, particularly with regard to timing, scale, and risk mitigation. Future work will comprehensively evaluate the comparative performance of traditional approaches and our new approach under a wide range of real world case studies.

3 - Modeling Signals and Learning Effects on the Information Acquisition Incentives of Decision Makers in Sequential Search Processes
Francisco Javier Santos-Arteaga, Debora Di Caprio, Madjid Tavana

Consider a rational decision maker (DM) who must acquire a finite amount of information sequentially from a set of products whose main characteristics are grouped in two differentiated categories. The information acquisition process of the DM depends on the values of the characteristics already observed together with the number and potential realizations of the remaining characteristics.

Moreover, the DM receives signals on the distribution of the characteristics and updates his expected search utilities following both Bayesian and subjective learning rules. Each time an observation is acquired, the DM modifies the probability of improving upon the products already observed with the number of observations available while accounting for the distributional consequences that result from the signal.

More importantly, the characteristic on which the signals are issued plays a fundamental role in determining the information acquisition incentives of the DM. We construct two real-valued functions that determine the decision of how to allocate each available piece of information. We provide several numerical simulations illustrating the information acquisition incentives that define the behavior of the DM. Applications to strategic knowledge management and decision support systems follow immediately from our results, particularly when formalizing online search environments.

■ WC-16

Wednesday, 14:00-15:30 - HS 46

Optimization Modeling and Applications in Energy Sector

Stream: Energy and Environment
Chair: *Gerhard-Wilhelm Weber*

1 - Optimal Control of Stochastic Hybrid Systems with Jumps under Markov Switching Processes - Applications in the Sectors of Energy, Environment, Finance and Economics

Gerhard-Wilhelm Weber, Emel Savku, Nuno Azevedo, Diogo Pinheiro, A. Sevtap Selcuk Kestel

Stochastic Hybrid Systems with Jumps (SHSJs) are natural, powerful and efficient candidate systems to model abrupt changes in financial and energy markets as a consequence of their heterogeneous nature, especially, under regime switches and paradigm changes. The internet bubble and the 2008-2009 economic crash forced researchers and practitioners to develop new ones rather than the traditional portfolio models and it is seen that stochastic regime-switching asset allocation significantly improves the performance compared with unconditional static alternatives. In addition to regime switches, which occur in the economic and financial sectors, our study is applicable for sudden paradigm changes. This means that cultural and also societal transformations, as far as they can be represented by equations of stochastic dynamics, may undergo 'switches' as investigated in this talk. Let us mention that, in the real world, cultural, societal, economical and financial developments are closely related with each other. In this respect, this presentation opens a new and wider view on the world of today and tomorrow. First we introduce SHSJs and provide an extension of Bellman's optimality principle for a Markov-switching jump diffusion stochastic differential equation in a finite time horizon. Moreover, corresponding Hamilton-Jacobi-Bellman equation is given and a consumption-investment strategy for a jump-diffusion financial market consisting of one risky and one risk-free asset whose coefficients are assumed to depend on the state of a continuous-time Markov process is presented. A more general model for portfolio optimization with time delay structure and numerical approaches are discussed as an outlook on SHSJs with delay.

2 - Optimal Operation of Virtual Power Plants

Sleman Saliba, Sabine Büttner, Felix Geyer, Sven Krumke

A virtual power plant connects multiple power generator units, power storage devices and power consumption units that are controlled by a central server. Especially small renewable power generation units can be integrated to participate in the electricity market.

In this talk we investigate the workflow from incoming weather forecast and load demand to trading on at the different energy markets to the unit commitment in real-time and show the potential of mathematical optimization at different stages.

One of the challenges in the operation of a virtual power plant is the optimal placing of the available capacities on the different energy markets. The available capacities are calculated from balancing the forecast of renewable production with the load demand and the long term obligations. We formulate a mathematical model that distributes the available power generation capacities of our virtual power plant to the different energy markets.

After optimizing the commercial operation, we turn to the operational challenges for delivering the committed power production and grid services. We apply mathematical models for real-time optimization in load balancing, unit commitment and providing grid services.

Finally we present successful real-world installations, where virtual power plant operators could increase the productivity and the financial benefits using mathematical optimization.

3 - Natural Gas Consumption Forecasting Models for Residential User with New Robust Optimization Tools

Ayse Özmen, Gerhard-Wilhelm Weber

Multivariate Adaptive Regression Splines (MARS) is very useful nonparametric technique to build high-dimensional and nonlinear multivariate functions in many areas of science, engineering, technology and finance in recent years. However, known regression models are not capable of handling data uncertainty. Since, with increased volatility and further uncertainties, economical, environmental and financial crises translated a high noise within data into the related models, the events of recent years in the world have allowed to radically untrustworthy representations of the future, and robustification has drawn more attention in many fields. In order to overcome that difficulty, new models have to be developed where optimization results are combined within real life applications. We have included the existence of uncertainty regarding future scenarios into MARS and Conic MARS (CMARS), and robustified them through Robust Optimization proposed to cope with data uncertainty. We have introduced the new methods called Robust MARS (RMARS) and Robust Conic MARS (RCMARS), which is more model-based and employs continuous, well-structured convex optimization that enables the applying of Interior Point Methods and their codes, e.g., MOSEK. This study is conducted for the responsibility area of Başkentgaz in Turkey. Başkentgaz owns approximately 90% of overall maximum permissible residential consumption capacity of Ankara City with its districts residential user gas distribution network. In this study, we develop and compare methods for forecasting of natural gas consumption based on R(C)MARS. We apply RMARS and RCMARS to predict one-day ahead natural gas consumption of residential users.

■ WC-17

Wednesday, 14:00-15:30 - HS 47

Supply Uncertainty (c)

Stream: Supply Chain Management
Chair: *Stephan Wagner*

1 - Optimal newsvendor ordering decisions in the presence of supply uncertainty

Dimitrios Pandelis

We study a newsvendor procurement problem with identical unreliable suppliers. For random yield models we derive a sufficient condition under which the optimal total order quantity from more than one supplier is larger than the optimal order quantity from one supplier. We also show that this is always the case for random disruption and random capacity models.

2 - Inventory control with advance supply information

Marko Jaksic

It has been shown in numerous situations that sharing information between the companies leads to improved performance of the supply chain. We study a positive lead time periodic-review inventory system of a manufacturer, who is faced by stochastic demand from his customer and stochastic limited supply capacity of his supplier. The supplier is willing to share the advance supply information (ASI) about the actual future replenishments of the pipeline orders placed by the manufacturer in the recent periods. ASI is provided at a certain time after the orders have been placed and the manufacturer can now use this information to decrease the uncertainty of the supply, and improve its

inventory policy. For this model, we develop a dynamic programming formulation, and characterize the optimal ordering policy as a state-dependent base-stock policy. In addition, we show some properties of the base-stock level. While the optimal policy is highly complex, we develop and test a state-dependent myopic inventory policy. Our numerical results show the benefits of using ASI and based on them we provide useful managerial insights.

3 - Some remarks to the shape of Clearing Functions

Frank Herrmann, Michael Manitz

In production systems occur nonlinear relationships between lead times of orders and the system workload. Analytically, this can be evaluated by queueing theory. Missbauer (2002) relates the expected output to the expected WIP level in an M/G/1 queuing system (assuming steady state). For multiple-product job-shop production systems, a queueing network has to be analyzed. Missbauer (2002) shows that the dynamic behavior of such a production system should be modeled assuming non-stationarity. Building appropriate queueing models that handle both complex structures of the flow of material and non-stationarity is very difficult and often impossible (see Haskose et al., 2002). Consequently, several authors suggest an empirical or simulation-based approach to determine the expected or maximum throughput of a capacitated resource as a function of some measure of the WIP inventory (cf. Asmundsson et al.) and call this clearing function (cf. Missbauer and Uzsoy, 2011). Due to all these approaches, a certain functional shape of the final clearing function is assumed motivated either by queuing-theory results and/or — piecewise - by capacity limits.

The presentation shows a simulation-based approach for determining clearing function. In real production systems the workload is more dynamic and the resource competition is more intensive than in the above mentioned approaches. It is shown, that this causes a significant fluttering of the clearing functions.

■ WC-18

Wednesday, 14:00-15:30 - HS 48

Energy Policy

Stream: Energy and Environment
Chair: *Franz Wirl*

1 - Changes in EU Future Natural Gas Supply and the Role of Turkish Hub

Yuri Yegorov, Jalal Dehnavi

EU dependency on imported natural gas is expected to increase in the next decades; from about 62 % in 2010 to 83 % in 2035 due to reduced domestic production of natural gas (IEA, 2012). Russia is the main gas supplier to EU today, but EU wants to increase diversification of gas imports in order to increase its energy security. Russia also has made relatively expensive efforts to find ways of reducing reliance on unreliable transit countries like Ukraine, and did that by construction of North Stream and plan of South Stream. Due to the problems with the third energy package and low cooperation from Bulgaria in December 2014 Russia has decided to replace South Stream by Blue Stream expansion coming via Turkey. Formally this arrangement satisfies third energy package since Russia will be not a unique country to transit gas to EU via Turkish pipeline. But this may not make EU happier since Turkey receives too much bargaining power as transit monopolist. This sets a problem also to other future gas exporters from Caspian region and Middle East. The article sets up some models about competitive behavior of different gas exporters and bargaining with Turkey over their quotas in pipeline and transit fee. There are possibilities for multilateral cooperation among producers but it is not clear to what extent. We model different scenarios for future gas export to EU by different countries using Turkish hub. We also study both non-cooperative and cooperative equilibria in corresponding games.

2 - Competition for Land and the Role of Water and Forest

Yuri Yegorov

Natural resource scarcity (including land and water) is increasing. Practically all arable land is already used, and it is split between food production and biofuels. The complementary problems is related to deforestation and water scarcity. Functional dependence between forested area and fresh water is assumed. In a simple model (without water) technological progress in agriculture allows to satisfy the food demand of growing population. The oil supply is modeled with Hubbert-type curve that describes oil peak. Exponential growth of both population and agricultural productivity is assumed. Biofuels emerge before oil peak, when marginal cost of oil extraction exceeds the cost of agricultural production. With constant land in use and growing oil scarcity, less land will be used for food production and more for biofuels. The second model adds water and forested area. It considers the positive link between forested area and available water and includes a possibility of partial deforestation. In this case the total arable land may grow, but global agriculture will face water scarcity, both for production of food and biofuels. Partial deforestation can make transition from oil to biofuels less painful. But the major problem in future will be satisfaction of personal water demand. The price of water grows in time to meet growing demand. For low water prices this will increase both food and energy production until water supply is sufficient. If the time of global water and oil scarcity will coincide, there will be complex interaction between these two processes. Those processes are regional since water is not globally tradable.

3 - The allocation of energy conservation

Franz Wirl

This paper tries to address the allocation of energy conservation forty years after Nordhaus' seminal paper on all energy resources. Conservation is a crucial resource and also a major objective of energy policy, in the past and recently in order to mitigate global warming. Unfortunately, the role of conservation as a mean for energy and environmental policies is heavily overestimated and the tasks are misplaced such as utilities running conservation programs. The misperceptions arise from the ignorance of economic aspects such as of the rebound effect, the assumption of stupid and non-strategic consumers. Using a simple demand framework the paper discusses market versus policy failures, and the prospects of conservation programs facing privately informed and strategically acting consumers. The result is that the promised energy conservation targets (20% by the EU for 2020) will not materialize.

■ WC-19

Wednesday, 14:00-15:30 - HS 50

Applications in Energy

Stream: Energy and Environment
Chair: *Florentina Paraschiv*

1 - Optimization of hydro storage systems and indifference pricing of power contracts

Michael Schürle, Raimund Kovacevic, Florentina Paraschiv

We present a medium-term planning model for hydropower production based on multistage stochastic programming. We decide about a production schedule for a horizon of one year from the point of view of a producer that owns pumped-storage hydropower plants. These consist of large, seasonal connected reservoirs. We consider stochastic inflows, stochastic electricity prices and stochastic loads. The produced electricity is sold at the spot market. In addition, we follow an indifference pricing approach for non-standard power contracts to determine the price at which the producer is willing to deliver electricity to individual consumers.

2 - Probabilistic modelling of demand and wind power forecast errors for predicting day-ahead imbalances

Tuomas Rintamäki, Afzal Siddiqui, Ahti Salo

The capacity of intermittent renewable energy sources has increased substantially in Europe in the past decade. Meanwhile, growing forecast errors of their day-ahead generation have increased volumes in the Nordic and German balancing and intraday markets. Because these markets offer high profits, flexible generators are interested in predicting the likely direction and volume of power system imbalances for optimal allocation between day-ahead and balancing markets (Boomsma et al., 2014).

We employ non-parametric probabilistic methods to capture situation-dependent and spatio-temporal information about wind power forecast errors (Pinson et al., 2011). Moreover, we include the forecast errors of heavily temperature-dependent demand, which exhibit correlation

with those of wind power. These factors are shown to improve the performance of time-series models (Klæboe et al., 2015) in predicting the direction and volume of day-ahead Danish energy imbalances.

Consequently, the profitability of the operational allocation between day-ahead and balancing markets should improve. The proposed model can be applied to various markets as it allows for other sources of uncertainty such as solar power.

3 - A fully parametric approach for solving quantile regressions with time-varying coefficients - application to electricity prices

Florentina Paraschiv, Derek Bunn, Sjur Westgaard

We propose a fully parametric approach for solving quantile regressions with time-varying coefficients that is flexible enough to be applied to fundamental models. We therefore propose an algorithm that recursively filters the time-varying coefficients to fundamentals with Kalman Filter, and model parameters are estimated with maximum likelihood, where the likelihood function is built on the Skewed Laplace (SL) assumption. There are some attempts in the literature on quantile regressions to estimate electricity price quantiles by fundamental factors. However, these models assume constant coefficients. To our knowledge, there is no published work so far on fundamental modeling of risk quantiles of German electricity prices with time-varying coefficients to fundamental factors. In this project, we further aim at closing this literature gap. Preliminary results show that indeed, there is evidence for price adaption process of electricity prices to market fundamentals, and it has several patterns across price quantiles. In addition, we show the different impact of renewable energies on electricity prices dependent on the risk level, as well as a substitution effect between the traditional fuels used in production in Germany, gas and coal.

■ WC-20

Wednesday, 14:00-15:30 - ÜR Germanistik 1

Simulation and Optimization for Service Operations under Uncertainty (i)

Stream: Stochastic Optimization
Chair: *Siqian Shen*

1 - Two-Stage Distributionally Robust Unit Commitment with Extended Linear Decision Rules

Yuanyuan Guo, Ruiwei Jiang, Jianhui Wang

Because of fluctuating weather conditions and/or a lack of complete historical data, it can be challenging to accurately estimate the joint probability distribution of the renewable energy. Based on a small amount of marginal historical data, we propose a two-stage distributionally robust unit commitment model that considers a set of plausible probability distributions with a high confidence level. This model is less conservative than classical robust unit commitment models, and also computationally tractable by using extended linear decision rules. Numerical case studies based on real data will be presented and discussed.

2 - Reconstructing Input Models via Simulation Optimization

Henry Lam, Aleksandrina Goeva, Bo Zhang

In some service operations settings, data are available only on an aggregated level as the "outputs' of the system. We consider the inverse problem of calibrating the probability distribution of the "input' model using these data, where the input-output relation is accessible by running stochastic simulation. We formulate optimization programs that aim to match the simulation to the empirical output data via basis functions, coupled with entropy-type objectives, in order to recover the most natural input model that respects the output data. We reduce this formulation, having typically non-convex stochastic constraints, into a parametrized sequence of optimization problems that have convex deterministic constraints but stochastic objective, which is subsequently locally solvable by constrained stochastic approximation. We also discuss how the parameter in the sequence relates to system misspecification bias and the task of model validation with other dimensions of output data.

3 - Distributionally Robust Appointment Scheduling with Random No-shows and Service Durations

Siqian Shen, Ruiwei Jiang, Yiling Zhang

We consider the distributionally robust (DR) server scheduling problem given a fixed sequence of appointments with random no-shows and service durations. The joint probability distribution is ambiguous and only the support and first moments are given. We study a class of DR models that incorporate the worst-case expected cost and the worst-case conditional Value-at-Risk (CVaR) of waiting, idleness, and overtime as objective or constraints. Meanwhile, our models can flexibly adapt to different prior beliefs of the maximum number of consecutive no-shows. The exact reformulations of the DR models lead to mixed-integer trilinear programs. To solve these models, we linearize and derive valid inequalities to strengthen the reformulations that facilitate efficient decomposition algorithms. In particular, for the least conservative (i.e., no consecutive no-shows) and most conservative (i.e., arbitrary no-shows) cases, our derivation provides the convex hull of the mixed-integer feasible region and leads to polynomial-size linear programming (LP) reformulations. We also derive even more compact LP reformulations for the DR CVaR constraints on overtime. We conduct numerical experiments on a set of diverse instances to test our approaches.

■ WC-21

Wednesday, 14:00-15:30 - ÜR Germanistik 2

Two-Stage Stochastic Programs - Glimpses from Theory and Practice (i)

Stream: Stochastic Optimization
Chair: *Matthias Claus*

1 - Two-stage stochastic gate assignment for LTL terminals

Lars Eufinger, Uwe Clausen

We investigate less-than-truckload (LTL) terminals, which are the hubs of the LTL transportation networks and operate as distribution centers with collection and distribution function of goods, e.g. cross docking. The task of a LTL terminal is the accurate and in time handling of shipments between vehicles on short-distance traffic and transport vehicles on long-distance traffic. The performance of a LTL terminal is largely determined by the proper use of the gates. A gate assignment plan should minimize the waiting times of the trucks while having short transportation distances for the goods inside the terminal. However, many uncertain factors influence the planning. Especially fluctuations in the arrival times of vehicles have great impact on the planning process. Thus it is reasonable to use stochastic optimization to create a gate assignment plan which can handle the occurring uncertainties. The developed optimization model is based on the two-stage stochastic optimization using scenario decomposition. A finite number of realizations of the random data, called scenarios, are considered to model the uncertainties. In our two-stage model for the gate assignment 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. By this, we get an iterative matheuristic to determine the gate assignments of the trucks.

2 - Qualitative and Quantitative Stability of Stochastic Dominance Constraints in Recourse Models

Rüdiger Schultz, Matthias Claus

An account of stability results for stochastic dominance constraints induced by linear and mixed integer linear recourse will be given. Special attention will be payed to verifiability of sufficient conditions, in particular for metric regularity.

3 - Weak continuity of risk functionals with applications to 2-stage mean risk models

Matthias Claus

Measuring and managing risk has become crucial in modern decision making under stochastic uncertainty. In 2-stage stochastic programming, mean risk models are essentially defined by a parametric recourse problem and a quantification of risk. From the perspective of qualitative robustness theory, we discuss sufficient conditions for continuity of the resulting objective functions with respect to perturbation of the underlying probability measure. Our approach covers a fairly comprehensive class of both stochastic-programming related risk measures and relevant recourse models and allows us to extend known stability results for two-stage stochastic programs to models with mixed-integer convex recourse and quadratic integer recourse, respectively.

■ WC-22

Wednesday, 14:00-15:30 - ÜR Germanistik 3

Market Design & Optimization II (i)

Stream: Accounting and Revenue Management
Chair: *Martin Bichler*

1 - Truthful Combinatorial Assignment without Money

Salman Fadaei, Martin Bichler

Mechanism design with agents who are not quasi-linear is an important line of research. The well known impossibility theorem by Gibbard and Satterthwaite rules out the existence of any truthful mechanism for general valuations. Approximation of social welfare could be a means to circumvent this negative result in some environments. We analyze combinatorial assignments without money and show that truthful deterministic mechanisms for general valuations and an approximation ratio better than 1/n, n being the number of agents, is impossible. However, for restricted settings we present truthful mechanisms with improved approximation ratios.

2 - Target-Adjusted Utility Functions and Expected-Utility Paradoxes

Robert Day, Mark Schneider, Robert Garfinkel

In this paper, we provide an alternative technique for modeling decisions under risk, in which the decision maker behaves as if having received a new endowment of wealth when given a choice set. We refer to the resulting choice-set-dependent model as Target-Adjusted Utility (TAU) and show that it explains classical violations of EUT, as well as other empirical observations such as the scale-dependence of the Allais paradox and a property we call global size-of-risk aversion, that cannot be explained by the standard specifications of EUT or Cumulative Prospect Theory. Further, using data from three prominent laboratory experiments, we find that TAU is effective in explaining observed behaviors.

3 - Cognitive time distortion as a source of economic risk

Fabian von Scheele, Darek Haftor

We introduce two novel types of risks that are present in the humanly conducted activities of any economic organization, yet that have not been articulated previously. These are the Risk of Cognitive Time Distortion and its consequence, the Risk of Economic Distortion due to Cognitive Time Distortion.

The firstly mentioned risk of Cognitive Time Distortion constitutes a source of operational inefficiencies, output quality deficiencies, as well as human not well-being. The secondly mentioned risk of Economic Distortion due to Cognitive Time Distortion articulates the economic inefficiencies that are produced by the firstly mentioned operational risk. Both types of risks may be identified and monitored, which constitutes an opportunity for their positive management. This paper provides conceptual foundations for the two kinds of risks.

Studies in mental and living sciences have found the empirical fact that humans manifest a temporal experience that diverges from the notion of physical time. This implies that cognitive time typically does not equal to clock time, which results in a cognitive time distortion — e.g. if we ask an employee to seat for sixty minutes and then inform us about her assessment of that time period, she will most probably make an underestimation, giving rise to time leakage; for sure there is a very low probability that her cognitive time will equal to the corresponding physical time. Empirical studies have found this characteristic to be nonlinear and unconditional to all human agents, hence inherent in all operations executed by humans. We introduce a formal elaboration of this cognitive time distortion and its probability as a means to offer a risk assessment approach.

■ WC-23

Wednesday, 14:00-15:30 - ÜR Germanistik 4

Linear and Quadratic Integer Programming

Stream: Integer Programming
Chair: *Dennis Michaels*

1 - Integrally maximal lattice-free polyhedra

Gennadiy Averkov

A polyhedron P is called integral if P is the convex hull of its integral points; P is called lattice-free if the interior of P contains no integral points. Integral lattice-free polyhedra occur in several areas of research including cutting-plane theory for mixed-integer optimization and the geometry of toric varieties.

We call an integral lattice-free polyhedron P integrally maximal if P is not a proper subset of another integral lattice-free polyhedron. It is known that, for each given dimension, there are essentially finitely many integral lattice-free polyhedra that are integrally maximal. However, classification of such polyhedra is a challenging task for each dimension starting from three. Benjamin Nill and Günter Ziegler (2011) asked whether in dimension three integrally maximal integral lattice-free polyhedra are also maximal in a certain stronger sense (within the family of all lattice-free polyhedra). I will present a result that answers the latter question in positive and enables to carry out a complete classification in the case of dimension three.

This is joint work with Jan Krümpelmann and Stefan Weltge.

2 - An FPTAS for minimizing some quadratic polynomials over integer points in polyhedra

Robert Hildebrand

Although integer linear programming is an NP-Hard problem, Lenstra showed that in fixed dimension it can be solved in polynomial time. Modifying the objective function to a polynomial of higher degree can make the problem much more difficult. For instance, the problem of minimizing a quartic polynomial objective function over the the integer points in polyhedra is NP-Hard even in dimension 2. The complexity of minimizing quadratic and cubic polynomials in fixed dimension remains an open question. As a step in this direction, we will present an FPTAS for minimizing some quadratic polynomials in fixed dimension.

3 - A Feasible Active Set Method With Reoptimization for Convex Quadratic Mixed-Integer Programming

Long Trieu, Christoph Buchheim, Marianna De Santis, Stefano Lucidi, Francesco Rinaldi

We propose a feasible active set method for convex quadratic programming problems with non-negativity constraints. This method is specifically designed to be embedded into a branch-and-bound algorithm for convex quadratic mixed integer programming problems. The branch-and-bound algorithm generalizes the approach for unconstrained convex quadratic integer programming proposed by Buchheim, Caprara and Lodi to the presence of linear constraints. The main feature of the latter approach consists in a sophisticated preprocessing phase, leading to a fast enumeration of the branch-and-bound nodes. Moreover, the feasible active set method takes advantage of this preprocessing phase and is well suited for reoptimization. Experimental results for randomly generated instances show that the new approach significantly outperforms the MIQP solver of CPLEX 12.6 for instances with a small number of constraints.

■ WC-24

Wednesday, 14:00-15:30 - ÜR Germanistik 5

Methodology (c)

Stream: Analytics
Chair: *Thomas Setzer*

1 - Towards Managing Systemic Risk in Networked Systems
Vladimir Marbukh

Since along with economic and convenience benefits, interconnectivity brings risks and drawbacks, system designers and operators are faced with problem of balancing the relevant systemic risk/benefit tradeoffs. Assuming that system components are exposed to local risk of overload, overstress, etc., we investigate a tradeoff between the positive effect of risk sharing among system components due to mitigation of the local risks and the negative effect due to risk exposure cascades. We assume that system evolution is described by a Markov process, where system topology is encoded as a directed graph with nodes representing system components and links representing the contagion flow. We define the individual node risk as the probability of this node being in an "undesirable' state, and systemic risk as the individual risk averaged over all the nodes in the system. Since dimension of the Markov description is prohibitively high, we propose a mean-field approximation for individual risks of much lower dimension. Negative externalities with respect to risk exposure due to risk sharing allow us to employ Perron-Frobenius theory to analyze the mean-field system of non-linear, fixed-point equations. We argue that economics drives networked systems towards the boundary of the "normal/operational' region with respect to the system parameters, where the mean-field equations have a "low systemic risk' solution. We suggest that systemic risk of abrupt/discontinuous instabilities should be of higher concern for networked system designers and operators than systemic risk of gradual/continuous instabilities, and propose a Perron-Frobenius based systemic risk management framework, which addresses this concern and quantifies the corresponding risk/benefit tradeoff.

2 - Robustness in Debiasing Judgemental Forecasts
Sebastian Blanc, Thomas Setzer

Corporate planning and decision making in almost all functional units of corporations today heavily rely on forecasts. Assessing and improving the accuracy of the forecasts consequently plays a vital role. Since qualitative expert knowledge is often considered relevant for forecasting tasks, forecasts are often produced by human experts. Judgemental forecasts are however regularly found to be biased, which leads to decreased forecasts accuracy. Statistical debiasing techniques such as Theil's method use past forecasts and corresponding errors to identify systematic biases which can then be removed from future forecasts. Theil's method however exhibits several issues resulting in low robustness. It is well-known that time-varying biases, structural breaks, and outliers can strongly influence the performance. In our work we demonstrate that Theil's method is additionally not robust against certain types of time series, for instance when time series exhibit a trend. The issues of outliers and time-varying biases have been addressed by extensions to the original method in a separate manner, however lacking an integrated view. The robustness against different types of time series has not been addressed yet. Overall, the robustness of the method still limits a broad and possibly fully automated application. In our work, we consequently aim at further increasing the robustness of statistical forecast debiasing approaches. We propose an extension to Theil's method to improve robustness against different types of time series. We integrate existing approaches in order to preserve robustness against time-varying biases and outliers. An empirical evaluation with simulated data confirms the increased robustness.

3 - Bounding the Dimensionality of a Multi-Dimensional Packing Problem's Solution Space
Thomas Setzer, Sebastian Blanc

Efficient algorithms for multi-dimensional knapsack problems typically aim at reducing the number of relevant variables — for example by applying core algorithms or solving subproblems with different sets of variables. Although practitioners are increasingly faced with high-dimensional data and resulting problems, research is focused on instances with few constraint dimensions compared to the number of items. Unfortunately, with increasing problem dimensionality, fewer variables can be fixed to their optimal values. We propose a technique to learn a more concise feature space from the original constraint matrix, where the problem can then be formulated in a lower-dimensional subspace. We successively generate novel constraint dimensions that (1) are mutually perpendicular linear-combinations of the original constraints, (2) have the highest duals amongst all potential candidate dimensions, and (3) allow for a problem formulation where the novel capacity limits depend (only) on the slacks of a previous dimension. The algorithm terminates when no capacity violations are observed in a dimension and an upper bound on the dimensionality of the solution space is found. Empirically learning concise subspaces is widely applied in machine learning, but we are not aware of their applications to develop exact techniques for discrete optimization problems. After introducing the general methodology, we present results of a computational study with benchmark instances from the literature We show that often dimensionality can be reduced even though the pre-solving engines of MIP solvers cannot reduce a problem's size.

■ WC-26

Wednesday, 14:00-15:30 - SR Geschichte 1

Advances in Nonlinear and Conic Programming

Stream: Continuous Optimization
Chair: *Mirjam Duer*

1 - Representations of the interior of the completely positive cone
Patrick Groetzner, Mirjam Duer

Many combinatorial and nonlinear problems can be reformulated as convex problems using the copositive and the completely positive cone. Therefore it is of interest, whether a matrix is in the interior of one of these cones. There are some characterizations for the interior of the completely positive cone, which just provide sufficient but not necessary conditions. The main goal of this talk is to extend these known characterizations using certain orthogonal transformations.

2 - On completely positive modeling of quadratic problems
Van Nguyen, Mirjam Duer

Copositive programming deals with linear optimization problems over the copositive cone and its dual, the completely positive cone. The motivation to study this type of problem is that many nonlinear quadratic problems (even with binary constraints) can be cast in this framework.

In order to have strong duality in conic optimization, strict feasibility of the problems is required. Strict feasibility is also advantagous in numerical solution approaches, for example when inner approximations of the copositive cone are used. We show that not all of the known completely positive formulations of quadratic and combinatorial problems are strictly feasible and discuss conditions which ensure this property.

3 - On proper efficiency in multiobjective semi-infinite optimization
Jan-J Ruckmann

We consider multiobjective semi-infinite optimization problems which are defined by finitely many objective functions and infinitely many inequality constraints in a finite-dimensional space. We discuss constraint qualifications as well as necessary and sufficient conditions for locally weakly efficient solutions. Furthermore, we generalize two concepts of properly efficient solutions to the semi-infinite setting and present corresponding optimality conditions. This is a joint work together with Francisco Guerra Vazquez from the Universidad de las Americas, Puebla, Mexico

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■ WC-27

Wednesday, 14:00-15:30 - SR Geschichte 2

Selected topics in Financial Modelling

Stream: Financial Modelling
Chair: *Erich Walter Farkas*

1 - A general closed form option pricing formula
Ciprian Necula, Erich Walter Farkas

A new method to retrieve the risk-neutral probability measure from observed option prices is developed and a closed-form pricing formula for European options is obtained by employing a modified Gram-Charlier series expansion, known as the Gauss-Hermite expansion. This new option pricing formula is also an alternative to the inverse Fourier transform methodology and can be employed in general models with probability distribution function or characteristic function known in closed form. We calibrate the model to both simulated and market option prices and find that the resulting implied volatility curve provides a good approximation for a wide range of strikes.

2 - Portfolio Selection with Active Risk Monitoring
Pawel Polak

The paper proposes a framework for large-scale portfolio optimization which accounts for all the major stylized facts of multivariate financial returns, including volatility clustering, dynamics in the dependency structure, asymmetry, heavy tails, and non-ellipticity. It introduces a so-called risk fear portfolio strategy which combines portfolio optimization with active risk monitoring. The former selects optimal portfolio weights. The later, independently, initiates market exit in case of excessive risks. The strategy agrees with the stylized fact of stock market major sell-offs during the initial stage of market downturns. The advantages of the new framework are illustrated with an extensive empirical study. It leads to superior multivariate density and Value-at-Risk forecasting, and better portfolio performance. The proposed risk fear portfolio strategy outperforms various competing types of optimal portfolios, even in the presence of conservative transaction costs and frequent rebalancing. The risk monitoring of the optimal portfolio can serve as an early warning system against large market risks. In particular, the new strategy avoids all the losses during the 2008 financial crisis, and it profits from the subsequent market recovery.

3 - Stress-Testing in Asset and Liability Management: A Coherent Approach Extended Version
Mario Schlener

The paper talks about how traditional stress tests are performed and why they are meaningless and couldn't prevent any of the financial crisis. Furthermore it explains how to develop and assign a probability number to a given stress event. In that light we compare and extend the frequentist methodology with the subjective methodology. In the end we apply the approach to a case study in asset management.

■ WC-28

Wednesday, 14:00-15:30 - HS 34

Infrastructure Protection I (c)

Stream: OR for Security
Chair: *Silja Meyer-Nieberg*

1 - Conflicting Evidence in Bayesian Classification: Definition Approaches, Occurrences and Interpretation, Applications in Air and Sea Surveillance
Max Krueger

Bayesian Classification Networks have various kinds of applications, e.g., technical and medical diagnosis, civil and military air and sea surveillance, financial scoring, behavior and pattern recognition. Based on findings (evidence) from different feature nodes (sources) in Bayesian Networks, states' probabilities of query nodes (classification results) are calculated. Conflicting evidence are findings from different sources that carry reliable but apparently contradicting pieces of information, that taken alone, indicate different classification results.

Starting from an operational experts' view regarding conflicting findings, characteristics of such situations are discussed and different definition approaches in Bayesian Networks are given. Typically, conflicts between sources' evidence can be traced back to failed or inaccurate source-measurements, or to situations not covered by the underlying Bayesian model. Occurrences of conflicts in applications due to different underlying causes as well as the difference between a conflict and a rare case is considered in more detail.

This contribution also sketches possible applications of conflicting evidence in air and sea surveillance. Used in Bayesian decision support systems, an alert based on conflicting evidence helps operators to judge reliability of the provided decision support and classification results. In configuration of Bayesian Networks, verification support can be given. Finally in monitoring surveillance systems, source failure detection can be implemented based on conflicting evidence, without the necessity of modeling failure situations in advance and without any cooperation of sources.

2 - Aspects of Network Vulnerability by Using Transportation Networks
Marian Sorin Nistor, Matthias Dehmer, Stefan Wolfgang Pickl

The vulnerability of a system it is an important aspect when studying transportation systems. The serviceability of a transportation system is highly dependent on the risk of a potential disturbance taking place in the system. A complex transportation system can be represented as a network and those have been investigated in several disciplines. Transportation networks considered for this work consist of nodes represented by stations, and links associated to their connections. From the diversity of types of transportation networks, only subway transportation networks will be addressed in this work.

We examine subway networks as a special graph class to study their vulnerability based on the network topology. Also we explore network topologies and see that radial network types are most likely for small subway networks with a heterogeneous character. Also grid-like networks are often found in big cities with a highly developed homogeneous subway transportation network.

A set of 34 worldwide subway networks will be analyzed. So far, these networks have been analyzed by using standard graph measures. In this article we explore the vulnerability by means of network reliability for a more realistic assessment based on several graph measures. Here we tackle the problem for deterministic networks. Also it has been far from trivial choosing the right network measure to capture structural information of a network as any measure captures this differently.

3 - Critical Infrastructure Protection and Simulation-Based Analyses: Risk Identification with the Help of Data Farming
Silja Meyer-Nieberg, Dominik Hauschild, Stefan Luther, Martin Zsifkovits

Critical infrastructure protection represents one of the main challenges for decision makers today. Simulation-based analyses provide an important means allowing to explore scenarios that cannot be studied in real-life experiments. This paper focuses on rail-based public transport and on the interaction of the station layout with passenger flows. Recurring patterns and accumulation points with high passenger densities are of great importance for an analysis since they represent e.g. critical areas for surveillance and tracking and further security implementations. In a first step, the paper focuses on the main station of Munich, a stub station. An agent-based model is developed for crowd behavior in railway stations. The model is configurable with real-life data and can therefore be adapted easily to conduct further analyses. It is used to perform simulation-based analyses focusing on high passenger densities in several scenarios, e.g. during the rush hour or for special events. For the analysis, we apply the methodology of data farming, an iterative, data-driven analysis process similar to the design of simulation experiments. It has been introduced in the context of military operations research in the 1990s and progresses today slowly towards other areas. It uses experimental designs to scan the parameter space of the model and analyses the data of the simulation runs with methods stemming from statistics and data mining. With its help, critical parameter constellations can be identified and investigated in detail. Data Farming represents an interactive approach requiring the researcher to focus the analysis on specific subparts of the parameter space. Therefore, simulation-based optimization methods which can at least partly automate the process are also explored.

■ WC-29

Wednesday, 14:00-15:30 - SR IÖGF

MCDM in System Design and Control (c)

Stream: Multiple Criteria Decision Making
Chair: *Lena Charlotte Altherr*

1 - Optimal Pulse-Doppler Waveform Design for VHF Solid-state Air Surveillance Radar
Nikola Zogovic, Milos Jevtic, Stevica Graovac

Radar-based air surveillance systems are widely used in both military and civilian domains. In such systems, early detection and reliable tracking are crucial for assessing the impact of aircraft behavior. At VHF band, radar cross section of an aircraft is larger than at higher frequencies, making detection easier. Due to this, and their cost-effectiveness, VHF radars are desirable in some air surveillance applications. Contemporary VHF radars are usually equipped with solid-state transmitters (SST) and employ pulse-Doppler (PD) processing. Typically, low pulse repetition frequency (PRF) regime is chosen, ensuring unambiguous range measurements, while Doppler ambiguities are inevitable, which leads to existence of blind speeds. To mitigate this problem, multiple PRFs must be used within a dwell. Low peak

power inherent to SST requires the use of long pulses to achieve acceptable signal-to-noise ratio (SNR) for long distance target returns, which causes significant range eclipsing. This can be compensated by interleaving short pulses, which cause acceptable range eclipsing, with long ones. Thus, to ensure coverage of all ranges and velocities of interest, a complex waveform is required. For a set number of coherent processing intervals (CPI) within a dwell, and assuming that pulse durations are same in all CPIs, design variables determining the PD waveform are pulse durations, and PRFs for each CPI. Design goals are increasing the SNR, efficient mitigation of blind speeds and increasing Doppler resolution. We show that design goals are conflicting with respect to variation of design variables, and that a multiobjective approach is needed to find the optimal design. We propose an approach with a posteriori articulation of preferences, and illustrate it with an example.

2 - Hierarchical Models in Multiobjective Stochastic Dynamic Programming

Tadeusz Trzaskalik, Maciej Nowak

Many decision problems are dynamic by their very nature. In such cases the decision is not made once, but many times. he consequences of decisions become apparent in the near or remote future, which is uncertain by its very nature. Precise assessment of the results of the choices made is usually not possible. In such a situation he or she should, as far as possible, expand his/her knowledge of the problem under investigation. Although it is usually not possible to obtain data allowing to apply a deterministic model, these efforts can result in a partial knowledge thanks to which it is possible to estimate probability distributions describing values of the criteria obtained for the decision variants under consideration. In such situations we apply methods using discrete stochastic dynamic programming approach based on Bellman's optimality principle. We will consider additive multi-criteria processes. At each stage, we estimate the realisation of the process using stage criteria. The sum of the stage criteria gives the value of the multi-stage criterion. We present methods based on hierarchical and quasi-hierarchical approaches. We assume that the decision maker is able to define a hierarchy of criteria and to determine the extent to which the optimal value of a higher-priority criterion can be made worse in order to improve the value of lower-priority criteria. To find the final solution , we start with determining the solutions for which the criteria take values no lower than the thresholds determined by the decision maker. Next, we use the hierarchy to determine the optimal solution of the problem. The final solution is found in interaction with the decision maker.

3 - Multi-criterial Design of a Hydrostatic Transmission System by Mixed-Integer Programming

Lena Charlotte Altherr, Thorsten Ederer, Ulf Lorenz, Philipp Pöttgen, Lucas Siervi Farnetane, Angela Vergé, Peter Pelz

While energy efficiency is a prerequisite for ecological sustainability of technical systems, investment costs and the availability of a system need to be considered for economical sustainability. Thus, the system designer is faced with a multi-criteria optimization problem. When planning the layout of a technical system, the designer has to choose between different components. The decision whether to use a specific component or not affects the economic value of the system: A component can be favorable in terms of investment costs. However, if it needs to be renewed or repaired often, the resulting system downtime can cause high costs. In this case, investing in a more expensive, but more robust component may be the better choice. Usual sustainability considerations mostly relate to a predefined system structure. To increase the sustainability of the overall system, individual components are replaced. It remains unanswered whether a sustainable system requires a completely different system design. With Technical Operations Research (TOR), we present a method which finds the global-optimal system topology which incurs minimal energy, investment and downtime costs. The multi-criterial optimization problem is formulated in the form of a Mixed-Integer Program. We present our approach using the example of a hydrostatic transmission system. The model formulation covers the components' characteristics as well as their failure rates.

■ WC-30

Wednesday, 14:00-15:30 - Visitor Center

Dynamic Planning (c)

Stream: Stochastic Models
Chair: *Rainer Schlosser*

1 - Tackling challenges for infrastructure investment planning under uncertainty

Krystsina Bakhrankova, Arnt-Gunnar Lium, Adrian Werner

Infrastructure development often embodies large and complex investments spanning years and decades. A number of features are common for the majority of such projects regardless of their particular application area: high degree of complexity, vast capital expenditures, significant up-front costs and little or no alternative or re-sale value, coordination and sequencing in a portfolio perspective, and integration with the existing infrastructure. Investment decisions are usually intertwined, combining several planning levels (i.e., strategic, tactical, and operational) and different time scales. Furthermore, uncertainty on various planning levels needs to be incorporated to render flexible and robust solutions. In addition, both market conditions and regulatory requirements often expedite change and call for more comprehensive and integrated decision-making.

To address the above-mentioned challenges we apply stochastic programming. Based on several application examples, a generic model for infrastructure investment decisions is exemplified. Starting with a basic model, focusing only on investments, we outline integration with tactical or operational levels, while handling uncertain information and risk. Finally, we adapt and apply the model to specific topics such as energy-efficient technology investments in buildings, natural gas transport infrastructure design, liquefied natural gas (LNG) supply chain modeling, and investment and maintenance decisions for railway infrastructure.

Thus, this contribution defines typical features of infrastructure investment planning, discusses applicability of stochastic programming, describes a generic model for infrastructure investment decisions and exemplifies its expediency on the selection of four presented topics.

2 - A Robust Optimization Approach in Capacity Planning Under Service Constraints

Hussein Naseraldin, Opher Baron

Capacity planning is an essential and strategic endeavor. Be it in industry or service, it affects the performance of the system at hand. Uncertainty and long horizon are two complicating factors that make that decision even harder to take. In this paper, we propose various models of multi-period capacity planning in an uncertain environment where customers' demand must be satisfied under certain service level constraints in M/M/1 and M/G/1 regimes. We analyze both regimes and derive optimal and approximate solutions. Namely, we compare a nominal model, where uncertainty is ignored, with a robust model, where uncertainty is incorporated into the decision making process, and with a globalized robust optimization model, where rare events are allowed to happen outside the uncertainty set. While typically such settings are tackled with expected approach, we propose applying a methodology that requires no distributional information. Specifically, we utilize the Robust Optimization approach, where the uncertainty is assumed to be bounded and symmetric, and show its impact on the performance. We compare the performance of the proposed methodology to the one where uncertainty is totally ignored. An illustrative example is provided in order to give the flavor of the results.

3 - Dynamic Pricing with Time-Dependent Elasticities

Rainer Schlosser

Many stochastic dynamic sales applications are characterized by time-dependent price elasticities of demand. However, in general, such problems cannot be solved analytically. To determine smart pricing heuristics for general time-dependent dynamic pricing models, we solve a general class of deterministic dynamic pricing problems for perishable and durable goods. The continuous time model has several time-dependent parameters, e.g., discount rate, marginal unit costs, and price elasticity. We show how to derive the value function and optimal pricing policies. On the basis of the feedback solution to the deterministic model, we propose a method for constructing heuristics to be applied to general stochastic models. For the case of isoelastic demand, we analytically verify the excellent performance of this approach for both, large and small inventory levels.

Schlosser, R. (2015). Dynamic pricing with time-dependent elasticities, Journal of Revenue and Pricing Management, advance online publication, March 27, 2015; doi:10.1057/rpm.2015.3

■ WC-31

Wednesday, 14:00-15:30 - Marietta Blau Saal

Health Care Operations Management II

Stream: Health and Disaster Aid
Chair: *Brigitte Werners*

1 - The impact of non-electives on operating room planning
Carla Van Riet, Erik Demeulemeester

The planning of the operating rooms (ORs) is a difficult process due to the different stakeholders involved. The real complexity, however, results from various sources of variability. This variability is important since it greatly influences the trade-offs between the hospital costs and the patient-related performance measures such as waiting times or cancellations. As a result, a need for policies guiding the OR manager in handling the trade-offs arises. Therefore, researchers have investigated different possibilities to incorporate non-elective patients in the schedule with the goal of maximizing both patient- and hospital-related measures. The literature on OR planning, where both elective and non-elective patient categories are involved, proposes various policies. Due to the differences in the research settings however, contradicting results on measures such as overtime and patient waiting time are reported. Decisions on both operational policies as well as on capacity are required to assure timely access and efficiency. Trough discrete event simulation, we show the impact of capacity allocation decisions on various performance measures. The developed simulation model is based on the data of a large OR complex of a university hospital. We include patient categories with different due times, the variability in the arrival process and the surgery durations and rescheduling actions.

2 - Perishability in integrated procurement and reprocessing planning of re-usable medical devices in hospitals
Steffen Rickers, Florian Sahling

This talk focuses on medical devices that can be reprocessed after usage in a specialized section for reprocessing and sterilization in a hospital. After reprocessing, the medical devices can be used again. A new model formulation for the so-called Optimal Ordering and Reprocessing Planning Problem (OORPP) of re-usable medical devices is presented. In the OORP, the limited shelf lives of sterile medical devices as well as capacity constraints of reprocessing and sterilization resources are taken into account. The dynamic demand is known and must be satisfied by purchasing new medical devices and/or by reprocessing used and expired ones. A solution approach based on Column Generation is applied and numerical results are presented.

3 - Influence of appointment times on interday scheduling
Matthias Schacht, Lara Wiesche, Brigitte Werners, Birgitta Weltermann

Patients often contact their primary care physician first, when facing a medical problem. From the pool of patients requesting an appointment with the doctor, two types of requests can be distinguished: urgent or same-day appointments and prescheduled appointments which are booked in advance. By scheduling the number and position of appointment slots one can influence direct and indirect waiting time of patients, the number of urgent overflow patients and the utilization of doctors: If there are little urgent appointments on a given day, a high number of prescheduled appointments can be offered. By this, other days with a high number of urgent patients have more capacity for same-day patients. Since the number of patient requests differs significantly between the seasons, week days and daytime, efficient appointment scheduling has to take different scenarios into account. Additionally, the physician does not know the exact number of requests for the next planning period in advance. Therefore, appointment schedules have to be robust with respect to the performance measures for each scenario. Using an intensive Monte-Carlo simulation, we compare appointment strategies with respect to their performance for different scenarios. We analyze the sensitivity of the solutions with respect to the effect of uncertain parameters.

Wednesday, 16:00-16:45

■ WD-04

Wednesday, 16:00-16:45 - HS 21

Semi-plenary: Cook

Stream: Semi plenaries I
Chair: *Ivana Ljubic*

1 - The Traveling Salesman Problem: A Blueprint for Optimization
William Cook

Given a list of cities along with the cost of travel between each pair of them, the traveling salesman problem is to find the cheapest way to visit them all and return to your starting point. Easy to state, but difficult to solve. In this talk we discuss the problem's history, applications, and computation, laying out a blueprint for future work in optimization and the practical solution of large-scale, possibly intractable, decision models.

■ WD-13

Wednesday, 16:00-16:45 - HS 41

Semi-plenary: Vigo

Stream: Semi plenaries II
Chair: *Richard Hartl*

1 - Fifty Years of Heuristic Algorithms for the Vehicle Routing Problem
Daniele Vigo

More than fifty years have passed since the publication of the well-known savings algorithm by Clarke and Wright, and the design of heuristics for the Vehicle Routing Problem (VRP) has emerged as an extremely active and interesting research area. Virtually all solution frameworks have been benchmarked on VRP and, particularly in the last years, very powerful and general heuristic approaches were developed to solve several variants of this large and practically relevant problem family. Moreover, the spread of industrial software applications for the solution of VRPs which assist the creation of routes for freight and people transportation, recently available also through the web, has on the one side increased the interest on effective and flexible VRP algorithms and, on the other side, has introduced new important challenges in this field. The aim of this talk is to review the most recent advances in the development of heuristics for the VRP by also examining, whenever possible, their computational effectiveness and their practical usability.

■ WD-17

Wednesday, 16:00-16:45 - HS 47

Semi-plenary: Grüne

Stream: Semi plenaries IV
Chair: *Gernot Tragler*

1 - From now to infinity: decision making on a moving horizon
Lars Grüne

Many dynamic decision problems are naturally posed on infinitely or indefinitely long time horizons. This, however, generates various problems for their solutions. Due to the infinite number of decision variables, designing appropriate numerical algorithms is notoriously difficult. Moreover, the necessary data may not be known for the entire future but only for a limited time span. For these reasons, decision making on a moving horizon - also known as receding horizon control or model predictive control - can be an attractive alternative. With this approach, the problem is split up into the iterative solution of problems on a moving and overlapping finite horizon. In this talk we investigate conditions under which such a moving horizon strategy is approximately optimal for the original infinite horizon problem. We highlight

the prominent role of the so called turnpike property, a property of optimal trajectories known in mathematical economy for 70 years. Several examples illustrate the theoretical results as well as potential applications of the moving horizon approach.

■ WD-19

Wednesday, 16:00-16:45 - HS 50

Semi-plenary: Leung

Stream: Semi plenaries III
Chair: *Marco Lübbecke*

1 - Humanitarian Logistics: Models and Challenges
Janny Leung

In April 2015, a magnitude-8 earthquake struck Nepal, killing 8 thousand people and injuring 20 thousand. The full extant and cost of the damages is yet to be assessed. This disaster follows others that are still fresh in the memory: the Ebola epidemic in West Africa in 2014, Typhoon Haiyan in the Philippines in 2013, droughts in North America in 2012, the tsunami in Tohoku Japan in 2011. The reporting on the global effort in response to these and other disasters have placed the spotlight on the importance of logistics planning and management for humanitarian relief. There are four phases of disaster management – mitigation, preparedness, response and recovery — each with different focus and time-scale. In the immediate aftermath of a calamity, the agility for quick response may be most important, whereas for longer-term recovery cost-effectiveness might be the objective. This talk will survey the growing literature on operational research models and methods for humanitarian logistics. Some case studies will also be presented.

Wednesday, 17:00-18:30

■ WE-02

Wednesday, 17:00-18:30 - HS 7

Project Management and Scheduling III (c)

Stream: Scheduling and Project Management
Chair: *Michael Römer*

1 - A decision support system for multi-mode project scheduling, monitoring and control
Oncu Hazir, Klaus Werner Schmidt

Project management contains scheduling the activities, monitoring and controlling them, and should support robustness. In this research, the relationship between scheduling, robustness and control functions, characteristics of data sharing among them and possible integration strategies are theoretically investigated. A decision support system (DSS) that takes account of these interdependencies and supports project managers is developed. Our DSS includes all relevant aspects such as system modeling, solution algorithms as well as a graphical user interface for user input and the presentation of solutions to the project manager. Regarding the underlying model, our DSS makes use of and extends multi-mode project scheduling models. On the one hand, we provide methods for generating schedules for multi-mode projects that are robust under uncertainties using a new robustness measure. In addition, our DSS supports the simulative evaluation of the generated schedules by Monte Carlo simulation with different types of uncertainty. On the other hand, our DSS determines the means and timing of control interventions. A novel integrated project scheduling and control model is developed and new solution algorithms based on the optimal control theory fill an important theoretical gap in project management. A fast solution computation is achieved by a specialized tabu search algorithm. We show the effectiveness and efficiency of the algorithm by testing our method on a large-scale project test bed. This work was supported by the Scientific and Technological Research Council of Turkey (TUBITAK) under grant SOBAG 113K245.

2 - Optimal rescheduling in automotive industry
Markus Kruber, Jonas Witt, Marco Lübbecke

In automotive industry long delivery periods and the Just-In-Time production yield to an inflexible production plan for several weeks. At the same time the exact prediction of incoming customer orders is nearly impossible due to mass customization. However, mass customization is a core concept of automotive industry. In combination with time consumption requirements these conditions generate a challenging problem in practice.

In this talk we will present an algorithm, where mixed integer programming is used to reduce the average waiting period for an ordered car. Based on an existing production schedule the algorithm is able to determine an optimal rescheduling with respect to restrictions in warehousing and customer preferences to guarantee the earliest possible delivery date.

3 - A multi-commodity flow-based mixed-integer linear programming formulation for nurse rostering problems
Michael Römer

This talk proposes a novel multi-commodity flow-based mixed-integer linear programming formulation for a nurse rostering problem with multiple qualifications and shift-based demand. In contrast to classical compact MIP formulations in which most of the roster legality rules are formulated explicitly as linear constraints, the new formulation employs network expansion to consider the majority of the rules in the construction of the network underlying each commodity layer. The results from first computational experiments with problem instances from the Second International Nurse Rostering Competition indicate that proposed model forms a promising new approach for exactly solving nurse rostering problems.

■ WE-03

Wednesday, 17:00-18:30 - HS 16

Diploma/Master Thesis Prizes

Stream: Prize awards

Chair: *Peter Letmathe*

1 - Development, implementation and analysis of exact algorithms for detecting cliques and clique relaxations in networks

Isabel Podlinski

Trukhanov et al. [Computational Optimization and Applications, 56(1), 113—130, 2014] published a combinatorial branch-and-bound algorithm to solve maximum weight pi problems in a simple and undirected graph. This so-called Russian doll search is generally applicable to identify vertex-induced subgraphs fulfilling a graph property pi, which is nontrival, interesting and hereditary. Examples are cliques as well as clique relaxations such as s-plex, s- defective clique, and s-bundle. A key component of a Russian doll search algorithm is the verification procedure. Trukhanov et al. (2014) suggested such a quadratic time verification procedure for s-plex and s-defective clique. The contribution of the master thesis is to present a corrected version for the s-plex problem and a faster version for the s-defective clique problem. The latter has a linear time complexity. Furthermore, the thesis introduces an efficient incremental verification procedure for s-bundle resulting in the first exact algorithm to solve the maximum weight s-bundle problem. Computational results for the benchmark instances of the second DIMACS implementation challenge (1993) are provided.

2 - Exploiting Solving Phases for Mixed Integer Programs

Gregor Hendel

Mixed integer programming (MIP) models have become the tool of choice for solving decision problems from various application areas. Modern MIP solving software incorporates dozens of auxiliary algorithmic components for supporting the branch-and-bound search in finding and improving solutions and in strengthening the relaxation to speed up the solving process. Intuitively, a dynamic solving strategy is desirable during the progress of the solver. In this paper, we decompose the branch-and-bound solving process into three distinct phases: The first phase objective is to find a feasible solution. During the second phase, a sequence of incumbent solutions gets constructed until the incumbent is eventually optimal. Proving optimality is the central objective of the remaining third phase. We propose a phase-based solver that dynamically reacts on phase transitions with an appropriate emphasis on different solving components and strategies. Based on the MIP-solver SCIP we develop and evaluate the use of the phase concept in two steps: First, we identify promising strategies for every solving phase individually and show that their combination is beneficial if an exact recognition of the transition between the second and third phase was practically possible.

This crucial point of the phase concept is then addressed with the introduction of three heuristic transition criteria. The proposed criteria either use a log-linear regression of the progress in the primal bound or global information about the search tree state of the solver. Computational results indicate that the use of our heuristic node rank criterium yields speed-ups similar to those of a phase-based solver that could detect the phase transitions exactly.

3 - An Extended Formulation for the Line Planning Problem

Heide Hoppmann

Line planning is an important strategic planning problem in public transport. The task is to find a set of lines and frequencies such that a given demand can be transported. Standard integer programming approaches for this problem employ some type of capacity or frequency demand constraints in order to cover a given demand. In this paper we present a novel extended formulation for the line planning problem to strengthen such constraints based on what we call 'configurations' of lines and frequencies. Configurations account for all possible options to satisfy a required transportation capacity on an infrastructure edge; they rule out the 'capacity numerics' and make the line planning problem purely combinatorial. The configuration model is strong in that it implies several facet-defining inequalities for the standard model: set cover, symmetric band, MIR, and multicover inequalities. However, the enormous number of configurations can blow up the formulation for large instances. We propose a mixed model that enriches the standard model by a judiciously chosen subset of configurations that provide a good compromise between model strength and size. We present Computational results for large-scale line planning problems that confirm the theoretical findings for the naive configuration model and show the superiority of the proposed mixed model. Our approach shows its strength in particular on real world instances. Although we restrict this presentation to a specific application in public transportation networks, the concept of configurations can also be adapted to other capacitated network design problems and can be generalized to obtain extend formulations for mixed integer programms containing knapsack substructures.

■ WE-04

Wednesday, 17:00-18:30 - HS 21

Combinatorial optimization in graphs (c)

Stream: Discrete Optimization

Chair: *Eranda Cela*

1 - Polynomial-time approximability of the k-Sink Location problem

Yuya Higashikawa, Remy Belmonte, Naoki Katoh, Yoshio Okamoto

A dynamic network N = (G, c, , S) where G = (V, E) is a graph, integers (e) and c(e) represent, for each edge e in E, the time required to traverse edge e and its nonnegative capacity, and the set S, which is a subset of V, is a set of sources. In the k-Sink Location problem, one is given as input a dynamic network N where every source u in S is given a nonnegative supply value (u). The task is then to find a set of sinks X = x1, . . . , xk in G that minimizes the routing time of all supply to X. Note that, in the case where G is an undirected graph, the optimal position of the sinks in X needs not be at vertices, and can be located along edges. Hoppe and Tardos showed that, given an instance of k-Sink Location and a set of k vertices X, which is a subset of V, one can find an optimal routing scheme of all the supply in G to X in polynomial time, in the case where graph G is directed. Note that when G is directed, this suffices to obtain polynomial-time solvability of the k-Sink Location problem, since any optimal position will be located at vertices of G. However, the computational complexity of the k-Sink Location problem on general undirected graphs is still open. In this paper, we show that the k-Sink Location problem admits a fully polynomial-time approximation scheme (FPTAS) for every fixed k, and that the problem is W[1]-hard when parameterized by k.

2 - Precedence Constrained Knapsack Problems and an Application to Open Pit Mining

Andreas Wierz, Britta Peis, Thomas S. McCormick

The open pit mining problem models the excavation process of an open pit mine which is to be extracted over a sequence of time periods. The task is to determine an excavation schedule, that is, an assignment of blocks of material to time periods which maximizes the total profit and meets several types of constraints. The two most familiar types of constraints invoke the total capacity of the available extraction machinery and the contour of the pit during each time period. Only a limited amount of material can be processed during each time period, hence, introducing knapsack type constraints for each time period restricting the total processing quantity. Moreover, the pit has to meet safety regulations in order to keep the mine from collapsing. Prior to the extraction of a block of material, any material in a cone directly above the block has to be extracted. This gives rise to a large number of precedence constraints. It is well-known that the linear relaxation of the described problem can be solved as a minimum cut problem in an auxiliary graph. We view this problem as a precedence constrained knapsack problem and discuss several novel solution techniques for both, the linear relaxation and integer feasible solutions based on structural properties of the underlying polyhedra. The techniques are evaluated from a theoretical and practical point of view.

3 - The (Monotonic) Bend Number of Certain Graph Classes and Consequences

Elisabeth Gaar, Eranda Cela

A graph G is called an edge intersection graph of paths on a grid if there is a grid and there are paths on this grid, such that the vertices of G correspond to the paths, and two vertices are adjacent in G iff the corresponding paths share a grid edge. Such a representation is called an EPG representation of G.

The bend number of a graph G is the smallest non-negative integer k, such that there is an EPG representation of G in which every path bends at most k times. Analogously, the monotonic bend number of a graph G is the smallest non-negative integer k, such that there is an EPG representation of G in which every path bends at most k times and where additionally the paths can only bend up or to the right.

Edge intersection graphs of paths on a grid are an interesting combinatorial object with applications in circuit layout setting and chip manufacturing. The decision problem whether the (monotonic) bend number of a given graph equals a given non-negative integer k is known to be NP-complete for k=1. We show that the monotonic bend number of outerplanar graphs is at most 2 and determine the exact bend number and the monotonic bend number of maximal outerplanar graphs and cacti by stating forbidden subgraphs. Moreover we consider the relationship between the bend number and the monotonic bend number of a graph. Clearly the bend number of a graph is smaller than or equal to its monotonic bend number. It is known, that there are graphs with bend number 1 with a monotonic bend number larger than 1. We extend this result to graphs with bend number k for all non-negative integers k except for k=4 and k=6.

■ WE-05

Wednesday, 17:00-18:30 - HS 23

POM applications II

Stream: Production and Operations Management
Chair: *Dmitry Efrosinin*

1 - Development of Mathematical Optimization Model of a Coal Concentrate Procurement. OAO MMK's Case Study.

Andrey Lipatnikov, Anna Stepanova, Dmitriy Shnaider

Magnitogorsk Iron and Steel Works (MMK) is one of the world's largest steel producers and a leading Russian steelmaking company. OAO MMK is a fully integrated production complex beginning with iron ore preparation process through the ferrous metals downstream production. It is focusing on cost saving of production and competitive recovery that are going hand-to-hand with Blast Furnace Shop's operation. The Blast furnace shop operative performances are significant for corporate economy therefore the cutting of the pig iron production costs is an important corporate task. Our goal is pig iron cost reduction due to coke cost cutting in Blast Furnace shop based on the coal concentrate procurement optimization. The coal concentrate procurement optimization task lies in a selection of the suppliers share participation that provides a minimum coal concentrate cost when the process coke quality defined by production process. The results of the research are: - development of coal concentrate optimal purchase method; - consideration of a possibility to model the process on the OAO MMK available statistical data; - the definition of nonlinear statistical interconnections between indicators of the quality of coal concentrate and coke quality indicators, indicators of the quality of coke and specified coke consumption at the 70-80% level; - reduction of the coal concentrate purchase cost with a similar quality or the coke quality improvement at a fixed price. The further development of the model lies in the area of development of the automated planning of coal concentrate shipment system as well as forecasting of coal concentrate quality considering the actual delivery conditions.

2 - Change Point Detection In Piecewise Stationary Time Series For Farm Animal Behaviour Analysis

Dmitry Efrosinin, Sandra Breitenberger, Wolfgang Auer, Andreas Deininger, Ralf Wassmuth

Detection of the abrupt changes in time series data structure is very useful in modelling and prediction in many application areas, where time series image recognition must be implemented. The known methods for change point detection can be classified in two groups, namely the real-time (online) methods and retrospective (offline) methods. Unfortunatelly these methods can not be efficiently applied to the time series where only the change points with certain constraints must be detected. In framework of the present paper we provide a heuristic method based on moving variance for specified change point detection. The method is applied for the farm animal behaviour analysis based on accelerometer' data providing the 3D acceleration. A herd of dairy calves was equipped with wireless ear tag sensors generating data sequence for each individual animal. The remote automatic monitoring of the data generated by these accelerometers can assist in understanding of the animal behaviour, managing of the farm infrastructure and automatic detection of the animal welfare. This technique can save the farmer's time comparing to the direct observation. The automated feeders controlled by the proposed change point method can e.g. help for optimal adjustment of the feeding plan, measuring of the individual volume of the consumed milk feed and have potential to recognize sick animals in group. The preliminary data analysis has illustrated the possibility to interpret the corresponding stochastic process as a piecewise stationary process. The proposed heuristic method has illustrated above 80% accuracy in identification of the starting and termination of the feeding period and above 90% accuracy in evaluation of the consumed milk feed.

■ WE-06

Wednesday, 17:00-18:30 - HS 24

Lotsizing and Inventory Management I

Stream: Production and Operations Management
Chair: *Horst Tempelmeier*

1 - Evaluating the Reliability of Inventories

Tobias Winkelkotte, Manuela Gärtner, Sascha Herrmann

For replenishment it is necessary to have reliable information about what is currently on stock. It is a well-known issue that this information is not always accessible in the daily business — e.g. due to data errors, lags in data transfers, or asynchronous data-handling.

At Zooplus people have always been aware of the described problem, but did not have a possibility to fix the data. Instead we suggest to give information about whether or not the available data is reliable. This will at least give people a hint of where to have a closer look at.

This analysis is done in two steps: First of all we made the problem visible by plotting the historic inventories of products on stock, including the probable development over time for every day's respective future. This makes it possible to post-evaluate which of the inventories in the past had not been reliable: If an observed inventory level is extremely smaller than the previously predicted value, a data error will be highly probable.

This insight led us in the second step to the development of a reliability measure of the present stock level. The "level of trust' will not only say whether an inventory level is reliable, but will also measure the degree of reliability on a scale from 0 to 1. The basic idea for this is extracted from the well-known possibility theory.

2 - Stochastic Dynamic Capacitated Lot-Sizing under Consideration of Customer Order Waiting Times

Timo Hilger, Horst Tempelmeier

We consider a stochastic dynamic capacitated lot-sizing problem with a constraint on the customer order waiting times. We propose a MIP model that allows to study the effect of the lot-sizes on the probability distribution of the waiting times. A numerical study outlines that the costs and inventory levels as well as the capacity requirements are significantly driven by the customer order waiting time constraints. Additionally, it is shown that the waiting time distribution in a supply chain may have a significant impact on the performance of downstream nodes in a supply chain.

3 - Single Machine Multi-product Capacitated Lotsizing and Scheduling Problem with Supplier Selection and Carrier Selection

Mehdi Bijari, Maedeh Sharbaf

This paper considers a single machine capacitated lot-sizing and scheduling problem with supplier selection and carrier selection. We address a problem in which a producer procures multiple ingredients in multiple periods from multiple suppliers. Each supplier has limited production capacity and a different unit price of the ingredients. The producer produces products to satisfy demand by using the ingredients. Ingredients could be shipped by using different size carriers. A particular size carrier can ship any lot-size up to its full truck load capacity. The transportation cost will be different for different carriers as well as for different suppliers because of carrier size and geographical locations. The problem is to select one or more suppliers as well as carriers and determine the lot-sizes and sequence of products while satisfying the demand requirements and the machine capacity in each period of a planning horizon. In particular, we consider sequence-dependent setup costs that depend on the type of the lot just completed and on the lot to be processed. The objective is to minimize the sum of setup costs, inventory holding costs for products and ingredients, purchasing costs and transaction costs. In fact an integrated production planning and procurement model has been developed. Considering suppliers and

carriers change the production plan include lot-size and sequence. We have developed MIP-based Relax & Fix heuristic for solving the problem.

■ WE-07

Wednesday, 17:00-18:30 - HS 26

Uncertainty in Vehicle Routing

Stream: Logistics and Transportation
Chair: *Dirk Christian Mattfeld*
Chair: *Marlin Wolf Ulmer*

1 - Anticipatory heuristics for a real-world dial-a-ride problem

Ulrike Ritzinger, Jakob Puchinger, Richard Hartl

The advance of information and communication technologies as well as the growing amount of available data allow to gather relevant information for advanced transportation problems. One application is the transportation of patients or elderly people, called the dial-a-ride problem (DARP) in the literature. The aim is to complete transportation requests between pickup and delivery locations under user inconvenience considerations. In this work, we consider a real-world application of the patient transportation problem resulting in the dynamic variant of the DARP. Due to the fact that not all information about transportation requests is available in advance but is revealed during the planning process, it is essential to anticipate future events in the solution approach. Recent research has shown, that exploiting information about future events gained from historical data leads to better results that pure myopic solution approaches. One possibility is to apply anticipation heuristics, where newly arising requests are inserted into existing tours and vehicles have to wait at specific locations to meet possible future requests with minimum late arrivals. Anticipatory heuristics benefit from little computational effort, which is essential in highly dynamic systems, and still provide a good solution quality. Therefore, we implement different anticipation heuristics for the given real-world DARP, by taking advantage of information regarding various aspects such as the likelihood of a request, the spatial and temporal information of a request, and the type of a request. We present first computational results of the performance of the different anticipation heuristics on a set of real-world based instances.

2 - Dynamic Routing for Same Day Delivery

Marlin Wolf Ulmer, Dirk Christian Mattfeld

In recent years, challenges for delivery companies in cities increase. At every time of the day, customer order goods (e. g., groceries) expecting fast and low-priced delivery. Therefore, companies route vehicles to deliver the ordered goods in the urban area. The dispatcher collects the orders in one (planning) period at the depot and serves them in another (execution) period, returning to the depot afterwards. If planning and execution period are at the same day, the company provides same day deliveries (SDD). If after all planned deliveries some free time of the working hours remains, vehicles may start a new (consecutive) tour with a subset of new orders appeared during the execution phase. Nevertheless, many of those dynamic orders might be included online in the current tour by dynamic routing allowing to fulfill an overall higher amount of SDD. For inclusion of new dynamic orders, vehicles have to revisit the depot on their route to pick up the ordered goods before serving the new customers. In this paper, we define a dynamic and stochastic SDD vehicle routing problem and present an dynamic delivery approach, dynamically including new orders in the current tour (DDA). We compare the approach with well-established wait-at-start strategies and planning using consecutive tours (plan-at-home). For the given problem, DDA outperforms the other approaches significantly allowing for a high number of additional SDD.

3 - Data Mining for Problem-Specific State Space Design in Routing Applications

Dirk Christian Mattfeld, Ninja Soeffker, Marlin Wolf Ulmer

We consider a routing problem, where a vehicle serves pickup requests. Some requests are known in advance, but many requests occur dynamically during the day at any point in the service area. Due to working hour restrictions, not every dynamic request can be served. By arrival at a customer, for each new dynamic request, the dispatcher has to decide whether to confirm or reject it. Then, the next customer is served. The objective is to maximize the number of confirmed dynamic requests regarding a time limit. Confirming a request significantly impacts the possibilities of confirming future requests. Therefore, anticipation of future requests is mandatory to achieve high quality solutions. For this problem, anticipation based on value function approximation (VFA) has been proven suitable in recent research. VFA evaluates problem-states (PRS) regarding the expected number of future confirmations. VFA draws on an a-priori defined VFA-state space (VS), evaluating PRS by the assigned VS-values. In some approaches, VS is refined later based on characteristics of the problem to improve VFA. Nevertheless, PRS depend on problem and even instance characteristics. Thus, many areas of the VS may still be inapplicable while others do not consider the PRS in sufficient detail. In this presentation, we propose an approach integrating data mining operations to exploit PRS information and to derive a problem specific a-priori VS. Therefore, we simulate the problem and derive a PRS-classification based on the observed PRS. The resulting classification defines the VS. Preliminary results show that this VS-approach leads to more efficient and effective VFA compared to conventional VS.

■ WE-08

Wednesday, 17:00-18:30 - HS 27

Forecasting - Applications (c)

Stream: Forecasting
Chair: *Oliver Ruhnau*

1 - Inspection of the Validity in the Frequent Shoppers Program by Using Particle Filter

Shinsuke Suzuki, Kei Takahashi

This paper discusses the validity in the Frequent Shoppers Program (FSP) by a model using particle filter's estimation. The FSP is one of marketing methods for a sales promotion in individual consumer level in order to improve sales and profitability. In more detail, a shop issues discount coupons to important customers through the FSP. From a viewpoint of customer relationship management, consumer's purchasing behavior has two characteristics, consumer heterogeneity and dynamic preference changes at individual level. Therefore, it is important for shops to achieve accurate measurement for effects of the FSP and appropriate revenue management through the FSP. We construct a model of category purchase decisions in order to analyze the FSP's effects by using scanner panel data of a retailer. The category purchase behavior is represented by the Nested Logit model, whether consumers choose to buy or not in upper level and which brand to buy in lower level. Parameters in our model are changed each time of purchasing opportunities, then we employ particle filter that enable to estimate parameters dynamically. In our model, explanatory variables include purchasing interval, household inventory, a purchase price, an internal reference price, brand loyalty and capacity of a brand. The internal reference price is standard for consumer to use for evaluating a purchase price. Purchasing interval is the number of days between one day and the last purchase date. Household inventory is capacity consumer keeps at home. Brand loyalty is a scale of consumer's brand preference. Through our model, we inspect the validity in the FSP that retailers have done by using the actual FSP data. In addition, we propose the appropriate contents of the sales promotion using the FSP.

2 - Consistent Forecast-Based Inventory Model

Torben Engelmeyer

Optimal inventory decisions are based on forecasts, but frequently there is an inconsistency between the stochastic inventory framework and the forecast model. While the forecast model usually considers all features of the demand series to produce most accurate forecasts, the stochastic inventory framework often uses only a subset of this information and typically relies on restrictive assumptions, such as Gaussian or Gamma distributed lead time demand. In turn, this means that most of the forecast information remains unused when the reorder levels are optimized, giving rise to non-optimal results in particular when average demand is low or intermittent. In this paper, I develop a framework where the forecast model and the inventory optimization model are integrated. This integrated model is based on the prediction of the future probability distribution by assuming an integer valued autoregressive process as demand process. I apply this model to the demand series of a German wholesaler and show, using simulations, that the integrated method outperforms a wide range of standard forecast/inventory model combinations. When using the integrated model,

I show that the mean inventory level can be lowered while the service level can be increased, compared to the results generated by standard approaches. Thus, the consistent forecast based model is shown to yield dominant replenishment strategies, which improve the overall inventory performance.

3 - Comparative Analysis of Day-Ahead Feed-In Forecasts for Photovoltaic Systems and Economic Implications of Enhanced Forecast Accuracy
Oliver Ruhnau, Reinhard Madlener

The combination of governmental incentives and falling module prices has led to a rapid increase of globally installed solar photovoltaic (PV) capacity. Consequently, solar power becomes more and more important for the electricity system. One main challenge is the volatility of solar irradiance and variable renewable energy sources in general. In this context, accurate and reliable forecasts of power generation are required for both electricity trading and grid operation. This study builds and evaluates models for day-ahead forecasting of the electricity feed-in from solar PV systems. Different state-of-the-art forecasting models are implemented and applied to a portfolio of ten different PV systems. More specifically, a linear model and an autoregressive model with exogenous input are used. Both models include inputs from numerical weather prediction and are combined with a statistical clear sky model using the method of weighted quantile regression. Forecasting-related economic implications are analyzed by means of a two-dimensional mean-variance approach. The economic performance of the two forecasting models is compared in order to quantify implications of enhanced forecast accuracy. Moreover, a mean-variance portfolio analysis is carried out with respect to the economic implications of electricity forecasting.

■ WE-09

Wednesday, 17:00-18:30 - HS 30

Approximate Equilibria

Stream: Game Theory
Chair: *Alexander Skopalik*

1 - On Approximate Equilibria in Network Creation Games
Pascal Lenzner

Many important networks, most prominently the Internet and almost all social networks, are not designed and administrated by a central authority. Instead, such networks have evolved over time by (repeated) uncoordinated interaction of selfish agents which control and modify parts of the network. The Network Creation Game [Fabrikant et al. PODC'03] and its variants attempt to model this scenario. In these games, agents correspond to nodes in a network and each agent may create costly links to other nodes. The goal of each agent is to obtain a connected network having maximum service quality, i.e. small distances to all other agents, at low edge cost.

One of the main drawbacks of this elegant model is the hardness of computing a best response strategy. Given a network and some agent, it is NP-hard to compute the agent's strategy which minimizes her cost. Thus, realisitic agents have to settle for inferior strategies which then yield weaker equilibria.

We survey results on two different views on approximating best response strategies. The first is to restrict the agents to very simple strategy-changes: Given any current strategy, an agent only checks if she can decrease her cost by single edge modifications, which consist of buying, deleting or swapping one edge. The second approach is to restrict the agents to perform only local strategy-changes, that is, they only consider to buy, delete or swap edges within some small neighborhood in the network.

2 - Computing Approximate Nash Equilibria in Network Congestion Games with Polynomially Decreasing Cost Functions
Luca Moscardelli, Vittorio Bilò, Michele Flammini, Gianpiero Monaco

We consider the problem of computing approximate Nash equilibria in monotone congestion games with polynomially decreasing cost functions. Such class of games generalizes network congestion ones, while polynomially decreasing cost functions include also the fundamental Shapley cost sharing value. We design an algorithm that, given a parameter g and a subroutine able to compute an approximated best-responses, computes an approximated Nash equilibrium with an approximation factor linear depending on g. The computational complexity of the algorithm heavily depends on the choice of parameter g. In particular, when g is constant, the complexity is quasi-polynomial, while when g is polynomially related to the number of players, it becomes polynomial. Our algorithm provides the first non-trivial approximability results for this class of games and achieves an almost tight performance for network games in directed graphs. On the negative side, we also show that the problem of computing a Nash equilibrium in Shapley network cost sharing games is PLS-complete even in undirected graphs, where previous hardness results where known only in the directed case.

3 - Approximate Pure Nash Equilibria in Bandwidth Allocation Games
Maximilian Drees, Matthias Feldotto, Alexander Skopalik

In bandwidth allocation games (BAGs), the strategy of a player consists of various demands on different resources. The players utility is at most the sum of these demands, provided they are fully satisfied. Every resource has a limited capacity and if it is exceeded by the total demand, that capacity has to be split between the players. Since these games generally do not have pure Nash equilibria, we consider approximate pure Nash equilibria, in which no player can improve her utility by more than some fixed factor A through unilateral strategy changes. We give both upper and lower bounds for the existence of these equilibria and show that the corresponding decision problem is NP-hard. The approximate price of anarchy for BAGs is A+1. If the demands of the players do not differ too much from each other (e.g. in symmetric games), then approximate Nash equilibria can be reached in polynomial time using the best-response dynamic. Finally, we show that a broader class of utility-maximization games (which includes BAGs) converges quickly towards socially good states.

■ WE-10

Wednesday, 17:00-18:30 - HS 31

Transportation Problems with Synchronization Constraints

Stream: Logistics and Transportation
Chair: *Julia Funke*

1 - A Mathematical Model Proposal for Fleet Planning Problem of a Real-Life Intermodal Transportation Network
Nurhan Dudaklı, Adil Baykasoğlu, Kemal Subulan, A. Serdar Tasan, Can Kaplan, Murat Turan

Recently, there has been a growing interest in fleet planning problems by both researchers and practitioners which operates in the intermodal transportation networks. Indeed, load planning, fleet sizing and the other fleet management issues are much more complex in intermodal transportation systems than the single mode transportation systems. However, there is a lack of studies in literature which emphasize on fleet planning problems in multi-mode transportation systems. In detail, determination of the fleet size and composition constitutes the strategic fleet planning decisions whereas the tactical level decisions incorporate load planning, vehicle allocation/reallocation, empty vehicle repositioning issues etc. Since all of these decisions are interconnected with each other, they should be taken into account in an integrated way. By this way, an appropriate fleet planning ensures not only cost reduction and profit maximization but also high level of customer satisfaction and low environmental effects. In this paper, a mixed-integer mathematical programming model is developed to solve multi-stage, multi-period fleet problems considering load planning and vehicle repositioning decisions. The proposed model aim at minimizing the overall total costs throughout the intermodal logistics network which consist of marine, rail and road freight transport costs. In order to show the validity and practicality of the proposed model, a real-life application is presented in large scaled logistics company in Turkey (This work is supported by Ministry of Science, Industry and Technology of Turkey in the scope of SAN-TEZ project No: 0617.STZ.2014).

2 - Measuring the impacts of synchronization constraints on route composition and sequencing
Jörn Schönberger

The consideration of synchronization constraints leads to several changes of the optimal route set compared to the same situation without the synchronization constraint to be respected. It is easy to compare the implied objective function variation in order to quantify the impact of synchronization requirements at customer locations. Furthermore, makespan prolongations and other temporal properties of a route set can be identified easily. However, from the operational route execution and transport process monitoring perspective changes of the induced route composition and of the visiting sequences are of higher interest. Unfortunately, the analysis of these changes requires a careful comparison of the complex route sets. The existence of equivalent vehicle types let this analysis of changes among the generated route sets become a quite challenging task. In this contribution, we propose a Hamming distance approach to quantity the changes of a route set. The proposed approach is evaluated within computational experiments with the goal to get a better understanding of the impacts of relaxing and shaping synchronization constraints in vehicle routing.

3 - Containers drayage problem with simultaneous routing of vehicles and handling equipment
Milorad Vidovic, Nenad Bjelic, Drazen Popovic

Containers drayage involves the delivery of a full container from an intermodal terminal to a receiver and the following collection of an empty container, as well as the provision of an empty container to the shipper and the subsequent transportation of a full trailer or container to the intermodal terminal. Most of the practical problems as well as researches related to the container drayage problem deal with the routing and scheduling of container vehicles only, where it is implicitly assumed that customer nodes, both pickup and delivery (P/D), are equipped with appropriate container handling equipment able to load or unload container. However, in real world systems some customer nodes, usually smaller companies, may have container P/D requests, although they are not equipped with appropriate handling equipment. For such a customer nodes service provider may leave containers on trailers until they are loaded or unloaded, or customer may rent appropriate handling device to perform container loading or unloading operation. In the second case, to avoid waiting of P/D vehicles it is needed to synchronize moments when vehicle and rented handling device arrive at customer nodes. When the P/D vehicle in a single route have to visit few nodes which are not equipped with appropriate handling devices, arises the problem of simultaneous routing both, vehicles and handling devices so that their arrivals at customer nodes are synchronized. In this paper we address the problem and propose mixed integer linear model to determine optimal synchronized routes of vehicles and handling devices performing containers' P/D operations.

■ WE-11

Wednesday, 17:00-18:30 - HS 32

Eco-oriented logistics planning

Stream: Logistics and Transportation
Chair: *Christian Bierwirth*
Chair: *Thomas Kirschstein*

1 - GHG-emission models for assessing the eco-friendliness of road and rail freight transports
Frank Meisel, Thomas Kirschstein

Intermodal rail/road transportation is an instrument of green logistics, which may help reducing transport related greenhouse gas (GHG) emissions. The GHG emissions of road and rail transports can be calculated by very detailed microscopic models, which determine vehicle emissions precisely based on a prediction of vehicle tours w.r.t. speed, acceleration, technical parameters etc. Besides, macroscopic models are available estimating GHG emissions more roughly from few parameters that are considered most influential. In this talk we present mesoscopic models for road and rail transports that combine the preciseness of micro-models with the simplicity of macro-models. We propose emission models designed for transport planning purposes which are simple to calibrate by transport managers. Despite their compactness, our models are able to incorporate the impact of traffic conditions on total transport emissions. Furthermore, we provide models for rail and road transports on a common basis. We validate the mesoscopic models using popular micro- and macroscopic models and we apply them to artificial and real world transport scenarios to identify under which circumstances intermodal transports can reduce emissions. It is illustrated that traffic conditions, travel speed and country-specific energy emission factors influence the eco-friendliness of intermodal transports most severely. Hence, the particular route chosen for a transnational intermodal transport is an important but so far neglected option for eco-friendly transportation.

2 - A Comparison of Hybrid Electric Vehicles with Plug-in Hybrid Electric Vehicles for End Customer Deliveries
Christian Doppstadt

Reducing exhaust gases and sooty particle is one of the most important challenges for the future, especially, within urban areas, where the health of the inhabitants is endangered. One way to archive this, is the use of hybrid electric vehicles instead of vehicles with a pure internal combustion engine. Within an extensive numerical study we compared the use of hybrid electric vehicles with the use of plug-in hybrid electric vehicles for end customer delivery tours and also included a comparison with pure combustion vehicles to be able to evaluate the potential savings for both types of electric vehicles. We introduce benchmark instances representing typical delivery areas for small package shipping companies to show the functionality of our approach. For small instance sizes, we are able to generate exact solutions with standard mixed-integer program solver software. In addition, we use a simple heuristic solution approach to solve the larger instances with practical and realistic sizes. The comparison of the exact solutions and the ones generated by the heuristic shows that the heuristic is able to solve the problem with an eligible good solution quality and within a prudential calculation time. Finally, it has emerged that the profitability of hybrid electric vehicles and plug-in hybrid electric vehicles highly depends on the structure of the delivery area and the number of customers to serve. Therefore, an individual analysis for each specific case in practice is required. Given this specific real-world data, our solution approach is able to calculate the profitability of hybrid electric vehicles and plug-in hybrid electric vehicles.

3 - Solving a pollution routing problem under emission allocation selection rules
Christian Bierwirth, Thomas Kirschstein

The consideration of environmental objectives more and more affects decision makers in most companies within the EU. Among them, transport service providers are confronted with the regulations of legal authorities to report the environmental impact of offered transport services. Furthermore, shippers demand transport services which are environmental friendly. Hence, the question arises how the total environmental impact of transportation is to be allocated to the corresponding shippers' orders provided they are moved together in one transport process. Among the various theoretically applicable allocation rules, the Euro-norm EN 16 258 recommends an egalitarian allocation, transport-performance based allocation, or a mix of both criteria. In this talk, we formulate a pollution routing problem (PRP) as mixed-integer linear program. The PRP aims to find a tour that minimizes the allocated emissions of a particular transport order. The allocation rules recommended by Euro-norm EN 16 258 are transformed into linear constraints. For the PRP with allocation constraints valid inequalities are derived. To tackle large-scaled problem instances a savings-based heuristic is proposed. The performance of the valid inequalities and the proposed heuristic is evaluated by computational experiments.

■ WE-12

Wednesday, 17:00-18:30 - HS 33

Maritime and Hinterland Logistics

Stream: Logistics and Transportation
Chair: *Anna Kolmykova*

1 - Measurement of port connectivity
Irina Dovbischuk

The paper works out three economical themes which are currently under scientific as well as practical discussion: innovation through better communication and cooperation, regional economic development through cluster formation as was as sustainable-driven logistics economics. The focus is placed on the question, whether and to what extent port connectivity succeeds in promoting innovation from

a regional-economical and company policy perspective as well as contributing to a more sustainable entrepreneurial and regional-economic development. A theoretical approach will be elaborated for this purpose. Against the background of the current scientific discussion about innovation-driven and sustainability-oriented cluster design and cluster management this article constitutes a very interesting and important contribution for the further economic development within business administration and regional economics disciplines.

2 - Optimal transportation mode decision under uncertainty with an intermodal option

Klaus Altendorfer, Stefan Minner

For container transport from an overseas port to the final customer destination, a relevant decision is if the transportation should be conducted by truck or by an intermodal option, including train and truck. In this paper, an optimization problem minimizing transportation costs and backorder costs is developed. The containers arrive with an overseas ship and have to be routed to different final destinations until a delivery date. For a setting with unknown container arrival times, deterministic transportation times for truck and train, and a predefined container delivery date, the optimal transportation mode decision is discussed. The train departure time is either predefined or a decision variable. If containers for which the intermodal option is decided arrive after the train departure time, an unplanned truck transport is scheduled. This unplanned truck transport leads to additional costs. A stochastic model for both transportation modes is created to identify the expected tardiness for each container and evaluate the properties of the optimal decision. Preliminary results show that a delivery date dependent threshold value for intermodal transportation time exists. If the intermodal transportation time is above this value, the truck transportation option becomes optimal. Furthermore, the results indicate the value of information if arrival times are known in advance and the effect of train departure time being either predefined or a decision variable. Finally, according to a set of numerical examples some managerial insights are provided.

3 - Short Sea Shipping Network Integration: the impact on performance

Anna Kolmykova, Hans-Dietrich Haasis

Short Sea Shipping Network is a specific intermodal transportation system with the high degree of integration. It should show a strong performance and some comparative advantages to provide a real alternative to road transport. This paper analyses the relationships between integration and performance in the short sea shipping (SSS) network from contingency perspective. With the aim to contribute to the development of a comprehensive framework, the nature of SSS-Integration and performance measurement are discussed. The integration is a multidimensional concept, which is determined by the degree and level of integration and operationalized through intermodal cooperation and organizational integration. Some additional independent variables and their positive influence on performance are identified. The model can be applied to specific regional contexts in order to recognize the drivers of inefficiency and the reasons behind the lack of success of SSS. An empirical example illustrates the implication.

■ WE-13

Wednesday, 17:00-18:30 - HS 41

Supply Chain Coordination (i)

Stream: Supply Chain Management
Chair: *Stefan Woerner*

1 - Coordination of a Supply Chain of Mobile Applications under Risk Consideration

Tatyana Chernonog, Tal Avinadav, Yael Perlman

We analyze pricing and quality investment strategies in a two-echelon supply chain of mobile applications (apps) under a consignment contract with revenue sharing. Specifically, we focus on how risk-sensitive behavior of supply chain members affects chain performance. The platform provider sets the level of revenue sharing, and the app developer determines the investment in quality and the selling price of the app. The demand for an app, which depends on both price and quality investment, is assumed to be uncertain, so the risk attitude of the supply chain members has to be considered. The members equilibrium strategies are analyzed under different attitudes toward risk: averse, neutral and seeking. We show that the retailer's utility function has no effect on the equilibrium strategies, and suggest schemes to identify these strategies for any utility function of the developer. We find that (i) the revenue sharing contract circumvents the double marginalization effect associated with vertical competition and therefore yields the best selling price for the customer; (ii) a decentralized supply chain sometimes performs better than a centralized one; and (iii) a risk-seeking developer may obtain a higher expected profit than does a risk-neutral developer.

2 - Supply chain coordination under asymmetric information and partial vertical integration

Grigory Pishchulov, Knut Richter, Sougand Golesorkhi

Most of the supply chain coordination models assume either independent firms engaging in a supply chain relationship or a vertically integrated supply chain structure with a common ownership. At the same time, management and organisation studies literature points to the existence of governance forms which involve shared ownership between the business partners — in particular, such forms where one supply chain member owns an equity share in the other. Such supply chain forms can be described by the term partial vertical integration. The literature suggests that a partial vertical integration via equity participation may help the firms to ease contracting problems by aligning firms' incentives, and thus improve the total surplus. We address the above proposition by studying a stylized model of a partially integrated supply chain in which the buyer holds an equity stake in the supplier. Assuming asymmetric information and a principal—agent form of relationship in this supply chain, we investigate optimal contracting between the parties within the classical joint economic lot size framework. We then study the effect of partial vertical integration on the contracting outcomes and demonstrate that the full vertical integration must not indeed be a pre-requisite for achieving supply chain coordination in the presence of asymmetric information; a minority stake may be capable of eliminating the transaction costs owing to information asymmetry and enable coordination. This does not however hold in general; in certain situations, achieving coordination is only possible with a majority ownership share. We also demonstrate that contrary to the intuition, increasing the degree of partial vertical integration may in some cases reduce the level of supply chain coordination.

3 - Bonus or Penalty? Designing Service Level Agreements with Different Performance Targets

Stefan Woerner, Yueshan Chu, Marco Laumanns, Stephan Wagner

We study the coordination of two-echelon supply chains — consisting of a manufacturer and a supplier — by Service Level Agreements (SLA), which are commonly used in practice. The most popular types of SLAs are bonus and penalty contracts, where payments are transferred between the involved parties to redistribute profit if a certain level of service is met or not. We assume that the manufacturer — our focal firm — tries to maximize its own profit while simultaneously making sure that the supplier can achieve a given performance target.

In particular, we focus on Return on Investment (ROI) as well as Reserved Profit (RP) as the supplier's performance measure, and show how to coordinate the supply chain in case of penalty as well as bonus contracts. We show that in the RP case, bonus and penalty contracts are equivalent. However, when using ROI it turns out that bonus contracts are superior to penalty contracts. Furthermore, we show that the overall supply chain performance is decreasing with increasing ROI-target of the supplier, whereas the supply chain can achieve the global optimum if a RP target is implemented. We provide numerical results to demonstrate our insights.

■ WE-14

Wednesday, 17:00-18:30 - HS 42

Optimization of Energy Systems (i)

Stream: Graphs and Networks
Chair: *Arie Koster*

1 - Decentralized Energy Supply Systems: An Adaptive Discretization Approach

Sebastian Goderbauer, Arie Koster, Marco Lübbecke, Björn Bahl, Andre Bardow, Philip Voll

Decentralized energy supply systems are highly integrated and complex systems to be designed to meet time-varying energy demands in, e.g., heating, cooling, and electricity. Various types of energy conversion units with different capacites, nonlinear investment costs, and nonlinear part-load performances can be chosen. This leads to mixed-integer nonlinear programming (MINLP) problems. In this talk, we present an adaptive discretization algorithm for such a synthesis problem consisting of an iterative interaction between mixed-integer linear programms (MIPs) and nonlinear programms (NLPs). Computational experiments on various-sized instances show that this algorithm computes significantly better MINLP solutions in less computation time compared to state-of-the-art MINLP solvers.

2 - Exact Approaches to the Network Design Problem with Relays

Ivana Ljubic, Markus Leitner, Mario Ruthmair, Martin Riedler

This work considers the Network Design Problem with Relays (NDPR). The NDPR arises in the context of network design when given node-pairs need to communicate with each other, but, due to signal deterioration, communication paths have to respect given distance limits. To cover longer distances, equipment for signal regeneration (i.e., relays) may be required. To enable required communications, one has to upgrade the network: by installing new links, by installing relays on the existing network, or by a combination of both. Besides applications in network design, the NDPR arises in the context of e-mobility where relays model charging stations for electric cars and edge costs correspond to road tolls.

In contrast to previous work on the NDPR, which was mainly focused on heuristic approaches, we propose new exact approaches based on different mixed integer linear programming formulations for the problem. We develop Branch-and-Price and Branch-Price-and-Cut algorithms that build upon models with an exponential number of constraints and variables. In a computational study, we analyze the performance of these approaches for instances with different characteristics.

3 - Polyhedral Aspects of Power Grid Design

Arie Koster, Stephan Lemkens

Designing a power grid is a highly complex tasks as it involves nonconvex, nonlinear equations. In this talk, we study the polyhedron resulting from (i) linearizing the nonlinearities and (ii) projecting out all variables, except the design variables. We provide sufficient conditions for the polyhedron to be full-dimensional and discuss the strength of valid inequalities. Some computational results conclude the talk.

■ WE-15

Wednesday, 17:00-18:30 - HS 45

Decision Analysis & Optimization Methods

Stream: Simulation and Decision Support
Chair: *Fatima Dargam*

1 - Decisions on optimal product portfolio plans: Can they be derived from consumers' psychographic variables?

Friederike Paetz

It is often stated, that psychographic variables lack the ability to reflect consumers' preference heterogeneity. This directly implies psychographic variables' inappropriateness for deriving beneficial decisions for product portfolio plan optimizations in producing companies. However, literature has hardly focused on consumers' personality as a specific type of psychographic variables. This contribution is meant to fill this research gap and operationalizes personality with the well-established Five-Factor approach. Using an empirical conjoint choice study in the product category of alcoholic beverages, evidence was found, that different personality types seem to differ in their preferences for specific product components. Finite Mixture Multinomial Logit models were estimated to achieve benefit-segments. It could be validated, that those preference-based segments differ in their personality structure and display different utility maximizing product solutions, respectively. So, obviously, personality as a specific aspect of psychographic variables bears the ability to reflect preference heterogeneity. This alleviates the general statement of psychographic variables' inappropriateness as core variables for product portfolio plan decisions and demonstrates their ability as decision support variables for the optimization of product portfolio plans.

2 - Portfolio optimization in the downside risk framework with loss aversion

Cristinca Fulga

In this paper, we consider the portfolio problem in the Mean-Risk framework and complement this approach with the consideration of investor's loss aversion. We propose a risk measure calculated only with the downside part of the portfolio return distribution which, we argue, capture better the practical behavior of the loss-averse investor. We establish the properties of the proposed risk measure, study the link with stochastic dominance criteria, point out the relations with Conditional Value at Risk and Lower Partial Moment of first order, and give the explicit formula for the case of scenario-based portfolio optimization. Moreover, in the proposed Mean-Risk model the investor's loss aversion is also captured in the first objective function where the usual expected return is replaced with an expected return - based function that presents the general characteristics of loss aversion. We analyze the efficient portfolios provided by the proposed model and compare them from different viewpoints with the classical Mean-Risk models, Mean-Variance, Mean-Conditional Value at Risk and Mean-Lower Partial Moment of first order. The comparisons between the models were performed using real data. In each case, we describe and interpret the results and emphasize the role and influence of the values of the loss aversion parameters on the optimal solutions.

■ WE-16

Wednesday, 17:00-18:30 - HS 46

Cycle Packing (c)

Stream: Graphs and Networks
Chair: *Peter Recht*

1 - A Dynamic Programming Approach for the Maximum Cycle Packing Problem

Peter Recht

Let G= (V,E) be an undirected graph. The maximum cycle packing problem is to find a collection C = C1, C2, . . . , Cs of edge-disjoint cycles Ci in G such that the cardinality s of the collection is maximum. In general, this problem is NP-hard. It is proved that if a collection C of edge-disjoint cycles satisfy the condition that -among all such collections- it is a minimizer of the total sum of the square length of all its cycles, then C is a maximum cycle packing. This result leads to a dynamic programming approach for getting "min-max" cycle packings of G. An A*-shortest-path procedure on an appropriate network N is presented to solve this problem. Within this procedure a special monotonous node potential heuristic is used.

2 - Maximum cycle packings in fullerene graphs

Stefan Stehling

The field of applications for fullerenes ranges from photovoltaic installations to medical use: There is an intense research throughout many areas ongoing. As a fullerene can be represented by so called fullerene graphs their chemical properties might relate to graph-theoretical properties of the corresponding polyhedral graphs. The lecture will focus on the determination of maximum cycle packings in fullerene graphs. First, structural properties of fullerene graphs are used to give upper bounds for the cardinality of such packings. A method is presented that determines fullerene graphs attaining these bounds. For nanotubes and Leap-Frog-Fullerenes suitable extensions of the approach are performed. So, an additional graph theoretical criterion is introduced to classify fullerenes.

3 - Maximum Cycle Packings by Decomposing a Graph into 3-Connected Components

Christin Otto

Let G=(V,E) be an undirected graph. The maximum cycle packing problem is to find a collection C=C_1, ... , C_s of edge-disjoint cycles C_i in G such that the cardinality s of the collection is maximum. In general, this problem is NP-hard. An approximation algorithm for

computing C on 2-connected (multi-)graphs G without loops is presented. Based on Tutte splits and a representation of the 3-connected components of G by SPQR-trees the approach can be considered as a generalization of decomposing graphs into blocks. For the class of generalized series-parallel graphs the algorithm computes the optimal solution.

■ WE-17

Wednesday, 17:00-18:30 - HS 47

Allocation and Coordination (c)

Stream: Supply Chain Management
Chair: *Marc-Andre Weber*

1 - Multi-Period Supply Allocation In Advanced Planning

Alexander Seitz, Martin Grunow

In cases of short supply, companies need to decide, which demand of which customers to fill. For this purpose, advanced planning systems contain so-called allocation planning (AP) procedures, which directly affect the short and long term profitability of a company. A multitude of partly conflicting goals and parameters has to be considered. We propose a novel AP algorithm allocating supply to a given number of individual customers and customer groups. Different from previous work on advanced planning, our approach explicitly considers (1) contractual obligations, the criticality of use for the customer and strategic minimum service level requirements, (2) product substitution over multiple periods respecting the willingness to substitute of individual customers, and (3) customer demand forecasts and their accuracy. Further, we (4) simultaneously take profit maximization and service level targets as well as (5) unfulfilled demand from previous periods into account. We also analyze the performance of our approach in a case study from the semiconductor industry.

2 - Omni-channel inventory allocation of seasonal goods

Andreas Holzapfel, Alexander Hübner, Heinrich Kuhn

Traditional retailers need to create new operations models that cope with online and bricks-and-mortar requirements in an omni-channel strategy. One of the major problems of retailers in this context is the allocation of inventories to the physical stores and the distance retail channel. An adequate allocation is thereby especially important for seasonal goods, due to the limited selling season. While inventory allocation is a well-known research topic in literature, an explicit application under consideration of the processes and costs relevant for omni-channel retailing is missing so far. Therefore, we holistically investigate the phases and processes coming along with inventory allocation within a selling-season. This builds the foundation to propose a stochastic dynamic program. Basing on a distribution structure with a central omni-channel distribution center (DC) and a set of bricks-and-mortar stores, the program supports the decisions, when to allocate how many items to the stores and the omni-channel DC. Additionally the optimal pricing policy for the discount phase is selected. We solve the problem for a dual-channel setting on a single SKU basis, taking into account the relevant phase-specific cost components. Finally, we apply the suggested solution approach to a real life case of a European fashion retailer and provide sensitivity analyses to gain managerial insights.

3 - Coordination as target of model-based optimization approaches to APS-Systems

Marc-Andre Weber, Rainer Leisten

Research on Hierarchical Planning Systems for Production Planning started in the 1970s (e.g. Hax and Meal, 1975/Gabbay, 1979/Axsäter, 1986) and developed ever since. More recent approaches were driven by faster computational capacities and an integrated view of Supply Chain Management. Modeling approaches were extended to the supplier as well as to the customer side of the Supply Chain (e. g. Pibernik, 2005/Stadtler, 2007/Günther and Meyr, 2009).Advanced Planning Systems [APS] focus on an integrated view on supply chain planning tasks within various planning horizons (Stadtler et. al. 2010), including procurement, production, distribution and sales on a long-term, mid-term and short-term level (known as the Supply Chain Planning Matrix [SCPM], see Rohde et. al. 2000). We propose a modified integrating optimization approach. A simple single linear model for each field within the SCPM is designed, resulting in 12 models. We refer to a setting as follows: Long-term models are for basic decision selections of suppliers, locations, products, etc. Mid-term models specify these decisions on a quarterly basis and short-term models generate jobs for make-to-stock production in simple flow shops, including available-to-promise decisions. Based on this, a Distributed Decision System (Schneeweiss, 2003) is established for which we propose coordination approaches with a focus on decentralized decision forming. Coordination takes into consideration feasibility of the solutions of the models as well as different objective functions of the various models and optimality criteria of the total system. The scope of all models is to maximize profitability by simultaneously minimizing costs. By using coordination approaches, a near-optimal solution should be provided.

■ WE-18

Wednesday, 17:00-18:30 - HS 48

New Directions in Energy Research

Stream: Energy and Environment
Chair: *Reinhard Madlener*

1 - Investments in Flexibility Measures for Gas-Fired Power Plants: A Real Options Approach

Barbara Glensk, Christiane Rosen, Reinhard Madlener

The promotion of renewable energy in Germany by means of guaranteed feed-in tariffs and preferential dispatch leads to difficulties in the profitable operation of many modern conventional power plants. Nevertheless, conventional power generation technologies made more flexible in their operational characteristics can contribute to balancing electricity supply and demand. For this reason, the operational flexibility of conventional power plants becomes important and has economic value. The focus of this research is on high efficiency gas-fired power plants; we tackle the following research questions: How can already existing conventional power plants be be operated more flexibly and thus be made more profitable? Which flexibility measures can be taken under consideration? What is the optimal timing to invest in flexibility measures? To answer these questions we propose an optimization model that is based on real options analysis (ROA) for the flexible operation of existing gas-fired power plants. In the model, the economic and technical aspects of the power plant operation are explicitly taken into account. Moreover, the spark spread, which is an important source of uncertainty, is used by the definition of the flexible plant operation regarding different load levels and corresponding efficiency factors. The usefulness of the proposed model is illustrated with some case study considering the decision process.

2 - Well Drainage Optimization in Mining Accounting for Electricity Price Uncertainty

Reinhard Madlener, Mathias Lohaus

Coal production in the Ruhr area in Germany will be abandoned in 2018. Nevertheless, it is indispensable to control the mine water levels, as the mine water must be strictly kept separate from the sediment layers carrying the ground water. Hence mine water must not exceed a predefined safety margin. Being the responsible party for the termination of subsidized coal mining in Germany, RAG uses wells to control the mine water levels in the old shafts. The maintenance costs for these wells are among the largest expenses faced by the RAG. The wells of the old mines offer the possibility to use underground flood detention basins. These flood detention basins can be used as storage facilities to minimize electrical energy costs of safeguarding the wells. In this study, we investigate how pump control optimized with respect to the prevailing electricity prices impacts the operating costs. The mathematical optimization of the well takes the dependency of electrical power with the heaved water volume and the changing water level into account. The nonlinear dependency is transformed into a linear optimization problem in multiple stages. First, a superstructure optimization is used. Subsequently, the characteristic pump profiles are linearized piecewise, resulting in a simplified problem where only the multiplication of a binary and a positive real variable remain. The multiplication of the two variables is replaced by a new variable; this way, the optimization problem is converted to a mixed integer linear optimization (MILP) problem. The results of the superstructure optimization yield the optimal pump size and the minimal cost involved. The results of the superstructure optimization are then used to execute the maintenance optimization. Well costs can be reduced significantly.

3 - Risk Analysis of Energy Performance Contracting Projects in Russia: An Analytic Hierarchy Process Approach

Maria Garbuzova-Schlifter, Reinhard Madlener

In Russia, the market for Energy Performance Contracting (EPC) projects is just emerging. But in spite of promising forecasts, the progress of EPC projects has so far been slow. A successful realization of EPC projects requires a sound understanding of the main project risks. Hence success highly depends on effective risk analysis and management, which should be essential parts of daily business activities of Energy Service Companies (ESCOs) and Energy Service Providing Companies (ESPCs) engaged in EPC projects in Russia. This study presents a new risk analysis framework that is applied to three sectors: (1) industrial; (2) housing and communal services; and (3) public. Empirically, general risks associated with EPC projects, identified from the international ESCO literature, were validated by Russian EPC practitioners in expert interviews. An Analytical Hierarchy Process (AHP) approach was used to rank the identified risks (risk factors and causes of risk) in terms of their contribution to the riskiness of EPC projects. Data were obtained from a web-based questionnaire survey conducted among Russian ESCOs and ESPCs. For improving consistency of the obtained AHP results, the Maximum Deviation Approach (MDA) for 88 matrices and the Induced Bias Matrix Model (IBBM) for 33 and 44 matrices were applied. Causes of risk related to the financial and regulatory aspects were indicated to contribute most to the riskiness of EPC projects performed in the three focus sectors.

4 - The Future Expansion of HVDC Power Transmission in Brazil: A Scenario-Based Economic Evaluation

Christian Köhnke-Mendonca, Christian Oberst, Reinhard Madlener

In this paper we present an economic evaluation of several scenarios to assess the future need for long-distance High Voltage Direct Current (HVDC) transmission lines for the Brazilian power sector. The scenarios are developed in light of current challenges and energy policy discussions of Brazil's hydrothermal power system. These include an increasing electricity demand, limited development potential of large hydropower plants, and the accompanying discussion on the need to diversify the power matrix and to expand the long-distance power transmission system. HVDC projects already implemented in Brazil demonstrate that HVDC is a promising technology for long-distance power transmission. The scenarios investigated focus on minor and strong expansion of hydropower, wind power, and solar power in Brazil. Based on these scenarios, we determine the required additional HVDC transmission lines per scenario using technical and economic criteria. The analysis is done by following a two-step approach. First, linear optimization is performed to find a minimum-cost transmission design, in which we account for seasonality in the power supply. The minimum-cost transmission designs are then further scrutinized using several energy economic criteria, in order to determine whether these results actually correspond to a credible need for HVDC under the corresponding assumptions. The results provide important arguments for a stronger utilization of new renewables in Brazil. While an expansion of the existing hydropower capacity would most likely entail high transmission costs, an expansion of the wind power, solar power, or biomass capacities does not necessarily so.

■ WE-19

Wednesday, 17:00-18:30 - HS 50

(c) Energy Markets

Stream: Energy and Environment
Chair: *David Wozabal*

1 - Modelling the EU ETS

Andreas Schröder

The EU emissions trading system (ETS) is undergoing structural reform with to upcoming political decisions on the Market Stability Reserve (MSR) and 2030 targets ahead of the Paris 2015 climate conference. In the light of these changes, the market promises to enter into some new equilibrium which fundamental supply & demand models may help in assessing from a quantitative point of view. Different modelling approaches co-exist: One school of models looks into actual trading balances which is particularly useful for short- to mid-term trading purposes. Adding to this, econometric and technical chart analysis are often used for trading this time horizon. Another stream of models uses the long-term structural balance based on abatement costs to derive prices but falls short of explaining current price volatility. We discuss different methodologies and explain the new situation imposed with the upcoming MSR mechanism. Analogies are made with the modeling of related certificate markets (e.g. Nordic green certificates market), in which banking of certificates operates in a similar manner. We present data requirements and challenges in conjunction with an overview of the most commonly used service providers.

2 - Bidding in German Electricity Markets — Opportunities for CHP Plants

Nadine Kumbartzky, Matthias Schacht, Katrin Schulz, Brigitte Werners

With the liberalisation of the German electricity markets, sale of excess power offers additional revenue potential for energy supply companies. However, a high share of renewable energy feed-in leads to a decrease of electricity market prices. Thus, generation companies are forced to incorporate new trading strategies. Due to the increasing importance of combined heat and power (CHP) plants, a power supply company that operates a CHP plant with heat storage is considered. In Germany, the electricity market is composed of a spot and balancing market. On the day-ahead spot market, power is traded for each hour of the following operation day. Since electricity supply and demand have to match exactly at all times, balancing power is needed. To secure sufficient reserve capacity, an online platform is operated by the transmission system operators for a joint tendering of control reserve. We consider a power supply company that engages in both electricity markets. When bids are submitted, clearing prices as well as dispatched volumes are uncertain. A new modelling approach is presented to support generation companies scheduling their participation in the different markets. To derive optimal bidding strategies, we formulate the bidding problem as an innovative and detailed multistage stochastic programming model taking into account the sequencing of market clearing. The optimisation model simultaneously determines the combined usage of the CHP plant and heat storage. An exemplary case study illustrates the benefit from coordinated bidding in the sequential electricity markets.

3 - Error Correction Neural Networks for Electricity Price Forecasting: Evidence from NWE Markets

Merlind Weber

Forecasting electricity prices is important to market participants in order to optimize their generation portfolio and to reduce their risk exposure. On the German electricity market, a priority feed-in regime for renewable energy has been established which resulted in a rapid capacity growth of renewable electricity. This has led to fundamental changes in the dynamics of short-term energy markets causing increased price volatility. At the same time, market coupling on European power markets had advanced leading to an increased price convergence. Addressing these issues, we apply ensembles of Error Correction Neural Networks to simultaneously forecast day-ahead prices and loads of the EEX Phelix and French power markets. Comparing the results to a recurrent neural network model and a linear model, the ECNN model outperforms on average both benchmarks.

4 - Contribution of variable renewable energies to generation adequacy - A locational marginal approach

Simeon Hagspiel

This paper investigates the contribution of variable renewable energies, such as wind and solar power, to the reliability of power systems. Specifically, we propose a locational marginal approach to measure contributions of individual units to generation adequacy. We apply concepts from cooperative game theory and the Shapley value for allocating payoffs according to these locational marginal contributions in a "fair" way. As a consequence, a number of desirable properties is achieved, including static efficiency and the effective support of dynamic efficiency of the system. Especially, the suggested approach achieves strikingly better results compared to other more simplistic approaches. In practice, it could be integrated in (current or future) support mechanisms for renewable energies to incentivize investments in projects contributing (besides sustainability) to system reliability in a more effective way. It may also serve as an important input to better design capacity mechanisms, e.g., while determining system reliability and capacity needs or for adequate prequalification purposes. In order to demonstrate the practical relevance and applicability of our approach, we investigate an empirical example based on wind power in Germany. We thereby confirm our analytical findings and contribute to ongoing academic as well as political discussions about the future design of renewable support schemes and capacity mechanisms.

■ WE-20

Wednesday, 17:00-18:30 - ÜR Germanistik 1

Risk measures and their use in stochastic optimization (c)

Stream: Stochastic Optimization
Chair: *Georg Pflug*

1 - The Benefit of Exploiting Conditional Independences in Network Reliability Calculations

Tamas Szantai, Edith Kovacs

Network reliability can be determined as the probability of the union of events representing the permeability of all paths from the source node to the sink node. In the case of real size networks we cannot determine all paths so the network reliability can be only approximated by using the first k most reliable paths from the source node to the sink node. In this talk we will give a method for discovering conditional independences between the permeability of paths which can be used when approximating the network reliability. We will present numerical results for small networks when the exact network reliability can also be determined. In the case of randomly generated large sized networks we will compare the approximation to simulation results.

2 - Multivariate Risk Tomography

Jinwook Lee, Andras Prekopa

cance of the new risk measure goes beyond risk calculation to characterize possible scenarios, lending itself to risk management techniques.

3 - Price Risk Based Power Portfolio Optimization with Liquidity Constraints

Gergely Mádi-Nagy

Electricity prices are substantially more volatile than any other commodity price. The extreme price volatility of wholesale electricity markets requires risk management in trading decisions. Risk management includes hedging, portfolio optimization, risk measurement and asset valuation.

This paper provides a technique based on stochastic programming to optimally solve portfolio (re)hedging problem. The power portfolio consists of a net consumption curve (typically based on bilateral contracts) and several standard derivative products. Risk aversion is modeled by the Conditional Value-at-Risk methodology. The price volatility is presented by price curve scenarios. In the asset valuation the finite liquidity of power markets are taken into account. The model has been implemented as a module of the Energy-Trading Informatics Platform of IP Systems. Realistic case study are presented and analyzed by the aid of this module.

The project is supported by the Research and Technology Innovation Fund, Hungary. Project ID: PIAC_13-1-2013-0012

■ WE-21

Wednesday, 17:00-18:30 - ÜR Germanistik 2

Gas Transportation and Applications in Engineering

Stream: Stochastic Optimization
Chair: *Claudia Stangl*

1 - Optimization on gas networks governed by the isothermal Euler equations

David Wintergerst

The rise of renewable energy and the decreasing popularity of nuclear energy are in the center of public attention for the last years. Changes in the energy market led to the need of an efcient and affordable energy supply. In this context gas will play an important role for the next decades. It is sufciently available, quickly obtainable, storable and can be traded. The physical behavior of gas pressure and gas ow can be described by the Euler equations — a system of hyperbolic balance laws. We focus on the stationary case for constant temperature. The network structure is modeled by coupling conditions for the ow and the density. In order to take care of the different behavior of real gas compared to ideal gas a model suggested by the American Gas Association for the compressibility factor is used. The pipe friction coefcient is nonlinearly depending on the Reynolds number and the roughness factor. Under the assumption that the system has reached its equilibrium, the partial differential equations reduce to a nonlinear ordinary differential equation. We present analytical solutions on networks, which are not only more exact than many known models such as Weymouth's equation, but also give structural insight other models fail to offer. For the solutions on networks the monotonicity properties of the solution on one pipe are decisive. The analytical solutions can be used as a basis for continuous optimization problems. One example problem is to nd the pressure in a source node such that the pressure in the remaining nodes stays in a certain interval.

2 - A Data Based Multiparametric Programming Methodology Using Ordinary Kriging Metamodels

Ahmed Shokry, Antonio Espuña

The MultiParametric Programming (MPP) is an efficient approach widely used in process engineering to manage the uncertainty in some of the process model parameters when this model is used for optimization. It enables to obtain the optimal solution as closed form mathematical functions of the Uncertain Parameters (UPs). But, many reasons can hinder the MPP application, as the difficulties to get a clear mathematical model (black box, sequential simulation based models), and the mathematical complexity of the resulting model (high nonlinearity).

This work proposes a multiparametric study method that can be used in such cases, based on ordinary kriging models which are trained to accurately describe the optimal solution as a function of the process UPs, using inputs-outputs training data (UPs-optimal solutions). The data is generated by the optimization of the original process model using different combinations of the UPs to find the corresponding optimal decisions and objective values. The method is tested with simple mathematical examples, and applied to a benchmark problem form the MPP literature. The results show that the method can accurately predict the optimal solutions via simple interpolations, saving the huge amount of the optimization time, using relatively small number of training data. Even more, a significant difference with the results of the standard MPP method; in all the tested cases, a single relation was enough to correctly reproduce the model optimal parametric behaviour.

Financial support received from the Spanish Ministry of Economy and Competitiveness and the European Regional Development Fund, both funding the Project SIGERA (DPI2012-37154-C02-01), and from the Generalitat de Catalunya (2014-SGR-1092-CEPEiMA), is fully appreciated.

3 - Building Nominations for Real-Life Gas Transportation Networks

Claudia Stangl, Benjamin Hiller, Robert Schwarz

Checking the feasibility of bookings belongs to the key tasks in gas pipeline operation. The customer orders a booking, that means a maximal in- or output of gas, at a node on the underlying gas network. The gas transportation company has to decide whether to agree to the booking or not. In its most basic form, they have to be able to sent all balanced nominations within the bookings on the exits and entries through the network. In this talk a method is presented to generate nominations for a given booking to decide afterwards whether the booking is feasible or not.

■ WE-22

Wednesday, 17:00-18:30 - ÜR Germanistik 3

Performance Measurement and Incentives (i)

Stream: Accounting and Revenue Management
Chair: *Thomas Pfeiffer*
Chair: *Markus Grottke*

1 - Goal congruence and preference similarity between principal and agent with differing time horizons — setting incentives under risk
Josef Schosser, Markus Grottke

We analyze in a parsimonious model how goal congruence or preference similarity can be obtained when both principal and agent are risk-averse and when a setting prevails in which the agent may have a shorter time horizon than the principal. Intertemporal dependencies in risky cash flows will be taken into account. Our paper offers a general roadmap designed to solve this problem and subsequently proceeds down on a particular path, producing the following results. First, we identify preferences that make it possible for the unique properties of the residual income measure to be preserved when both agent and principal are risk-averse. Second, we are able to demonstrate that, in addition to the preferences identified, constant absolute risk aversion ensures that the agent's and the principal's risk attitudes are reconciled. Finally, in building on earlier results produced by Rogerson (1997, J. Political Econom. 105(4) 770-795) and Reichelstein (1997, Rev. Accounting Stud. 2(2) 157-180), we find a new risk allocation schedule for this setting, which, when cash flows are normally distributed, permits the achievement of both goal congruence and preference similarity. The information requirements needed to establish this procedure are exposed.

2 - Relative Performance Evaluation, Strategic Differentiation and Endogenous Correlation Levels
Peter Schaefer

This paper reexamines optimal performance schemes in a setting where a manager not only exerts effort but also decides in how far a company differentiates its strategy or products from the strategy of a certain benchmark such as the industry or a competitor. Differentiation can increase the expected profit of the firm, but it also decreases the extent to which the performance of the company is correlated to the performance of its benchmark. We show that relative performance evaluation provides incentives to choose a suboptimal low level of differentiation as differentiation diminishes the risk filtering effect of a relative performance component. Consequently, the sensitivity of the optimal performance scheme to the competitor's success decreases, i.e. less relative performance evaluation is used in presence of a differentiation decision. Our model predicts that managers want to decrease the differentiation level and thereby increase the correlation between the performances of their firm and its benchmarks when relative performance evaluation is used. We test this hypothesis with data from firms in Germany and the UK that introduced a relative performance component between 2006 and 2013. Our event study gives evidence that the adoption of relative performance evaluation components will lead to stronger correlated returns of the adopting firm and its peers. We thereby add an important argument to the relative performance evaluation puzzle by highlighting that correlation between performances of different firms is not necessarily exogenously given but is influenced by managerial decisions.

3 - Utility-based investment neutral tax systems for decisions of tax payers with heterogeneous risk attitudes
Markus Grottke, Markus Diller, Josef Schosser

We examine the opportunities of a government to create investment neutral tax systems for risky cash flows that are evaluated by tax payers with heterogeneous risk attitudes. Our results are as follows. First, we identify a tax system which allows for tax neutrality under risk for tax payers with heterogeneous risk attitudes. This system needs, however, three new tax (refund) components which are tax rate, tax payer and investment specific. We show also that it is possible to project the effects of all three components into one neutral tax rate. A closer examination demonstrates why those components are naturally to be expected. Moreover, it seems desirable to search for conditions in which less is necessary to guarantee investment neutrality. Such conditions are found in two areas. First, the government can reset the tax payers risk aversion to the desired degree by introducing appropriate tax bases and second, tax risks can be eliminated (mitigated) when markets exist that allow for (partial) hedging the emerging tax risks. Finally, we point to limits of governments to provide the outlined tax neutral setting such as governmental budgetary concerns.

■ WE-23
Wednesday, 17:00-18:30 - ÜR Germanistik 4

Integer Programming Models for Ordering Problems

Stream: Integer Programming
Chair: *Philipp Hungerländer*

1 - Optimal Scheduling of Latency-constrained Tasks by Branch-and-Cut
Sven Mallach

The talk presents a branch-and-cut approach to a task-scheduling problem with precedence and latency constraints that is originally motivated from technical computer science, but models a quite general scheduling problem. Several integer programming formulations to tackle this problem are discussed, one of which is newly developed and based on the linear ordering problem. Experimental results are given to show that a branch-and-cut implementation based on this formulation can solve large instances and that it can compete with the currently best methods from constraint programming.

2 - New ILP Approaches for Row Layout Problems
Frank Fischer, Philipp Hungerländer, Anja Fischer

We consider the multi-row layout problem in which departments are to be placed on a given number of rows so that the sum of the weighted center-to-center distances is minimized. While the optimal solution for a single-row problem will normally have no spaces between departments, for multi-row layout problems it is necessary to allow for the presence of spaces of arbitrary lengths between departments. We establish several new combinatorial properties for this problem that have a significant impact for a computational perspective. Most importantly we show that although the lengths of the spaces between the departments are in general continuous quantities, every multi-row problem has an optimal solution on the grid and hence only spaces of integer lengths need to be used when modeling the problem. We exploit the combinatorial structure of multi-row layouts to tailor exact ILP approaches for different versions of the multi-row layout problem: We consider layouts with and without spaces and with and without fixed row assignments. Finally we demonstrate in a computational study that our approaches outperform all other methods from the literatur for the various layout types.

■ WE-24
Wednesday, 17:00-18:30 - ÜR Germanistik 5

DEA & Education (c)

Stream: Analytics
Chair: *Ralph Grothmann*

1 - Applying Analytics and Optimization using AIMMS: An Educational Perspective
Ovidiu Listes

We share our experiences in training both academics and practitioners for developing application skills for Analytics and Optimization using AIMMS. Whether the users are students moving from theory to practice or professionals who need to acquire skills in a short time, AIMMS can contribute to bridging the education gap in the Analytics and Optimization areas. Data forecasting, fast and flexible modeling, powerful solvers and integrated visualization are among the AIMMS features which facilitate learning, create understanding and stimulate further application refinements. Furthermore, cloud deployment and web-based user interface in AIMMS PRO complete our view on the application path.

2 - Two Stage Data Envelopment Analyses
Zilla Sinuany-Stern

This paper deals with Data Envelopment Analysis (DEA) where we have several organizational units (or Decision Making Units — DMUs). Each DMU has multiple inputs and multiple outputs. DEA calculates the relative efficiencies of DMUs via linear programming. In the Operations Research (OR) literature the term "Two Stage DEA"

(TS/DEA) is used in several meanings. In the first stage DEA efficiency is calculated, and in the second stage, further analysis is done, such as regression where the functional relationship between the efficiencies and environmental variables is verified, parametric or non-parametric statistical analysis is performed, or Cross Efficiency (CE) analysis is performed to cross-evaluate the DMUs and rank them. In the second type of TS/DEA, there is a two stage system or process, where the outputs of the first stage of the system are the inputs of the second stage of the system. In this case, TS/DEA provides the overall efficiency of the two staged system/process and its components. Sometimes these two types of TS/DEA are employed, such an example is presented here - evaluating the efficiency of 197 local municipalities in Israel in providing traffic safety using TS/DEA. The inputs of the first stage reflect the resources allocated to the local municipalities (such as funding). The intermediate variables known as safety performance indicators (SPI): measures that are theoretically linked to crash reductions (such as use of safety belts). These intermediate variables are the outputs of the first stage and the inputs of the second stage. The outputs of the second stage include measures that reflect reductions in accidents (such as accidents per population). In the other type TS/DEA applied here, CE and regression analysis are performed.

3 - An Analysis of Technical and Scale Efficiencies of the Brazilian Civil Construction Sector Using DEA Models

Carlos Ernani Fries, Paulo Henrique Rodrigues, Fernanda Christmann

The Brazilian construction market has been characterized by strong demand variations over the past decade. After a strong deceleration in 2004, the market reacted when investors, focusing on the need to supply the housing deficit, landed considerable amounts in the sector. Later, affected by the global crisis in 2008, reacted again motivated by various countercyclical development programs launched by the government, mainly in the area of logistics and transportation infrastructure. The impact of these fluctuations in performance and size of the largest companies that operated in the Brazilian civil construction market in the period 2005-2014 is analyzed in this work. The study is supported by Data Envelopment Analysis (DEA) models using secondary data provided by specialized sources. Results show that firms with lower revenues have faced internal organizational difficulties preventing inputs to be applied in ideal range to generate revenues while a positive relationship between revenues and technical efficiency score could be observed. Generally, firms with lower revenues were the ones with problems to correctly allocate inputs, presenting the worst scale efficiency scores while just a few firms with higher revenues are located beyond the ideal scale observed in each year of the time series. This suggests that the Brazilian construction market still offers, beside external forces, such as government programs, funding sources, business reputation and legislation, good conditions for expansion of construction companies.

■ WE-26

Wednesday, 17:00-18:30 - SR Geschichte 1

Variational Problems and Equilibria

Stream: Continuous Optimization
Chair: *Giancarlo Bigi*

1 - An iterative algorithm for solving the Constrained Equilibrium problem

Paulo Sergio Marques Santos, Susana Scheimberg

In this work, we study the Constrained Equilibrium Problem (CEP), its particular cases and related problems. We propose an algorithm, based on projections and reflections, for solving (CEP). Convergence properties of the method are established under mild assumptions. Some numerical results are reported.

2 - Gap functions and descent methods for quasi-equilibria

Mauro Passacantando, Giancarlo Bigi

In this talk we focus on the quasi-equilibrium problem (QEP) which is modeled upon quasi-variational inequalities (QVIs). Also generalized Nash equilibrium problems (GNEPs) can be reformulated as QEPs with the Nikaido-Isoda bifunction. Unlikely QVI and GNEP, the QEP format did not receive much attention. The goal of the paper is to reformulate (QEP) as an optimization problem through a suitable gap function and develop an ad-hoc descent algorithm. Gap functions have been originally conceived for VIs and later extended to EPs, QVIs and GNEPs. Though descent methods based on gap functions have been extensively developed for EPs, the analysis of gap functions for QVIs and GNEPs is focused on mathematical properties while no descent algorithm is developed. Indeed, the reformulation of (QEP) as an optimization problem brings some difficult issues which are not met in the EP case: the gap function is not necessarily differentiable even though the equilibrium and the constraining bifunctions are; the feasible region is given by the fixed points of the set-valued constraining map and is therefore more difficult to handle; the so-called stationarity property, which guarantees all the stationary points of the gap function to be solutions of (QEP) requires monotonicity assumptions both on the equilibrium and constraining bifunctions. These issues are dealt with in the talk. After the gap function has been introduced, its smoothness properties are analysed; in particular, an upper estimate of its Clarke directional derivative is given, which provides a key tool in devising the descent method. Furthermore, classes of constraints which allow guaranteeing the stationarity property are identified. The convergence of the descent method is proved and error bounds are given too.

3 - A close look at auxiliary problem principles for equilibria

Giancarlo Bigi, Mauro Passacantando

The auxiliary problem principle allows solving a given equilibrium problem (EP) through an equivalent auxiliary problem with better properties. In the talk two families of auxiliary EPs are investigated: the classical auxiliary problems, in which a regularizing term is added to the equilibrium bifunction, and the regularized Minty EPs. The conditions that ensure the equivalence of a given EP with each of these auxiliary problems are investigated. This analysis leads to extending some known results for variational inequalities and linear EPs to the general case; moreover, new results are obtained as well. In particular, both new results on the uniqueness of solutions and new error bounds based on gap functions with good convexity properties are obtained under weak quasimonotonicity or weak concavity assumptions.

■ WE-27

Wednesday, 17:00-18:30 - SR Geschichte 2

Risk measures and utility

Stream: Financial Modelling
Chair: *Emanuela Rosazza Gianin*

1 - Portfolio Choice Under Cumulative Prospect Theory: Sensitivity analysis and an empirical study

Elisa Mastrogiacomo, Asmerilda Hitaj

In this paper we study the portfolio selection problem under cumulative prospect theory (CPT), both from a theoretical and empirical point of view. Our aim is twofold. First, we study through a simulation-based procedure, the implication of higher-moments and CPT parameters on Mean/Risk efficient frontier. In this part, motivated by recent results, we assume a multivariate variance gamma (MVG) distribution for log-returns. On a second stage, we investigate empirically, for a hedge fund portfolio, the optimal choice problem for an investor who behaves according to the CPT. We construct several optimal CPT portfolios by considering different parameters for the CPT utility function. We then compare our empirical results with the Mean Variance (MV) and the Global Minimum Variance (GMV) portfolios, from an in-sample and out-of-sample perspective.

2 - Return Risk Measurement: Orlicz-Type Measures of Risk

Emanuela Rosazza Gianin, Fabio Bellini, Roger Laeven

In this work we provide an axiomatic foundation of Orlicz measures of risk in terms of properties of their acceptance sets, by exploiting their natural correspondence with shortfall risk (see Foellmer and Schied, 2004). We explicate that, contrary to common use of monetary risk measures, which measures the risk of a financial position by assessing the stochastic nature of its monetary value, Orlicz measures of risk assess the stochastic nature of returns: they are return risk measures. This axiomatic foundation of Orlicz measures of risk naturally leads to several robust generalizations, obtained by generalizing expected utility to ambiguity averse preferences such as variational preferences (Maccheroni et al., 2006) and homothetic preferences (Cerreia-Vioglio et

al., 2011, Chateauneuf and Faro, 2010, Laeven and Stadje, 2013). We also consider the case of ambiguity over the Young function in the definition of the Orlicz measure of risk and the case of a state-dependent functional leading to Musielak-Orlicz measures of risk. From a purely mathematical point of view, the resulting functionals can be seen in a unified way as suprema of Orlicz norms on a suitable rearrangement-invariant Banach space. We study the properties of these robust Orlicz measures of risk and analyze and provide dual representations of their optimized translation invariant extensions (Rockafellar and Uryasev, 2000, Rockafellar, Uryasev and Zabarankin, 2008), that generalize the class of Haezendonck-Goovaerts risk measures, leading to robust Haezendonck-Goovaerts measures of risk. An application to optimal risk sharing is also provided.

■ WE-28

Wednesday, 17:00-18:30 - HS 34

Infrastructure Protection II and IT security (c)

Stream: OR for Security
Chair: *Alf Kimms*

1 - Cologne Mass Casualty Incident Exercise 2015 - Evaluation by Use of Linked Databases to Improve Risk and Crisis Management in Critical Infrastructure Protection

Florian Brauner, Ompe Aime Mudimu, Alex Lechleuthner, Andreas Lotter

Critical Infrastructure Protection (CIP) is a challenging operation for all involved organisations such as authorities, critical infrastructure providers, and even policies. On one hand, an integrated risk management is required to keep risks as low as possible, on the other hand a well-developed crisis management helps to mitigate the effects of occurred events. Achieving the right balance is difficult especially for anthropogenic threats such as terrorist threats that are difficult to assess with normative risk management approaches. In May 2015, the Cologne University of Applied Sciences (CUAS) executed two exercises to address risk and crisis management in case of terrorist threats. The exercises were embedded in the research project RiKoV funded by the German Federal Ministry of Research and Education. In a first exercise, a new approach for the determination of vulnerability was validated by verifying the determined values with real—life values in a scenario. In a second exercise, the crisis management were trained to improve the efficiency of the involved forces. To collect the necessary data, the Institute of Rescue Engineering and Civil Protection of CUAS used an own developed methodical Framework consisting of technical support systems such as a Mass Casualty Incident Benchmark that rates the patient care according to the individual satisfaction of basic needs in the incident with a mobile tele-dialog system. A local positioning system (LPS) collects additional the locations and times of forces or victims and gains special events. So, it is possible to evaluate where limited resources came into action. All the data are combined in a complex database to understand the processes of prevention and mitigation of terrorist attacks in a critical infrastructure.

2 - Robust optimization of IT security safeguards using standard security data

Andreas Schilling

Finding an appropriate IT security strategy by implementing the right security safeguards is a challenging task. Many organizations try to address this problem by obtaining an IT security certificate from a recognized standards organization. However, it is often the case that the requirements of a standard are too extensive to be implemented, particularly by smaller organizations. But the knowledge contained in a security standard may still be used to improve security. An organization that has an interest in security but not in a valid certificate faces the challenge of selecting safeguards from the given standard. As a solution for this problem, a new robust optimization model to determine an optimal selection of safeguards is proposed. By incorporating multiple threat scenarios, the solution obtained is robust against uncertain security threats. The model utilizes data of the IT baseline protection catalogues, a standard published by the German Federal Office for Information Security. The catalogues contain more than 500 threats and over 1200 safeguard alternatives to choose from. Integrating the approach into an existing risk management process supports the establishment of an effective IT security strategy.

3 - A multi-objective Cat Swarm optimization for Intrusion Detection in cloud computing Environments

Lynda Sellami

Cloud computing provides scalable, virtualized on demand services to the end users with greater exibility and lesser infrastructural investment. This facility makes the networks vulnerable to attacks coming from either inside or outside the network. Several solutions have been implemented to ensure and enhance the security of these networks. These solutions are insufficient and/or incomplete because they are based on the monitoring of intrusion or attack. In this paper, we are interested in intrusion detection systems (IDS)as tool for detection and protection against intrusion. This work discuss about the ways of implementing a cat swarm intelligence approach to data clustering to detect intrusions in cloud computing environment. Mobile agent technology is used to initially collecting data properties. These data are evaluated by the combining of the artificial Immune recognition system and the artificial fuzzy ants clustering systems. Our approach allows us to recognize not only known attacks but also to detect suspicious activity that may be the result on knowledge Discovery and Data Mining (KDDCup 1999) dataset compared to a standard learning schema that use the full dataset.

4 - Bi-Objective Safe and Resilient Urban Evacuation Planning

Marc Maiwald, Alf Kimms

We consider an evacuation scenario for an urban area, where the street network is transformed into a cell-network. The problem is modelled by the assumptions of the Cell-Transmission-Model and various additional restrictions (e.g. rescuing all evacuees). As the urban area can be divided into different hazardous areas, the objective is to minimize the suffered hazard for the evacuees. The results are the evacuation routes and the assignment of the evacuees to these routes. One major problem of these evacuation plans is that the main (=fastest or safest) evacuation routes are mostly utilized up to the capacity limit. Thus a potential street capacity drop, caused by the disaster itself or traffic accidents, could lead to great complication in the entire evacuation process. We overcome this problem by introducing the aspect of resilience to evacuation planning and define an evacuation plan as more resilient, if a capacity drop has no significant impact on the evacuation process.

This aspect of resilience is implemented by utilizing the available capacities of the street network as balanced as possible. Therefore we present a new bi-objective path-based evacuation model. We cope with the two conflicting objective functions by applying the Epsilon-Constraint Method. Furthermore we consider a predefined set of evacuation paths, because detours are explicitly allowed in regard to the aspect of resilience. As the determination of such proper evacuation paths (with detours) represents a tricky problem, we introduce a special Path Generation Algorithm. Finally a predefined number of Pareto optimal solutions is computed for giving the decision maker various solutions and demonstrating the relationship between both objective functions.

■ WE-29

Wednesday, 17:00-18:30 - SR IÖGF

Evolutionary Multiobjective Optimization

Stream: Multiple Criteria Decision Making
Chair: *Sanaz Mostaghim*
Chair: *Günter Rudolph*

1 - A-posteriori Optimization for Many-objective Problems - Is There a Future?

Robin Purshouse

A posteriori optimization is one of the major quantitative approaches to supporting decision-making for multi-objective problems. In this approach, an optimizer attempts to identify a representation of the Pareto-optimal solution set that can be presented to a decision-maker (DM). The DM, suitably informed about the trade-offs in the problem, can then reflect on, and subsequently apply, his preferences to choose a single solution to the problem. For bi-objective and tri-objective problems, a variety of a posteriori methods are available — within which multi-objective evolutionary algorithms (MOEAs) based

on Goldberg's seminal concept of using Pareto dominance in combination with niching have proved especially popular. However, these methods encounter difficulties for problems with four or more objectives (sometimes referred to as 'many-objective' problems). This talk will discuss the technical and cognitive challenges involved in a posteriori optimization for many-objective problems, which are fundamentally related to the high dimensionality of the objective-space. It will discuss in detail the failure modes associated with existing MOEAs - demonstrating that these are subtler than many of the studies on many-objective optimization have tended to suggest. The talk will also outline the most promising directions for a posteriori optimization: in terms of solvers, innovations in decomposition-based methods will be discussed (including a priori and co-evolutionary schemes for weighting vectors); in terms of DM support, consideration will be given to how such solvers may be integrated into wider decision-making workflows.

2 - Evolutionary Approaches to the Multiobjective Orienteering TSP with Time Constraints

Günter Rudolph

In the Orienteering Traveling Salesperson Problem the tour of a single vehicle is a routing that serves mandatory and optional customer locations. In the multiobjective version of the problem we seek a tour from start to end depot (which may be identical) that minimizes the tour length and maximizes the number of visited customers. In the dynamic variant of the problem the optional customers become gradually known only after the tour has been started. The solutions of the a posteriori version of the problem, in which the time of disclosure of an optional customer is known before the tour starts, may be used to understand the decisions and to assess the quality of online routing methods. Here, we compare two multiobjective evolutionary algorithms with different problem encodings for the a posteriori problem before considering an algorithmic concept to approximate only desired parts of the Pareto frontier.

■ WE-30

Wednesday, 17:00-18:30 - Visitor Center

Statistics and Estimation (c)

Stream: Stochastic Models
Chair: *Nora Dörmann*

1 - Designing and analyzing tolerances of unidentified distributions: using stochastic method

Mohammad Mehdi Movahedi

The mechanical tolerances are set to restrict too large dimensional and geometrical variation in a product. Tolerances have to be set in such a manner that functionality, manufacturability, costs and interchangeability are optimized and balanced between each other. The tolerances and available tolerance design techniques are represented in this text. Statistical tolerance design is emphasized because statistical behavior describes the nature of the manufacturing processes more realistically than worst-case methods. To this end, the Generalized Lambda Distribution (GLD) has been used for design of tolerance. This distribution is highly flexible and based on the available data, can identify and present the related probability distribution function and their statistics. After recognizing the underlying probability distribution function, the results can be employed for the design of tolerance.

2 - Nonparametric estimation of replacement rates

Nora Dörmann

Consider a sequence of random variables representing lifetimes of articles being renewed. The goal is to estimate the replacement rate 1/ where stands for the expected lifetime of an article. The variables are assumed to be non-negative and identically distributed; they may be dependent and the common underlying distribution is unknown. As maximum likelihood methods are not applicable, the method for moments is implemented. But this method is not suitable for derivation of corresponding moments. Therefor the delta method for determination of moments and independent random variables is generally preferred. But, in either case, strict requirements on the boundedness of the function or its derivatives need to be fulfilled. As the rate of replacement is a reciprocal function, this method can neither be chosen. Meanwhile and in contrast to the literature, Weba and Dörmann (1) show that the delta method is valid for a broader class of functions. Provided mild requirements upon the global growth of f are met, also functions where the function itself or all its derivatives are unbounded may be considered. Moreover, a quantitative version of the weak law of large numbers is sufficient and necessary for the approximation of f and the expansion of its moments. Furthermore, observations are allowed to be dependent and no assumptions on their distributions are required. It is the purpose to apply this method on reciprocal functions of renewal theory dependent on with dependent observations. Moreover, numerical examples and results of simulations are presented. (1) M. Weba and N. Dörmann (2014). The delta method for moments when observations are dependent. Working Paper.

3 - Greedy algorithm for the construction of truncated vine copulas by exploiting some of the conditional independences between the random components

Edith Kovacs, Tamas Szantai

Copulas are widely used for modeling multivariate probability distributions as they make possible to model the dependence structure and the marginal probability distributions separately. However in higher dimensions the dependence structure becomes more and more complex and one copula type cannot model multiple types of dependences. To overcome this problem there was introduced the concept of the regular vine copula which uses only pair copulas as building blocks. The drawback of these copulas is that their complexity strongly increases with the dimension. To overcome this, truncated regular vine copulas were introduced. These structures assume the existence of conditional independence between some of the components.

In the present talk we relate the truncated regular vine copulas to special Markov random networks and give a greedy algorithm for discovering their structure. In the literature there exist other models which are based on exploiting conditional independences as the multivariate Gauss copula model and the Bayesian network (Directed Acyclic Graphical (DAG)) model. The Bayesian network model supposes that the causal network between the components is known. Our approach is more general since it works without information on the multivariate copula or on the causal network.

We highlight also the advantages of our approach against those building the truncated regular vine copulas as a sequence of k-trees in a greedy way.

■ WE-31

Wednesday, 17:00-18:30 - Marietta Blau Saal

IBM Decision Optimization on Cloud

Stream: OR Software, Modelling Languages
Chair: *Susara van den Heever*

1 - Bringing prescriptive analysis into an analytics service dedicated to LOB users

Xavier Ceugniet

By leveraging simple interactions and dynamic adaptative visualisations, visual analytics provides rapid insight on data. Combined with predictive analytics it automatically does the hard math to show business users the most relevant facts, patterns and relationships in their datasets. As a next step, prescriptive analytics supports the business in transforming insights into optimized decisions.

This talk presents a prescriptive analysis plugin running as part on IBM Watson Analytics service. Demoing an industry use case, we show how a LOB user can conduct in a single user experience, an interactive analysis process, combining visualization, predictive and prescriptive. Starting from an input dataset, the main steps of a prescriptive analysis are discussed : prescriptive intents suggestion and selection, elicitation of the business problem to be solved through suggested business goals and business constraints, generation of optimization model from the elicited problem and solving the optimization model on the cloud. Finally we show how the service provides LOB user with a current solution, using dynamic adaptive visualizations to assess the quality of this solution and allowing for further refinement of the business problem definition.

A special attention is given in this talk to important challenges of a prescriptive analysis that is (1) to capture the business problem to be solved from interactions with the LOB user, (2) to translate it into an optimization model and (3) to support smart solution visualization and problem refinement.

2 - The use of cloud-based decision optimization in an energetic flexibility market platform

Olle Sundstroem

An increased penetration of distributed renewable energy sources, such as wind and solar, increases the demand for balancing resources both at the transmission level but also at the distribution level. The Flexibility Clearing House (FLECH) is a market based platform for trading flexibility products. FLECH provides a platform for grid operators to access large numbers of distributed flexible resources. Such resources can both be individual loads, such as flexible industrial processes, but also aggregators that pool large numbers of small flexible loads. The platform interacts with buyer and sellers of flexibility and collects flexibility offers and demands. The offers are cleared based on market conditions using a cloud-based optimization service and holds sellers and buyer accountable for their commitments and contracts. The platform is designed to handle products for emergency situations, local voltage control, local and regional peak shaving, as well as other grid congestion scenarios.

For grid operators the benefits of acquiring and contractually reserving flexibility from FLECH is that costly grid reinforcements can be deferred. FLECH provides a way of securing flexibility in the future from flexible loads that can compensate for uncertainty in grid loading. These financial benefits can be realized by the grid operator and in part passed on to the sellers who provide the flexibility. The availability of additional regulation power can also facilitate a higher penetration of renewable energy resources.

In this talk we will present the market platform and the underlying reasons for moving to a cloud-based solution including the market clearing process. The focus is on showing a real-world application where decision optimization in the cloud is used.

3 - Taking Sales and Operations Planning to the next level with IBM Analytics on Cloud

Hans Schlenker

In this presentation we will demonstrate how embedding the power of IBM CPLEX Optimization on Cloud into IBM Cognos TM1 takes traditional Sales and Operations Planning to the next level. Even though TM1 is rich in functionality for planning purposes, including demand planning, forecasting, capacity and production planning, data entry, top-down and bottom-up distribution, rolling horizon planning, process and workflow support, teamwork, and simulation for what-if analysis and scenario comparison, it relies on manual planning processes. Embedding CPLEX Optimizer into TM1 takes this manual planning process to the next level via automated and optimized planning. This allows planners to compare a set of "best possible plans', instead of manually created "feasible plans', while still accessing the richness of TM1's manual planning environment.

We will give a brief overview of TM1, show how a planner can define goals and constraints for use by the optimization process, and discuss the integration architecture between TM1 and CPLEX Optimizer. We will also present a case study involving simultaneous capacity and inventory planning to demonstrate the benefits, which include reduced planning cycle time, reduced stock, reduced production costs, increased reliability of delivery times, and flexibility in combining automated optimization and manual planning.

4 - Prescriptive analytics on the cloud with Python

Vincent Beraudier, Philippe Couronne

Python is extremely popular in the data science community but not yet very well known in operational research world.

Its wide but very well organized open source community provides viable tools for large-scale data predictive and prescriptive analysis that can compete with commercial offers for manipulating, processing, cleaning, and crunching any amount of data. Interactive notebook tools also allow seamless integration of text, mathematical equations, Python code and publication-quality graphics. Moreover, such tools can be available on the Web, without any software installed. The integration of these tools with both state-of-the art OR solvers and cloud computing capabilities will allow new users to enter the world of OR.

As a result of this easy familiarity and thanks to powerful modelling layers, users with lightweight development skills can leverage the power of state-of-the-art solvers to develop, tune and publish their results without installing any software. Analyzing large-scale data can now be done in few lines of codes. More and more massively scalable algorithms are getting available and can be extended in python.

The talk will consist in a presentation and live demo of the python scientific ecosystem to get ready-to-be-deployed code for effective optimization models, with data cleansing and visualization report/analysis, without the need of any long configuration thanks to popular libraries of data scientists. It will specifically focus on the cloud environments that make easy the creation of complex work-flows with web-services to offload computing intensive tasks done with existing solvers such as CPLEX.

Thursday, 8:30-10:00

■ TA-02

Thursday, 8:30-10:00 - HS 7

Project Management and Scheduling IV (i)

Stream: Scheduling and Project Management
Chair: *Walter Gutjahr*

1 - Lot Sizing and Scheduling for Biopharmaceutical Production
Juergen Branke

Biopharmaceutical manufacturing requires high investments and long-term production planning. For large biopharma companies, planning typically requires assigning quantities of multiple products to several production facilities over time, leading to large and complex scheduling problems. Production is usually done in batches with a substantial set-up cost and time for switching between products, and the goal of satisfying demand while minimizing manufacturing, set-up and inventory costs. The resulting production planning problem is a complicated variant of the capacitated lot-sizing and scheduling problem, over multiple facilities and multiple products. Inspired by evolutionary algorithm approaches to job shop scheduling, this paper proposes a tailored construction heuristic that schedules demands of multiple products sequentially across several facilities to build a multi-year production plan (solution). The sequence in which the construction heuristic schedules the different demands is optimized by an evolutionary algorithm. We demonstrate the effectiveness of the approach on a real-world biopharmaceutical lot sizing problem by examining the influence of different algorithm components and comparing it with a state-of-the-art mathematical programming model.

2 - Stochastic project scheduling and personnel planning of multiple projects with multi-skilled human resources
Thomas Felberbauer, Walter Gutjahr, Karl Doerner

This paper presents a stochastic optimization model for simultaneous project scheduling and personnel planning, extending a deterministic model previously developed by Heimerl and Kolisch. For the problem of assigning work packages to multi-skilled human resources with heterogeneous skills, the uncertainty on work package processing times is addressed. In the case where the required capacity exceeds the available capacity of internal resources, external human resources are used. The objective is to minimize the expected external costs. We decompose the problem into a project scheduling and a staffing subproblem. A metaheuristic, using iterated local search, determines the project schedules. The staffing sub-problem is solved by means of the Frank-Wolfe algorithm for convex optimization. Experimental results for synthetically generated test instances inspired by a real-world situation are provided and some managerial insights are derived.

3 - Scheduling chains of unit-time multiprocessor tasks with a weighted completion time objective
Roland Braune

The problem under consideration is concerned with scheduling chains of multiprocessor tasks on parallel processors. The tasks have unit processing time and a predefined size. Each chain consists of equally sized tasks that are subject to start-to-start precedence constraints involving minimum and maximum delays. All maximum delays are equal to 1, implying that a task is allowed to start no later than one time period after its predecessor. The minimum delays are equal to zero, meaning that a task may be scheduled earliest in the same time period as its predecessor. Every chain of such tasks can in fact be regarded as a discrete malleable task whose duration depends on how many 'subtasks' are allocated at the same time.

The objective function is of weighted completion time type, where the weights are equal to the task sizes. Minimizing that objective function leads to a load profile of the multiprocessor resource which is distinctly skewed to the right, i.e., the utilization is preferably higher in earlier time periods, as it is a requirement in a real-world scenario that constitutes the problem background.

We show that the problem at hand is a generalization of the multiple knapsack problem and thus NP-hard. Alternatively, it can be mapped to a bin packing problem with (linear) usage cost. We propose several packing-based lower bounding schemes for that specific kind of objective, including Lagrangean relaxation and decomposition approaches. The lower bounds are then incorporated into a branch-and-bound algorithm. Furthermore, we devise enhancements to an existing global constraint for linear usage cost bin packing to effectively cover the chain precedence constraints. Computational experience is acquired using randomly generated and real-world problem instances.

■ TA-03

Thursday, 8:30-10:00 - HS 16

New Research Directions in Scheduling (i)

Stream: Scheduling and Project Management
Chair: *Alena Otto*
Chair: *Thorsten Ederer*

1 - The production routing problem with pickups and deliveries
Florian Sahling

In the production routing problem (PRP), decisions regarding production, inventory, distribution, and routing are made simultaneously, i.e. the PRP combines lot-sizing and vehicle routing. In this talk, we present a new variant of the PRP by taking pickups at customers of product returns into account. These product returns can be remanufactured to become as good as new. Thus, they can be used to fulfill the dynamic demand. The objective of the PRP is to determine a feasible (re)manufacturing and routing schedule at minimal costs. A solution approach is proposed and first numerical results are shown.

2 - An infinite-dimensional Skorohod map as a model for priority
Rami Atar

We construct a map in the space of paths over the set of finite measures on the real line, that is reminiscent of the Skorohod map. We apply it to queueing models in which tasks are prioritized according to a continuous parameter and obtain new results regarding their fluid limits. These models include the earliest deadline first, the shortest job first and the shortest remaining processing time disciplines.

3 - Algorithmic System Design using Scaling Laws
Thorsten Ederer, Lena Charlotte Altherr, Philipp Pöttgen, Christian Schänzle, Ulf Lorenz, Peter Pelz

There are many high-quality software tools which aid engineers to simulate, validate and construct systems. The choice of components and their arrangement are still a matter of human intuition. However, the initial set-up has a strong influence on the quality of the technical system: Optimized components do not automatically lead to energy-efficient systems. At TU Darmstadt, a new field of research named Technical Operations Research (TOR) is established. It utilizes mathematical optimization techniques to find the optimal design and operating strategy simultaneously.

In previous works, we provided the algorithm with a preselected construction kit of suitable components. This approach may give rise to a combinatorial explosion if the preselection cannot be cut down to a reasonable number by human intuition alone. The physical behaviour of the technical components is described by their characteristic diagram. The characteristics of components of a production series have certain similarities which can be described by scaling laws. By embedding such scaling laws into our optimization models, we are able to reduce the number of discrete decisions significantly. The construction kit now consists of a small number of production series. Therefore, the number of possible set-ups is greatly increased.

In this work, we present how to integrate scaling laws into the Technical Operations Research methodology. We focus on the modeling aspect and give a technical example.

■ TA-04

Thursday, 8:30-10:00 - HS 21

Facility location problems (c)

Stream: Discrete Optimization
Chair: *Bettina Klinz*

1 - Composed min-max and min-sum radial approach to the emergency system design

Marek Kvet, Jaroslav Janacek

In the host situations, a public service system is designed so that the average disutility is minimized. In this contribution, we deal with the special member of the family of public service systems known as emergency service system. Designers of this sort of service systems must take into consideration not only the disutility of an average user, but also the disutility of the worst situated user. Optimization of the average user disutility is related to the large weighted p-median problem. The necessity to solve large instances of the weighted p-median problem has led to the approximate approach based on a radial formulation, which enables to solve bigger instances in admissible time making use of a universal IP-solver. The p-median problem objective denoted as min-sum criterion often causes such situation that the average users disutility is minimal, but the disutility of the worst situated user can be extremely high, what is considered as unfair design. To mitigate this unfairness, we suggested two-phase method of the emergency service system design. The first phase consists of the process, when the disutility of the worst situated user is minimized making use of the radial formulation. The second phase is based on the above mentioned min-sum approach, where the result of the first phase is used to reduce the size of the radial model. This way, we can obtain either optimal or near-optimal solution of the composed problem. If necessary, we are able to make a trade-off between a little loss of optimality and the computational time of large instance solving process. Hereby, we focus on effective usage of the reduction of the radial model for accelerating the second phase of our composed method. Also the possibility of mentioned trade-off is explored.

2 - A Constant-Factor Local Search Approximation for Two-Stage Facility Location Problems

Felix J. L. Willamowski, Andreas Bley

We present a constant-factor local search approximation algorithm for the metric two-stage uncapacitated facility location problem and a variation of this, where the demands of the clients are served via trees. To the best of our knowledge, this is the first constant-factor local search approximation for stochastic facility location problems. Additionally, we show that a general mutable metric does not allow constant approximation factors and that the introduced algorithm permits a more general mutable metric in contrast to previous algorithms, which only allow scenario-dependend inflation factors.

3 - Upper bound and exact method for the capacitated competitive facility location problem

Andrey Melnikov, Vladimir Beresnev

We consider the capacitated competitive facility location problem, where two competing firms open facilities to maximize the profit, obtained from clients' serving. Both the set of candidate sites where the firms can open their facilities and the set of clients are finite. Clients' preferences and demands are known for firms, and the firm can serve the client only with the facility, which is more preferable than any of the competitor's ones. Total demand covered by each of the facilities cannot exceed its capacity, and it's not necessary that all clients are served in the end. The decision process can be considered as a Stackelberg game: the first firm, called a Leader, opens its facilities in some candidate sites at the first step. Another firm, called a Follower, takes into account Leader's decision and opens the facilities at the second step. The goal is to find the location of the Leader's facilities which maximizes the profit from clients' serving after deduction of opened facilities costs, anticipating the influence of the Follower's facilities. The problem can be written as a bi-level mixed-integer mathematical program where upper and lower level problems are similar to the capacitated facility location problem. We propose the upper bound for Leader's objective function based on solving of the auxiliary MIP. Exact procedure utilizes the upper bound proposed in the B&B scheme.

■ TA-05

Thursday, 8:30-10:00 - HS 23

POM applications III

Stream: Production and Operations Management
Chair: *Sven Krumke*

1 - Optimization model for the design of levelling patterns with setup and lot-sizing considerations

Mirco Boning, Heiko Breier, Dominik Berbig

Production levelling (Heijunka) is one of the key-elements of the Toyota Production System. By decoupling customer demand from production orders levelling is a powerful method to dampen the negative impacts of highly fluctuating customer demand. For the decoupling period a levelling pattern has to be designed. Existing approaches for the design of levelling patterns are majorly limited to large-scale production.

Therefore, this paper develops an optimization procedure for the design of levelling patterns regarding the requirements of lot-size production. Relevant, sequence-dependant changeovers are considered. An integer, combined lot-sizing and scheduling model is formulated. The model is based on a novel approach by transforming and modifying the distance-constrained vehicle routing problem (DCVRP) for levelling purposes. Four target criteria of levelling are identified. These involve changeover times, smoothness of daily workload, variance of lot-sizes and similarity of production sequences. The latter has been modeled with a modified version of the Hamming-distance. The criteria are integrated into different target functions and solved to optimality with Gurobi.

Random scenarios are generated to evaluate the target functions. The results reveal that a proposed multi-criteria target function outperforms all other target functions. The impact of a variation of the weighting factors, a reduction of the available capacity and the length of the levelling period is analyzed. In a real case study of an existing production plan a clear improvement of changeover times, similarity and smoothness of workloads is realized. With the new leveling pattern cost reductions can be realized as the maximum available capacity can be reduced.

2 - Optimizing profit for energy distribution in the German electricity market

Sabine Büttner, Felix Geyer, Sven Krumke, Sleman Saliba

For energy companies, the decision of the shares and markets to sell the available volume of current to maximize the profit is a recurrent task. On the German electricity market, the trading of supply is organized on several auction-based markets (superordinately grouped into the „Spotmarkt" and the „Regelenergiemarkt"). The markets each follow certain rules and differ crucially in the products which can be offered, the way the prices and contracts are formed and the temporal aspects. We analyze the structure of the optimization problem to determine a maximum-profit distribution of the available energy over the markets, depending on the specifics of the auction. Moreover, we analyze the theoretical mathematical properties of the profit functions from the trader point of view. We show how to exploit the structure of the potentially discontinuous profit functions. For some markets, for instance, maximizing the profit turns out to be a special case of a resource-allocation problem with piecewise linear profits. We show that even this case is still NP-hard to solve and provide a new efficient dynamic-programming algorithm with pseudo-polynomial running time. Other market rules lead to optimization problems with completely different structure. We give algorithms for other settings, for example on a market where the traded time-intervals are laminar.

3 - Optimizing Open Pit Block Scheduling with Exposed Ore Reserve

Jorge Amaya, Jose Saavedra-Rosas, Enrique Jelvez, Nelson Morales

A crucial problem in the mining industry is to determine the optimal sequence of extraction of blocks, in which the mine has been structured for exploitation. A common practice for the formulation of these problems consists in describing an ore reserve via the construction of a three-dimensional block model of the three-dimensional mining site. Typically a mine can be constituted by several thousands or millions of blocks. Each block corresponds to a unitary volume of extraction characterized by geologic and economic properties which are estimated from sample data. Block models can be represented as directed graphs where nodes are associated with blocks, while arcs correspond to the precedence of these blocks in the ore reserve. The precedence order is induced by physical and operational constraints as those derived from the geo-mechanics of slope stability. This approach gives rise to huge combinatorial problems whose mathematical formulations are special large-scale instances of Integer Programming Optimization problems. Operational mine plans are usually produced on a yearly basis and further scheduling is attempted to provide monthly, weekly and daily schedules. A portion of the ore reserve is said to be exposed if it is readily available for extraction at the start of the next period. In this work, we propose an integer programming model to generate pit designs under exposed ore reserve requirements. For this purpose, we

introduce a set of binary variables, representing the extraction, wasting and processing decisions. The model has been coded and tested in a set of standard real instances, showing very encouraging results in the generation of operational sequences of extraction and destination of blocks.

■ TA-06

Thursday, 8:30-10:00 - HS 24

Metaheuristics I (c)

Stream: Metaheuristics
Chair: *Christian Puchert*

1 - Heuristics based on ng-Relaxation for large scale CVRP instances

Elena Rocchi, Francesco Strappaveccia, Marco Antonio Boschetti, Vittorio Maniezzo

Ng-Relaxation proved to be an effective technique to compute good quality lower bounds for multiple variants of the Vehicle Routing Problem, thus a good base for exact approaches. The solution of the Capacitated Vehicle Routing Problem in particular, gained benefits from this relaxation, actually a state space relaxation, in that several previously unsolved instances could be solved this way. The dynamic programming recurrence at the core of the relaxation constructs data structures related to the state space, that can be used in a heuristic framework. We considered information integrated in the bounding procedure (e.g. ng-paths and ng-routes) and used this information to guide our heuristic. We assessed our algorithm on standard large scale CVRP testsets from the literature. Moreover, as standard instances are either very structured or essentially random, thus prone to introduce a bias in the behavior of some heuristics, we included in our tests new large real-world instances.

2 - Truly Problem Independent Hyper-heuristics Framework

Mateusz Cichenski, Jacek Blazewicz, Grzegorz Pawlak

Hyper-heuristics are search methodologies often described as a heuristics to choose heuristics. In general, it allows to solve complex combinatorial problems using a two-level architecture: the top level hyper-heuristic algorithm, and the low level heuristics, which contains a set of simple heuristics.

The top level is problem independent and is responsible for picking the heuristic, which will be applied to the current solution. The only available information for the hyper-heuristic algorithm is the performance measures of the low level heuristics, e.g. processing time, memory used, objective function value. On the other hand, the algorithms in the low level set are problem specific — they are tailored to solve the problem at hand efficiently, e.g. 2-OPT neighborhood operator for Traveling Salesman Problem.

The huge benefit of using a hyper-heuristic approach is the reusability of the hyper-heuristic algorithm from the top level. Unfortunately, this does not simplify the work of the researcher, because he still needs to provide a sufficient number of good low level heuristics for his problem domain. From previous research it follows that hyper-heuristics can be efficiently used to solve problems such as timetable scheduling or nurse rostering to obtain good-enough solutions.

For a more general approach, one could use a unified representation for the solution. Following this step, one could define a set of low level heuristics that would operate on this representation, rather than on the problem domain. This will create a problem independent framework based on the hyper-heuristics approach. The only part that has to be defined is the objective function, which has to be problem specific. This idea has been prototyped and initial results will be presented.

3 - Search Strategies for MIP Diving Heuristics

Christian Puchert, Marco Lübbecke

In mixed integer programming, diving heuristics have proven to be a successful class of heuristics. Mainly applied inside a branch-and-bound algorithm, they start with a linear (but not necessarily integer) feasible solution and then iteratively impose a branching decision on a fractional variable and solve the resulting LP.

If an infeasible LP is encountered, a backtracking may be applied. A simple backtracking—as e.g. implemented in the non-commercial MIP solver SCIP—takes the last chosen variable and branches it in the other direction. Joncour et al., who apply diving heuristics in branch-and-price algorithms, suggest a limited discrepancy search (Harvey et al.). If the backtracking fails, the heuristic stops.

However, both strategies have their weaknesses. The first one only focuses on the latest search decision and ignores that the infeasibility may have been caused much earlier. The second one, on the contrary, only diversifies at an earlier point in the search and may fail if infeasibility was only caused by the latest decision.

In our talk, we discuss possible alternatives and improvements to the two strategies. We will investigate the advantages and disadvantages over traditional diving heuristics in terms of running time, found solutions and solution qualities.

■ TA-07

Thursday, 8:30-10:00 - HS 26

Districting and Clustering Problems (c)

Stream: Logistics and Transportation
Chair: *Stefan Nickel*

1 - The multi-period sales districting problem: An introduction and a heuristic approach

Matthias Bender, Nitin Ahuja, Boris Amberg, Anne Meyer, Stefan Nickel

The classical sales districting problem consists of partitioning customers into sales districts such that some relevant planning criteria, e.g. workload balance between salesmen, are met. However, in many practical use cases of our industry partner PTV Group — a commercial provider of districting software — the problem is extended by a temporal dimension: Customers must be visited multiple times during the planning horizon; therefore, the visits must be distributed over time. In this talk we introduce the resulting problem, which we call the multi-period sales districting problem, and propose a heuristic solution approach.

The multi-period sales districting problem comprises the following two subproblems: (1) Like in the classical sales districting problem, customers must be partitioned into sales districts; (2) customer visits must be distributed over the planning horizon. In the latter supbroblem, a valid visit schedule must be determined for each customer, i.e., visits must be in accordance with customer-specific visit rhythms and valid weekday patterns. Daily and weekly workload must be balanced. Furthermore, compactness plays an important role. Since the salesmen need to travel to their customers, the daily visits of each salesman should be concentrated in a geographically compact area. In some use cases, compact weekly visit clusters can also be desirable.

As it is common in practice, we solve subproblems (1) and (2) sequentially. Subproblem (1) can be tackled by classical districting methods. In this talk we present a MILP formulation for subproblem (2) and propose a matheuristic approach which is based on variable fixing. The approach is evaluated on real-world instances from our industry partner PTV Group.

2 - Geometric Algorithms for Districting Problems

Alexander Butsch, Stefan Nickel

Districting is the problem of grouping small geographic areas, called basic areas, into larger geographic clusters, called districts, subject to a number of relevant planning criteria. In this talk we will focus on applications where the basic areas are represented as points. This occurs for example in the context of sales or service districting, where a basic area corresponds to a single customer location and a district corresponds to the area of responsibility for one sales or service person. Three important planning criteria are balance, compactness and contiguity. Balance describes the requirement for districts to have approximately the same size with respect to a quantifiable activity measure, e.g. sales potential or working time. A district is said to be geographically compact if it is closely and firmly packed together, e.g. nearly round-shaped or square and undistorted. Compact districts reduce the sales persons' unproductive travel time. Contiguity means that it is possible to travel between the basic areas of a district without having to leave the district. We present a geometric heuristic that uses a divide and conquer approach to generate an initial districting plan. After that a two stage iterative approach based on Additively Weighted Voronoi Diagrams or Power Diagrams is used to improve this plan. In each

main iteration a new set of Voronoi generators is determined, followed by an iterative process, which updates the weights of the generators in each sub-iteration. Besides Euclidean distances, we are also able to consider network distances, although we use a geometric approach. Tests on real-world data confirm the efficiency of our algorithm and the quality of the solutions obtained.

■ TA-09

Thursday, 8:30-10:00 - HS 30

Network Games

Stream: Game Theory
Chair: *Pascal Lenzner*

1 - A Network Game of Resource Providers

Andreas Cord-Landwehr

We study the quality of equilibria in a network creation game in which every agent aims to improve access to her required resources. Resources are provided redundantly by the agents, so there is no prefixed assignment by which agent another agent is served. In particular, in the considered game there are n agents, whereas each agent provides exactly one out of k < n available resources. This is different to previous models, which usually have an a priori assignment to whom an agent wants to minimize her distances. Instead of this, an agent wants to reduce the distance to anyone from the group of resource providers who can redundantly serve a specific demand. The specific objective of an agent is to minimize either the sum (SumRG) or the maximum of distances (MaxRG) to some set of agents that provide the demanded resources, while minimizing the costs spent for creating edges. Edges can be bought at a fixed price of alpha and any agent providing a resource can serve an uncapacitated number of agents. First, we consider the cases when every agent is interested in all provided resources. Later, we drop this constraint and focus our analysis on non-uniform resource demands but more natural networks that might emerge from improving response dynamics.

2 - Multicast Network Design Game on a Ring

Akaki Mamageishvili, Matús Mihalák

In this paper we study quality measures of different solution concepts for the multicast network design game on a ring topology. We recall from the literature a lower bound 4/3 and show a matching upper bound for the price of stability, which is the ratio of the social costs of a best Nash equilibrium and of a general optimum. We prove an upper bound of 2 for the ratio of the costs of a potential optimizer and of an optimum, give a construction of a lower bound, and provide computer-assisted arguments that it reaches 2 for any precision. We then turn our attention to players arriving one by one and playing myopically their best response. We provide matching lower and upper bounds of 2 for the the myopic sequential price of anarchy (achieved for a worst-case order of the arrival of the players). We then initiate the study of myopic sequential price of stability, and for the general multicast game we give matching upper and lower bounds of 4, while for the multicast game on the ring we construct a lower bound of 4/3, and provide an upper bound of 26/19. To the end, we conjecture and argue that the right answer is 4/3.

■ TA-10

Thursday, 8:30-10:00 - HS 31

Compound Vehicle Routing Problems (c)

Stream: Logistics and Transportation
Chair: *Stefan Irnich*

1 - Auto-Carrier Transportation Problem with Pickup and Delivery Operations

Marcel Schmickerath, Dirk Briskorn

Like in the transportation industry in general, the pickup and delivery of finished vehicles is a field of strong competition. A major challenge arises from the fact that the majority of vehicles have to be brought from relatively few plants and vehicle compounds to widespread dealer locations, where it is particularly difficult to quickly find a suitable next load near to where a truck has dropped its last vehicle. As a result, the empty mile factor in North America is estimated to be as high as 42%, whereas it ranges between 12% and 17% in the general freight sector. There are two main strategies to improve the auto-carriers' utilization. Especially large companies can take advantage of their network and route trucks to the next compound for the next load instead of returning them to where it started. This may involve social disadvantages and overnight costs for the drivers and is thus only an option within certain limits. Another strategy is to also offer collection services for cars spread in the field and to either directly move them to their destination or bring them to a compound for consolidation with other volumes. Our contribution is threefold. First, we bring to attention a problem variant of the vehicle routing problem. We stress its meaning by detailling a case concerning the distribution network of a major car manufacturer. Second, we provide formal problem definitions differing in the degree of freedom when constructing routes. Finally, we apply neighborhood search techniques established for vehicle routing problems and evaluate their performance when applied to our problem settings. In particular, we analyze the tradeoff between solution quality achieved and computational effort when varying the freedom of route construction.

2 - Cluster-based routing for small package delivery

Timo Hintsch, Stefan Irnich

In this presentation we introduce a planning problem for small package delivery. Given is a grouping of private households into clusters. The service region consists of given service territories (with several clusters) and additional flexible clusters. The task is to assign flexible clusters to routes serving a single service territory and to route the vehicles that perform the package delivery. It is assumed that each cluster must have been served in total before the next cluster can be served. This decomposes the routing problem into two subproblems, the routing inside a cluster and the routing between clusters. The first task requires the solution of several postman problems, one for each possibility to start (entrance) and end (exit) the route through the cluster. The chosen start-end-pair of the clusters also affects the second subproblem for routing between clusters. It can be modelled and solved as generalized VRP (GVRP).

3 - Vehicle assignment in the long-term planning of intercity bus transportation

Balazs David, Miklos Kresz

Public transportation companies usually create their schedule in advance for a longer planning period. The days of this period belong to different day-types (workdays, holidays, etc.). Days that share a day-type have the same underlying theoretical schedule. Such a schedule gives the set of trips for each duty, and the execution order of tasks for each duty. Such a duty will always be executed by a single vehicle, however, it doesn't necessarily have to be the same vehicle every day. In our presentation, we examine the problem of assigning vehicles to each day of the planning period based on existing theoretical schedules. The assignment of a bus to a day has to satisfy certain conditions; for example, regular mechanical inspection of the vehicles. We also want to minimize the arising travelling and operational costs. As the problem addresses long-distance bus transportation, returning buses to their starting depots would usually result in a high additional cost. Because of this, we also have to assign a garage to each vehicle where they spend the night and from where they start their next daily schedule. We give a network-based mathematical model for the problem. We examine solutions both of the model and of heuristic methods, and present their results.

■ TA-11

Thursday, 8:30-10:00 - HS 32

Energy-efficient Mobility I

Stream: Logistics and Transportation
Chair: *Christoph Helmberg*

1 - Algorithmic Methods for Flight Trajectory Optimization on the Airway Network

Marco Blanco, Nam Dung Hoang, Ralf Borndörfer, Thomas Schlechte

A central problem in airline optimization is that of computing a cost-efficient trajectory for an aircraft under given initial conditions. Common elements of the cost function are consumed fuel, overflight fees and flight time. We consider the scenario where aircrafts are constrained to fly over a given airway network, which is prevalent on most airspaces. A simplified version of the problem can be formulated as a shortest-path problem, but a reasonably general model is highly non trivial to derive. This is partly due to state-dependent arc costs and complex air traffic rules.

In this talk, we introduce the problem and outline a novel algorithm that incorporates techniques from classical approaches for the Shortest Path Problem, Time Dependent Shortest Path Problem and Resource Constrained Shortest Path Problem, as well as several heuristic approaches.

2 - European Air Traffic Flow Management with Conflict-Potential Reduction

Jan Berling, Alexander Lau, Volker Gollnick

To guarantee a safe journey of each and every aircraft, air-traffic-controllers make sure that standard separation minima are maintained. To prevent controller-overburdening, each controller-team is responsible for one confined sector, which has a limited amount of flights entering each hour. Compliance to all sector and airport capacity constraints in daily business is ensured by EUROCONTROLs Network Management function and respective air-traffic-control centers. It balances the flights demand of airspace with available capacity by re-allocating departure-timeslots. When two aircraft converge in space and time in such a way, that a loss of separation is predicted, they are in conflict. Conflicts are solved by controllers who provide pilots with instructions to maintain separation. Hence, conflicts increase controller workload and as a consequence, tighten sector capacity. Therefore, a lowered number of conflicts is desirable. Consequently, the aim of this work is a reduction of conflict-potential. Here, conflict-potential refers to planned trajectories that don't observe separation minima in every calculated point in space and time. Mimicking a future Network Management, departure-times are re-allocated to reduce the conflict-potential while satisfying sector and airport capacity constraints. As a basis for conflict prevention, genuine datasets of planned trajectories, sector bounds and airport features are aggregated to a most realistic model of the European Air-Traffic-Management Network. The allocation problem of departure-timeslots is formulated as a Binary-Integer-Program with linear delay cost, bilinear conflict cost and linear capacity constraints. Finally, the trade-off between conflict reduction and delay is assessed.

3 - Freeflight Route Planning

Armin Fügenschuh, Liana Amaya Moreno, Zhi Yuan

Flight trajectories for civil airplanes are in most parts of the world aligned to the air travel network (ATN), a virtual street network in the sky. In several regions it is already allowed to perform true free-flight, so that the full 4D space (3D+time) can be used for flight operations, in order to further reduce travel cost and time. More such free-flight regions are expected to emerge in the future. The computational challenge is to find a fuel-efficient trajectory that avoids head-winds and benefits from tail-winds, which change over the 4D space. The airplane's unit distance fuel consumption depends on its speed, weight, and altitude. Furthermore, the air traffic control cost is different for each country, so flying a longer detour over cheaper countries may pay off in total. Besides finding a trajectory, the total fuel consumption must be accurately computed. We present a mathematical formulation of this problem, which turns out to be a highly difficult mixed-integer nonlinear optimization problem, even after decomposing the overall problem into a separate horizontal and a vertical planning process. We formulate this problem as nonlinear models using AMPL, and solve it to local optimality using nonlinear programming solvers such as Conopt and Snopt. We also developed greedy-type heuristics for finding feasible solutions. To achieve global optimality, piecewise linear approximations of the nonlinear functions and mixed-integer linear programming techniques (using SCIP, Cplex, and Gurobi) are also applied. The locally optimal solution found by nonlinear solvers or greedy algorithm can be used as initial feasible solution for the global approach. We present numerical results on instances using real-world data provided by our project partner Lufthansa Systems AG.

■ TA-12

Thursday, 8:30-10:00 - HS 33

Railway Planning I (c)

Stream: Logistics and Transportation

Chair: *Pascal Lutter*

1 - On Optimally Allocating Tracks in Complex Railway Stations

Reyk Weiß, Michael Kümmling, Jens Opitz

Timetabling and capacity planning of railway traffic faces ever-growing challenges now and in the future. On the one hand, infrastructure measures have to be planned well in advance and corresponding train path system for passenger an freight trains have to be generated. On the other hand, in the short term horizon economical, natural and political influences affect the available railway capacity for timetabling as well. Due to the high number of different influences on capacity, timetable optimization in the railway network cannot be efficiently handled by manual effort. In recent years, the group of the chair of traffic flow science at TU Dresden in close collaboration with the DB Netz AG has successfully developed a software system, which allows to compute automatically strictly synchronized and conflict-free timetables for very complex railway networks. The complexity increases significantly in the consideration of highly frequented main railway stations which may also have a very complex infrastructure. Firstly, the complexity is reduced by ignoring minimum headway constraints resulting from conflicting routes within these stations. As a result, timetables with possible conflicts in those covered railway stations will be computed. Consequently, there is the need for efficient algorithms and its corresponding conjunction to solve the remaining conflicts, such as detecting alternative stopping positions and routes within a main railway station and the optimized selection. In this work, an approach in solving conflicts in highly frequented railway stations and computational results for complex real-world scenarios will be presented and discussed.

2 - Train Platforming at a Terminal and Its Adjacent Station to Maximize Throughput

Susumu Morito, Kousuke Hara, Jun Imaizumi, Satoshi Kato

Terminal stations in intercity rail transportation are often equipped with many platforms, and trains go into/out of these stations frequently. Reduction of headway time, however, would be limited due to technical reasons of signal equipment as well as safety reasons, and certain methodology will be required to fully utilize the capacity of these terminal stations. These terminal stations are often so-called stub stations, i.e., dead-end stations where trains change direction. Time for passengers to get off/on a train together with time for clean-up would be needed, but it is not desired for trains to unnecessarily occupy platforms. We focus on lines in which an intermediate station exists in the close proximity of the terminal, and propose a mathematical optimization model to quantitatively evaluate the effects of utilizing an intermediate station on the line throughput. The model gives departure and arrival times of trains at the terminal and its adjacent station during one hour horizon assuming cyclic timetable, so that the number of trains of the line is maximized. Factors considered in the model are stopping time at each station, minimum headway time between successive trains, and headway limited by crossover structure. Two cases are studied for bullet-train (Shinkansen) lines both originating from Tokyo terminal. Both of these lines have intermediate adjacent stations (Shinagawa and Ueno) in less than 7 minutes of Tokyo terminal. CPU time to solve a typical integer programming model is roughly 5,000 seconds. Two typical results among others are: turn-back at an intermediate station 1) increases throughput in one of the lines, and 2) allows longer stopping time at turn-back possibly leading to better service and efficient clean-up operations.

3 - Optimization models for decision support at motorail terminals

Pascal Lutter

The problem under consideration deals with the loading of cars and motorcycles onto motorail wagons under realistic technical and legal constraints. The load planning problem for motorail trains, introduced as motorail transportation problem (MTP), aims at assigning a giving set of vehicles to trains. The MTP occurs during the booking process in case of order acceptance. Decision support for order acceptance management has already been developed and is currently running at DB Fernverkehr AG. Another application arises during the loading process at motorail terminals. Motorail terminals serve for the loading of vehicles onto motorail wagons. Terminals are directly connected to the rail system and are commonly located next to railway stations. Motorail trains arrive and depart according to a predetermined timetable. Vehicles are pre-booked and the train length, e.g. the number of transportation wagons, is known before departure. Due to differing and unknown arrival times of vehicles, pre-calculated loading plans can hardly be implemented in practice. Storage space is limited and thus

vehicles need to be loaded as early as possible. Once loaded, vehicles are not allowed to change their position anymore. Thus, loading plans need to be consecutively revised in accordance with the current terminal situation and the already loaded vehicles.

Optimization based decision support aims at speeding up the entire loading process while guaranteeing the feasibility of the proposed loading plan at all times. Real-world decision support mainly relies on the computational performance of the MTP. Previous model formulations in literature reveal considerable running times in real-world instances. We propose two novel formulations of the MTP and show their superior performance.

■ TA-13

Thursday, 8:30-10:00 - HS 41

Closed-Loop Supply Chains (i)

Stream: Supply Chain Management
Chair: *Tina Wakolbinger*

1 - Revisiting the consumers' willingness-to-pay approach in reverse logistics and closed-loop supply chain modeling

Gernot Lechner, Thomas Nowak

In reverse logistics and closed-loop supply chain literature, a common modeling approach for reflecting consumer's heterogeneity of preferences is to distinguish customer segments according to their willingness-to-pay. Since reprocessed goods are typically sold at a lower price than new goods, consumers with a relatively low willingness-to-pay are expected to buy reprocessed goods, while consumers with a relatively high willingness-to-pay are expected to buy brand new products. Consequently, a profit-maximizing company offering new and reprocessed products seeks to set prices according to consumers' willingness-to-pay in order to exploit a large part of consumers' surplus. To the best of our knowledge, all of these market segmentation models assume that consumers' willingness-to-pay are uniformly distributed on the open unit interval. In this article, we relax this assumption by replacing the uniform distribution with the Kumaraswamy distribution, a highly versatile beta-type distribution. In our numerical examples, we shed light on the impact of the underlying distribution assumption of consumers' willingness-to-pay on practical reverse logistics decision making by comparing the results of our extended framework with the results of other reverse logistics models.

2 - Integrating dual sourcing with recycling options for the procurement of critical and conflict materials

Patricia Rogetzer, Lena Silbermayr, Werner Jammernegg

In many consumer and industrial products like electronic gadgets (e.g. mobile phones, computers), batteries for electric and hybrid vehicles, and wind turbines so-called critical and conflict materials (e.g. rare earth materials, gold) are needed for production. Whereas the recycling rates of steel, aluminum, and lead are considerably high, the cost-effective recycling of rare earth materials is still a challenge. Companies in that respect are increasingly faced by securing a steady stream of supply of critical and conflict raw materials for their production. Due to increasing unreliability of supply (e.g. due to legislative restrictions, social conditions) and volatility of prices including the required amount of raw materials also from recycling options in the procurement process is advisable. To improve the economic and environmental sustainability and the resource efficiency of the mentioned products it is necessary to analyze technical as well as supply chain processes of recycling critical and conflict materials. In this paper we investigate a dual sourcing strategy where critical materials can be procured on the one hand from a primary raw materials supplier, i.e. directly from the mine and, on the other hand, from recycled materials as a secondary source. Hence, we take into account flows of new and returned materials simultaneously. Considering uncertain prices for primary materials, uncertain yield rate from product returns and uncertain demand for the finished product as well as their potential dependencies we develop a single period inventory model to derive the order quantities of recycled and primary materials by optimizing the economic and the environmental performance.

3 - Optimal used-product acquisition by a recommerce provider

Gerrit Schumacher

Recommerce providers play an important role in many reverse supply chains. Decision-making pertaining to this specific business model is an interesting and yet largely unexplored research field. One major challenge for recommerce providers is the uncertainty about volume, timing, and quality of the supply of used products. Product acquisition management addresses this issue. Within this context, this presentation analyses the negotiation process between a consumer and a recommerce provider for a quality-dependent acquisition price. It expands an extant basic game-theoretic model of this process and addresses the impact of incomplete information. Based on the arising dynamics in this game, it then derives the optimal acquisition prices for different quality classes of a given product.

■ TA-14

Thursday, 8:30-10:00 - HS 42

Robust and Bi-Level Network Optimization (c)

Stream: Graphs and Networks
Chair: *Dennis Michaels*

1 - The Budgeted Minimum Cost Flow Problem with unit Cost

Annika Thome, Christina Büsing, Sarah Kirchner

We present an uncapacitated bi-linear minimum cost flow optimization problem. In this problem, we are given a directed graph with several sources and sinks. The arcs are associated with lower and upper costs. We consider the problem of finding a selection of K arcs where the lower costs apply and finding a minimum cost flow that satisfies the demand. This problem can also be interpreted as a special case of the Budget Constrained Mininum Cost Flow problem as described by Maya et al. and Coene et al. We prove this problem to be strongly NP-hard. However, for special graphs we present polynomial algorithms.

2 - A robust optimization model for a combined heat and power plant with a heat storage.

Nils Spiekermann, Stefano Coniglio, Alexander Hein, Arie Koster, Olaf Syben

Considering the change in the energy supply systems in Europe, the potential of running small sized and variable energy generators attracts a great amount of interest, especially from private investors. In this talk the operation of a combined heat and power plant is considered, taking into account a fixed heat to power ratio, heat storage and the day ahead electricity market. The heat demand is uncertain and has to be met self-sufficiently, whereas power demand can be covered, and spare power can be sold, at the market. We present a robust optimization model that, given an uncertainty set, computes an operation plan consisting of the energy production as well as the market activities. Here the freedom given by the heat storage is twofold, as it can be used to shift power production into more profitable times, as well as to compensate for uncertainties in the heat demand. The plan is robust feasible if the storage values remain within their limits for all possible realizations in the uncertainty set. Preliminary computational experiments show the tractability of the model.

3 - Robust perfect matchings

Dennis Michaels, David Adjiashvili, Viktor Bindewald

We consider the perfect matching problem on a graph under uncertainty, where uncertainty is given by a collection of subsets of edges. Each subset from the collection defines a scenario that, if emerged, leads to a deletion of the corresponding edges from the underlying graph. An edge subset from the graph is called a robust perfect matching if it contains a perfect matching for each scenario. Our goal is to determine a robust perfect matching of a minimum cardinality. In this talk, we discuss complexity results und derive properties for feasible and optimal solutions, where we focus on bipartite graphs and on structured sets of scenarios.

■ TA-15

Thursday, 8:30-10:00 - HS 45

Simulation: Frameworks, Concepts, and Tools

Stream: Simulation and Decision Support
Chair: *Joachim Block*

1 - Machine Configuration via Simulation-Based Optimization

Jens Weber, Wilhelm Dangelmaier

The "Intelligent work preparation based on virtual tooling machines" research project presents an idea for pursuing an automatically optimized machine setup to obtain minimized tool paths and production time for CNC tooling machines. A simulation-based optimization method was developed for this implementation, which is installed in combination with a virtual tooling machine to validate the setup parameters and configuration scenarios. The virtual tooling machine was provided from a project partner and can be regarded as a 1:1-simulation model of a real tooling machine. This simulation software offers a lot of features such as material-removal simulation and collision detection during the production process. These features are associated with a sharp increase in the simulation complexity level which leads to a high level of effort for a simple simulation-based optimization approach where a high number of iterations are typically necessary to evaluate the optimization results. This contribution describes the research project's current results focusing on how to implement the machine setup optimization in a way that is practical and useful for industrial application for cutting machines. The contribution takes into account an asynchronous execution of a population-based optimization technique which reaches a faster near-optimal simulation result. A preprocessing system for the evaluation of the optimization results which consists of a fitness interface and a NC-parser was developed for this purpose to avoid needless simulation runs of the virtual tooling machine in order to achieve time savings for the work preparation process and resources.

2 - A new advancement in Ranking and Selection; Racing Algorithms

Jawad Elomari

This work presents two new multiple comparisons fully-sequential procedures for ranking and selection problems. Both are based on Racing algorithms. The first is suitable for independent or low correlated systems (KW-RaceR), while the second is suitable for highly correlated systems (F-RaceR). The methods are rank based and do not require any distributional assumptions. It will be shown that these methods can achieve a lower probability of incorrect selection given a fixed sampling budget, compared to efficient methods like OCBA and its correlated version CBA. The test bed is composed of a number of distributions with monotonically increasing means combined with: constant variance, linearly or exponentially increasing or decreasing variance, and no, low, high, or mixed correlation. It will also be shown how the exploration vs. exploitation balance patterns of the proposed methods differ greatly from that of OCBA and CBA, but more importantly they are more reactive to the characteristics of the systems.

3 - A Conceptual Framework for Developing Multi-method Simulation Models

Joachim Block

Simulation is among the most widely used quantitative approaches to management decision making. A rich body of knowledge about theoretical aspects and practical application of models based on discrete event simulation (DES), system dynamics (SD), and more recently agent-based modeling and simulation (ABMS) exists. Although these simulation paradigms are successfully applied in isolation, some scholars argue that building multi-method models could reveal new insights into complex real world problems. Despite some impressive progress in coupling e.g. ABMS with SD or SD with DES research on multi-method simulation seems still to be in its infancy. We aim to contribute to filling the existing research gap by presenting a conceptual framework for developing multi-method simulation models based on ABMS, DES, and SD. Basic idea is that agents in an ABMS model not only show continuous and discrete behavior but also are under control of a central command. Simulation models for disaster and epidemic response, human resource management (HRM), autonomous driving traffic control, and even stock farming are possible areas of application. Our proposed framework is founded on discrete event system specification and control theory. While continuous changing attributes and behavior of an agent are modeled by the use of SD, discrete events from the controller or the agents are handled via DES. In a case study we apply our conceptual framework on operations research strategic workforce planning. The employees of an organization are modeled as agents with attributes and job relevant behavior. In addition, a controller applies HRM policies upon the agent population. The case study demonstrates that the framework can provide guidance for the development of multi-method simulation models.

■ TA-16

Thursday, 8:30-10:00 - HS 46

Time Series, Electric Vehicles and Semantic Analysis (c)

Stream: Graphs and Networks
Chair: *Jörg Rambau*

1 - The onset of congestion in charging of electric vehicles for proportionally fair network management protocol

Lubos Buzna, Rui Carvalho

With the expected uptake of electric vehicles in the near future, we are likely to observe overloading in the local distribution networks more frequently. An important property of a suitable network capacity management protocol is to balance efficiency and fairness requirements. Assuming simple stochastic model, we use the proportional fairness protocol managing the network capacity in charging of electric vehicles. We analyze the inequality in the charging times as the arrival rate of cars demanding charging is increasing. We explore the onset of congestion by analyzing the critical arrival rate, i.e. the largest possible arrival rate that can still be fully served by the system. Based on the comparison between the proportional fairness management protocol with the max-flow management protocol, we derive results estimating how the critical arrival rate depends on the system parameters.

2 - Q3-d3-lsa

Lukas Borke

QuantNet is an integrated web-based environment consisting of different types of statistics-related documents and program codes called Quantlets. The QuantMiner creates reproducibility and offers easy access by means of a powerful and specialized searching interface. This Q3-concept increases the information retrieval efficiency but there is still a need for incorporating semantic information. We employ the D3 (Data-Driven Documents) framework concentrating on semi-structured small or medium size corpora of documents. Relying on the QuantNet platform we examine 3 semantic analysis approaches: VSM (Vector Space Model), GVSM (Generalized Vector Space Model) and LSA (Latent Semantic Analysis). Amongst these three models, LSA has been successfully used for IR (Information Retrieval) purposes as a technique for capturing semantic relations between terms and inserting them into the similarity measure between two documents. Subsequently, the performance of LSA is presented applying it for the IR, document clustering and visualization tasks in the self-developed visualization framework.

■ TA-17

Thursday, 8:30-10:00 - HS 47

Cooperative Games I (c)

Stream: Game Theory
Chair: *Tamás Solymosi*

1 - On the Inverse Problem and the Coalitional Rationality of values and semivalues.

Irinel Dragan

In cooperative Game Theory a classical problem is that of fairly dividing the worth of the grand coalition among the players. Any efficient value may be taken as a help, but the division is in general not fair. In an earlier work, we solved the Inverse Problem for Semivalues (IJPAM 2005). In case that the efficient value is not coalitional rational, we consider the connected problem of finding in the Inverse Set a new

game, with the same efficient value, but coalitional rational, that is belonging to the CORE of the game. The procedure for getting such a game is given and some examples are illustrating it. In the case of a Semivalue, which is non efficient, we consider the same problem but now we should define what does it mean to be coalitional rational. We follow the ideas appearing in a joint work (Dragan-Martinez-Legaz, 2001), and define the Power Game, as well as the coalitional rationaliy relative to this game. We solve the same problem, for this case; again, some example is illustrating the procedure.

2 - The monotonicity of the nucleolus of assignment games
Miklos Pinter, Jaime Brugueras, Tamás Solymosi, T. E. S. Raghavan

Assignment games are models of two-sided matching markets, where only bilateral cooperations can generate added value. Thus, an assignment game is completely determined by the matrix consisting of the profit values of all possible mixed pairs of players. In this paper we consider various monotonicity concepts on assignment games: aggregate monotonicity, coalitional monotonicity, marginality, strong monotonicity and pairwise monotonicity. We show only three of the above monotonicity concepts are meaningful for assignment games: marginality, strong monotonicity and pairwise monotonicity, and also demonstrate that all but marginality and strong monotonicity are fulfilled by the nucleolus of assignment games. We conclude the most fitting monotonicity notion for assignment games is the pairwise monotonicity, where if we increase one entry in the profit matrix but keep all other entries fixed, the payoff cannot decrease for either the row or the column player in the corresponding assignment game. We show that the nucleolus is pairwise monotone for the assignment games.

■ TA-18

Thursday, 8:30-10:00 - HS 48

Network Management Regimes in Electricity and Gas Markets

Stream: Energy and Environment
Chair: *Gregor Zöttl*
Chair: *Martin Schmidt*

1 - Transmission and Generation Investment in Electricity Markets: The Effects of Market Splitting and Network Fee Regimes
Martin Schmidt, Veronika Grimm, Alexander Martin, Martin Weibelzahl, Gregor Zöttl

We propose an equilibrium model that allows to analyze the long-run impact of the regulatory environment on transmission line expansion by the regulator and investment in generation capacity by private firms in liberalized electricity markets. The model incorporates investment decisions of the transmission operator and private firms in expectation of an energy-only market and cost-based redispatch. In different specifications we consider the cases of one vs. multiple price zones (market splitting) and analyze different approaches to recover network cost - in particular lump sum, generation capacity based, and energy based fees. In order to compare the outcomes of our multistage market model with a first best benchmark, we also solve the corresponding integrated planner problem. In a case study we illustrate that energy-only markets can lead to suboptimal locational decisions for generation capacity and thus imply excessive network expansion. Market splitting heals these problems only partially. These results are valid for all considered types of network tariffs, although investment slightly differs across those regimes.

2 - Regionally Differentiated Network Fees to Provide Proper Incentives for Generation Investment
Christian Sölch, Veronika Grimm, Bastian Rückel, Gregor Zöttl

We propose an equilibrium model that allows to compare different market mechanisms providing incentives for locationally differentiated choice of production facilities. Our framework takes into account both generation investment decided upon by private investors and redispatch and network expansion decided upon by a centralized network planner. In order to take into account the different objectives and decision variables of those different agents in our equilibrium framework, our approach exhibits a multi stage structure. We analyze the case of different price zones which are already taken into account at the spot market, where potentially arising regional price difference provide long run investment signals. Alternatively we analyze the case of different types of regionally differentiated network fees which have to be paid by production facilities (a so called G-component). The resulting investment and production decisions can be compared to an equilibrium model in the absence of such regional differentiated investment incentives and to an overall optimal (first best) benchmark. To provide economically and politically relevant statements based on our computation we calibrate our framework for the German Electricity market. Our results reveal that regionally differentiated network fees do have a significant impact on locational choice of generation facilities resulting in a reduced network expansion and welfare increase of 50 Mio.EU/year. However, we find that the annual welfare gains for the German Market are surprisingly moderate in comparison to a slight modification of the network expansion planning: Large welfare gains of 250 Mio.EU/year can be implemented by taking into account a flexible handling of redispatch decisions at the time of planning network expansion.

3 - Technical Capacities of Gas Transportation Networks – Theoretical and computational challenges
Lars Schewe, Christine Hayn

We discuss the notion of technical capacities of gas transportation networks. We show that under current European regulations the computation of these capacities would lead to a three-level optimization problem, where the core problem is a mixed-integer nonlinear program. We discuss how the entry-exit system introduces this level of complexity. We propose a method to solve the resulting optimization problems and show that under simplifying assumptions we can still compute relevant estimates for real-world networks.

■ TA-19

Thursday, 8:30-10:00 - HS 50

Optimal compensation schemes for power markets and electricity demand systems

Stream: Energy and Environment
Chair: *Martin Densing*

1 - A Demand Side Management model for load scheduling in healthcare facilities
Paolo Pisciella

We propose a model for defining the optimal scheduling of electric powered devices with the aim of reducing energy expenditures in a healthcare facility. The model considers day ahead prices and weather forecasts in order to schedule AC and ventilation settings minimizing total costs while maintaining a minimum comfort treshold.

2 - Minimizing discontinuities in electricity tariff structures
Kai Helge Becker, Alex Bahnisch

Electricity retailers typically offer a set of different electricity tariffs to their customers. The individual tariffs that make up the tariff structure of an electricity retailer are often characterized by different price components, i.e. the total price to be paid by a customer can depend on several variables, such as the peak energy demand or the total energy consumption over a period of time. To determine a particular customer's tariff within the tariff structure offered, electricity retailers may use certain thresholds regarding the customer's peak demand or energy consumption, i.e. a customer may be forced into a different tariff when its demand or consumption exceeds, or remains under, a relevant threshold. This can lead to a situation in which small changes in the energy demand or consumption of a customer may lead to a large difference in the electricity price that the customer has to pay. A customer friendly approach therefore would be to design the tariff structure such that discontinuities between tariffs are minimized. The paper presents a linearized optimization model with stochastic components to address this problem for a case in the Australian electricity market.

■ TA-20

Thursday, 8:30-10:00 - ÜR Germanistik 1

Optimal decisions for stochastic models (c)

Stream: Stochastic Optimization
Chair: *Jannik Vogel*

1 - Adaptive simulated annealing with homogenization for aircraft trajectory optimization in a random environment

Clément Bouttier, Sébastien Gadat, Sébastien Gerchinovitz, Florence Nicol

Optimizing an aircraft trajectory is an attracting subject of investigation, both in the academic and industrial communities. Most optimization procedures are based on deterministic modelling in the sense that they do not take into account the uncertainties on environmental conditions (e.g., wind) and on air traffic control operations. However, aircraft performance in a real-world context are highly sensitive to these uncertainties. The aim of this work is twofold. First we provide some numerical evidence of the sensitivity of fuel consumption and flight duration with respect to random fluctuations of the wind and the air traffic control operations. The presented numerical simuations rely on in-service aircraft performance models. These numerical results extend earlier works (cf. B.Schwartz et al. 2000) that only studied a single source of uncertainty. Second, we develop a global stochastic optimization procedure for general aircraft performance criteria. The goal is to minimize a certain expected cost associated to the trajectory in the random environment. This problem is a non-convex optimization problem. Since we consider general (black-box) cost functions, we develop a derivative-free optimization procedure: adaptive simulated annealing with homogenization (A.S.A.H.) in the same spirit as in T.M.Alkhamis et al. 1997. At each iteration, our algorithm uses several Monte Carlo evaluations of the noisy cost function. A key ingredient is to increase the number of evaluations of the cost function with the number of iterations. We relate the accuracy of the cost function to the temperature parameter of the A.S.A.H. algorithm to obtain good performance of the method. Numerical results validate the proposed approach.

2 - Decision models for queueing systems with adaptive service rates

Jannik Vogel, Raik Stolletz

In queueing system literature it is common that the service rate of a server is a given and fixed parameter. In various situations however, considering the service rate as a time-dependent decision variable improves and stabilizes the performance of the queueing system. In this paper, a general decision model in combination with a time-dependent queueing model is developed. The cost structure comprises holding costs for items in the system, service costs for the service rate chosen, and a penalty for items in the system at the end of the time-horizon. The SBC-approach to evaluate the time-dependent performance of a queueing system is described in detail and the relationship between period length and performance approximation quality is investigated. This leads to the development of an iterative procedure that provides a reasonable solution for every choice of the parameters. The numerical analysis shows the benefit of assuming the service rate as a decision variable and reveals, how the optimization model improves the performance approximation compared to an evaluation.

3 - Estimating Performance in a Mobile Fulfillment System

Tim Lamballais Tessensohn

The aim of this research is to model and analyze a new type of material handling system: Mobile Fulfillment Systems. A Mobile Fulfillment System is an automated storage system, where robots carry shelves containing products to the workers. Inventory is mobile and can be continually sorted to adapt for fluctuating demand. The most popular products are therefore usually close to the workers. This work presents some of the first queueing models for this type of system and contributes by including accurate driving behavior of robots, storage zoning, and multi-line orders. Storage zoning is included to model the sorting of inventory. Semi-open queueing networks are used to model this system, because these networks allow the warehouse layout to be optimized by evaluating a large number of layout configurations in a short time period. We show that the queueing networks can accurately estimate maximum order throughput, average order cycle, workstation utilization and robot utilization. We also investigate the maximum order throughput for different length-to-width ratios of the storage area, the effect of changing the location of workstations and the effect of storage zoning.

■ TA-21

Thursday, 8:30-10:00 - ÜR Germanistik 2

Advances in Stochastic Optimization I (i)

Stream: Stochastic Optimization
Chair: *Huifu Xu*

1 - SAA Regularized Methods for Multi-Product Price Optimization under the Pure Characteristics Demand Model

Hailin Sun

Utility-based choice models are often used to determine a consumer's purchase decision among a list of available products; to provide an estimate of product demands; and, when data on purchase decisions or market shares are available, to infer consumers' preferences over observed product characteristics. They also serve as a building block in modeling firms' pricing and assortment optimization problems. We consider a firm's multi-product pricing problem, in which product demands are determined by a pure characteristics model. A sample average approximation (SAA) method is used to approximate the expected market share of products considered and the firm's profit. We then apply a regularized method to compute a solution of the SAA problem and study the convergence of the SAA solutions when the sample size increases.

2 - Scenario tree reduction algorithms based on a new distance function

Zhiping Chen

To develop practical and efficient scenario tree reduction methods, we introduce a new distance function to measure the difference between two scenario trees, it has a simple structure and can be calculated easily. Based on minimizing the new distance, we first construct a single period scenario tree reduction model. It is proved that the new reduction model also minimizes the Wasserstein distance between the reduced tree and the initial tree, and in this case, it is better than the reduction model in Dupacova, Growe-Kuska and Romisch (2003). Depending on how to solve the encountered combinatorial optimization problem, we design two scenario tree reduction algorithms, the recursive-type method and the cluster method, which are superior to the simultaneous backward reduction method in terms of complexity. Then, we extend the above two reduction algorithms to the fan-liked multi-period scenario tree and the multi-period tree with general structure, respectively, and propose associated reduction algorithms. Numerical experiments demonstrate the practicality, efficiency and robustness of proposed reduction algorithms.

3 - CVaR Risk Measures and Minimax Limits

Huifu Xu

Conditional value at risk (CVaR) has been widely used as a risk measure in finance. When the confidence level of CVaR is set close to 1, the CVaR risk measure approximates the extreme (worst scenario) risk measure. In this paper, we present a quantitative analysis of the relationship between the two risk measures and its impact on optimal decision making when we wish to minimize the respective risks measures. We also investigate the difference between the optimal solutions to the two optimization problems with identical objective function but under constraints on the two risk measures. We discuss the benefits of a sample average approximation scheme for the CVaR constraints and investigate the convergence of the optimal solution obtained from this scheme as the sample size increases. We use some portfolio optimization problems to investigate the performance of the CVaR approximation approach. Our numerical results demonstrate how reducing the confidence level can lead to better overall performance.

■ TA-22

Thursday, 8:30-10:00 - ÜR Germanistik 3

Advanced Analytics in Revenue Management (i)

Stream: Accounting and Revenue Management
Chair: *Catherine Cleophas*

1 - Nonparametric Demand Estimation in Airline Revenue Management

Johannes Ferdinand Jörg, Catherine Cleophas

A central theme of airline revenue management is analyzing historical booking data to draw conclusions on the underlying demand structure. A multitude of sources influence booking data, e.g. availability control and product restrictions have large censoring effects. This leads to a discrepancy between historical data and real demand. Studying this issue helps to understand the market and to react to changes. To apply revenue management techniques, we have to be able to segment the market to identify several different customer types. The goal is to optimize the availability of products over time such that the customers' willingness to pay is exploited. Naturally, this motivates identifying customer types and their behavior to forecast the number of customers arriving in a certain time frame. We focus on nonparametric estimation of demand structures, which uses large data sets to remove the assumption of a specific underlying distribution. For this end, we model our approach with finite mixtures of customer types. Using matrix decompositions, we obtain an estimation procedure which allows us to calculate a lower bound for the number of customer types given observations of bookings over two time periods. This estimation procedure is then tested in an airline revenue management simulation. We discuss the results with respect to the simulated demand and identified customer types. Since the procedure involves computing matrix decompositions and eigenvalues, we also perform a sensitivity analysis concerning values which are considered zero. Finally, we discuss the extension of this model to include more observable characteristica and how this approach deals with incomplete data sets.

2 - Optimal pricing of discrete and continuous airfares in the presence of endogeneity for revenue maximization

Jan Felix Meyer, Goeran Kauermann

As the remaining capacities on a flight are perishable assets the airline's revenue management evaluates two cost types in order to maximize revenue. Because sold seats cannot be offered again opportunity costs are considered to minimize the risk of spoilage by having to reject high yield customers due to overselling at low rates. Simultaneously the passenger's willingness to pay is evaluated to control for price elasticity cost. Those may occur if a seat is sold for a fare which is below the individual's willingness to pay. This presentation will focus on the latter. We propose to exploit the demand-price-relationship to capture the price elasticity cost by the fare which maximizes revenue. A comparison of a discrete and continuous pricing-scheme is done to show that the maximum may not be achievable by an airline which uses booking classes as not every fare-value is available for pricing. As proposed within the literature estimation of the demand-price-equation may give a downward biased price influence as price could depend itself upon demand. This would mean that we would falsely assume a less price elastic demand. In order to identify the potential endogeneity three approaches are benchmarked. Our reference, ignoring the endogenity issue, is given by a flexible approach which relaxes the assumption of a specific functional form by implementing unspecified but smooth functions. The remaining two models add upon the reference by employing a flexible instrumental variable approach. Here we use the airline's estimated opportunity costs as an instrument. Within the third alternative we use the estimated Rank-Order as an Instrument. Here the data itself is used to create an instrument. For demonstration purposes booking-data from a large western airline is used.

3 - More efficient forecasting for airline revenue management

Alexander Dyskin

State-of-the-art forecasting methods in airline revenue management (ARM) systems are driven by the desire for higher accuracy and higher degree of detail. Integrated feedback loops and a growing number of parameters were added to the demand models to better reflect short-term changes and new trends in passengers' behavior.

As a result, industry applications of ARM systems have become increasingly sophisticated and complex. Requirements with regard to the hard- and software as well as to data availability have significantly increased. At the same time ARM analysts struggle with calibrating and controlling the system, leading to an increase in manual overwrites — a tool that should be limited to exceptional cases.

This talk will present ways to solve the conflict between accuracy, flexibility and user transparency of demand forecasting methods. We suggest to split the ARM demand forecasting process and to apply a different set of parameters clustered by time to departure. In addition, we will present a simulation model and set-up to evaluate the effect of substitution of historical booking data by available booking data for future flights with similar characteristics.

■ TA-23

Thursday, 8:30-10:00 - ÜR Germanistik 4

Decomposition in Integer Programming (c)

Stream: Integer Programming
Chair: *Jonas Witt*

1 - A Benders Decomposition Approach for Static Data Segment Location to Servers Connected by a Tree Backbone

Goutam Sen, Narayan Rangaraj, Mohan Krishnamoorthy, Vishnu Narayanan

We consider a video-on-demand (VoD) database and study the problem of allocating the content in a content distribution network (CDN). This location-allocation problem of locating such data to multiple servers is a cost-optimization problem. Many other decisions such as server location, query routing, user assignment are addressed simultaneously. The modelling approach builds on the uncapacitated single allocation p-hub median problem. The servers that host subsets of content (database segments) are treated as data hubs. The data hubs are connected to each other by high-bandwidth links (backbone). The primary attraction of a hub location model is that the cost of routing large volumes of queries through these links is discounted due to the economies of scale.

We consider a variant in which the backbone is restricted to be a tree. Our model is inspired by the "tree of hubs" problem from physical logistics. This variant is extremely difficult to solve because the construction of the tree, given other decisions a-priori, is itself an NP -hard problem, known as the optimum communication spanning tree problem (OCSTP). However, prior information on the segment allocation, server location, and the tree backbone, reduces the original problem to a simple assignment problem, and therefore, indicates the suitability of a decomposition approach. We reformulate the problem to a 4-subscripted MILP yielding tight LP bounds and develop a Benders decomposition approach. Due to the hardness of the master problem, we solve it heuristically to obtain a reasonable upper bound on the original problem in a short period of time. The success of the algorithm is particularly significant in large problems, for which CPLEX struggles to obtain even a feasible integer solution.

2 - Dantzig-Wolfe Reformulations for the Stable Set Problem

Jonas Witt, Marco Lübbecke

Dantzig-Wolfe reformulation of an integer program partially convexifies a subset of the constraints, which yields an extended formulation with a potentially stronger linear programming (LP) relaxation than the original formulation. This presentation is part of an endeavor to understand the strength of such a reformulation in general. We investigate Dantzig-Wolfe reformulations of the edge formulation for the maximum weighted stable set problem. In particular we characterize reformulations not yielding a stronger LP relaxation than the edge formulation and present necessary as well as sufficient conditions such that the reformulation is best possible.

■ TA-24

Thursday, 8:30-10:00 - ÜR Germanistik 5

Social Networks & Customer Reviews (c)

Stream: Analytics
Chair: *Jochen Gönsch*

1 - Models and Methods for the Analysis of the Diffusion of Skills in Social Networks

Alberto Ceselli, Marco Cremonini, Simeone Cristofaro

Social networks are a pervasive phenomenon. While commonly exploited in industry, they are still largely unexplored from the scientific point of view, leaving a huge application potential unexpressed. Their study is hardened by two important factors: the high complexity of the systems at hand and the large amount of data to be considered.

In this work we propose Linear and Integer Linear Programming models to analyse the diffusion of skills through social networks. We assume a set of individuals and a set of topics to be given. Each individual has a certain level of interest and skill on each topic, that change through interactions with other individuals. Links among individuals evolve according to these interactions. As shown in the literature such a phenomenon well represents the dynamics of opinions, relationships and trust.

Our models are suitable for both predictive and prescriptive analytics. In particular, they can be used (a) to predict the skill level on each topic for each individual, by taking as data a sampling of the status of network links during a certain time horizon (b) to predict the status of network links, by taking as data a sampling of skill levels (c) to indicate which individuals affect most the network when their own skill is artificially increased (d) to indicate which missing links would improve the average skill level of the network.

We present computational results, exploiting a simulation tool from the literature, and considering networks with up to fifty individuals, twelve topics and thousands of time steps. These show that our approach is computationally viable also on large scale data, requires very few parameters to be tuned during training, and provides results of reasonable accuracy, especially in tasks (a) and (c).

2 - What Makes Consumers Unsatisfied with Your Products: Review Analysis in a Fine-Grained Level

Ping Ji

Online product reviews contain valuable information about customer requirements (CRs). Intelligent analysis of a big volume of online CRs appeals the interest of researchers in different fields. However, many research publications only concern sentiment polarities in product feature level. With these results, designers still need to read a list of reviews to absorb comprehensive CRs. In this research, online reviews are analyzed in a fine-grained level. Particularly, aspects of product features and detailed reasons of consumers are extracted from online reviews to inform designers about what on earth leads to unsatisfied opinions. This research starts from the identification of product features and the sentiment analysis with the help of pros and cons reviews. Next, the approach of conditional random fields is employed to detect aspects of product features and detailed reasons from online reviews simultaneously. In addition, a co-clustering algorithm is devised to group similar aspects and reasons to provide a concise description about CRs. Finally, utilizing customer reviews of six mobile phones from Amazon.com, a case study is presented to illustrate how the proposed approaches benefit product designers in the elicitation of CRs by the analysis of online opinion data.

3 - Supporting Product Optimization by Customer Data Analysis

Tatiana Deriyenko, Dirk Christian Mattfeld, Tetiana Zinchenko

The work introduces a concept for product optimization support based on mining integrated customer data sources. The motivation is a common presence of a misunderstanding gap between the manufacturer and the customer. While the customer has certain needs, the manufacturer aims to understand and satisfy them. However, due to wrong interpretation or implementation mistakes, the end product can vary from the needs of the customer. Product optimization can help to remedy that, resulting in costs saving and higher customer satisfaction. The concept aims at supporting product optimization by combining diverse data sources related to the customer into a single view. While the first source is a structured description of customer-product interaction, the second one comprises natural language messages from social media. Due to different business perspectives and low technical compatibility, sources integration is challenging. The key contribution of the concept is bringing the sources together in a semi-automatic manner to reveal the nature of the product nonconformity to the customer needs. Expected outcome consists of two main components. The first one is customer-product interaction patterns, which might indicate the need for design optimization, for instance, when a particular function is rarely used. The second component is the hypotheses about the reasons of the patterns' occurrence, i.e. product aspects that do not entirely meet customer needs. The findings can be related to product aspects, usability or visual attractiveness. The hypotheses can be evaluated against customer surveys. The concept involves methods of quality evaluation, information retrieval, ontology alignment, etc. Preliminary results of applying the concept in automotive field are shown.

■ TA-25

Thursday, 8:30-10:00 - ÜR Alte Geschichte

Fuzzy Decision Systems

Stream: Neural Networks and Fuzzy Systems
Chair: *Jaroslav Ramik*

1 - What automaton model captures decision making? A call for finding a behavioral taxonomy of complexity

Bodo Vogt

When investigating bounded rationality, economists favor finite- state automatons — for example the Mealy machine — and state complexity as a model for human decision making over other concepts. Finite-state automatons are a machine model, which are especially suited for (repetitions of) decision problems with limited strategy sets. In this paper, we argue that finite-state automatons do not suffice to capture human decision making when it comes to problems with infi nite strategy sets, such as choice rules. To proof our arguments, we apply the concept of Turing machines to choice rules and show that rational choice has minimal complexity if choices are rationalizable, while complexity of rational choice dramatically increases if choices are no longer rationalizable. We conclude that modeling human behavior using space and time complexity best captures human behavior and suggest to introduce a behavioral taxonomy of complexity describing adequate boundaries for human capabilities. We discuss our findings in the context of fuzzy modeling.

2 - Incomplete preference matrix on alo-group and its application to ranking of alternatives

Jaroslav Ramik

A preference matrix is the result of pairwise comparison a powerful method in multi-criteria optimization. When comparing two elements, the decision maker assigns the value from a given scale which is an Abelian linearly ordered group (Alo-group) of the real line to any pair of alternatives representing the element of the preference matrix (P-matrix). We generalize the well known multiplicative and addi- tive preference matrices, and also multiplicative and additive fuzzy preference ones.Then we focus on situations where some elements of the P-matrix matrix are missing. We propose a general method for completing fuzzy matrix with missing elements called the extension of the P-matrix. We investigate some important particular case of fuzzy preference matrix with missing elements. Eight illustrative numerical examples are supplemented.

■ TA-26

Thursday, 8:30-10:00 - SR Geschichte 1

Optimization Algorithms and Duality (c)

Stream: Continuous Optimization
Chair: *Nico Strasdat*

1 - Adaptive Representation of Large 3D Point Clouds for Shape Optimization

Damir Vucina, Milan Ćurković

Engineering is increasingly focused on designing, analyzing and optimizing objects for requested functionality while aspiring excellence in performance. Accordingly, numerical analysis and optimization must interact with 3D geometry. A numerical procedure for adaptive parameterization of changing 3D objects for knowledge representation, analysis and optimization is developed. The object is not a full CAD model since it involves many shape parameters and excessive details. Instead, optical 3D scanning of the actual object is used (stereo-photogrammetry, triangulation) which leads to the big-data territory with point clouds of size 108 and beyond. Such a 3D shape model is highly accurate but inadequate for representation. Parameterization of the point clouds is hence accomplished by integral or chained piecewise B-spline entites best-fitted to point clouds. The total number of inherent surface parameters corresponds to the dimensionality of the shape optimization space. Parameterization must be highly compact and efficient while capable of representing sufficiently generic 3D shapes. By employing a modest number of parameters in the model, optimization algorithms will search in lower-dimensional space. The procedure must handle dynamically changing shapes in optimization quasi-time iterations. It must be adaptive and autonomously adaptable as edges and peaks may disappear and new ones may arise. Adaptive re-allocation of the control points is based on feature recognition procedures (edges, peaks) operating on eigenvalue ratios and slope/curvature estimators. The procedure involves identification of areas with significant change in geometry and formation of partitions. This offers significant advantages in engineering shape optimization using meta-heuristics.

2 - Efficient optimization of hyper-parameters for least squares support vector regression

Nico Strasdat, Andreas Fischer, Gerd Langensiepen, Klaus Luig, Thorsten Thies

Support Vector Regression (SVR) is a basic tool for machine learning. It is used in many applications to estimate a functional relationship based on a given set of labeled data elements. However, the generalization performance of a generated regression function highly depends on the right choice of some hyper-parameters. Recently the problem of determining suitable parameter values has been stated as a bilevel optimization problem. For the special case of Least Squares Support Vector Regression we suggest an efficient method to compute local solutions of the bilevel program. Moreover, we show that the proposed optimization method leads to good regression performance for real-world data sets.

■ TA-27

Thursday, 8:30-10:00 - SR Geschichte 2

Stochastic optimization in energy trading

Stream: Financial Modelling
Chair: *Nils Löhndorf*

1 - Optimal gas storage valuation and futures trading under a high-dimensional price process

Nils Löhndorf, David Wozabal

We study the problem of optimal gas storage valuation under a high-dimensional multifactor price model. The problem is modeled as a Markov decision process which leads to a stochastic version of the popular rolling intrinsic value. Using the nested conditional value-at-risk, we show that the rolling intrinsic solution is optimal for the case of extreme risk aversion. We solve the problem by combining optimal quantization with approximate dual dynamic programming. Our quantization method reduces the high-dimensional multifactor price model to a discrete lattice. We find that it is necessary to match price expectations on the lattice with price expectations of the continuous process. In a numerical study, we demonstrate that our approach results in 26-55% higher values than another state-of-the-art approach from the literature on the exact same problem instances.

2 - Medium-Term Planning for an Alpine Hydro Storage Power System in a Market Environment by Stochastic Optimization

Andreas Eichhorn, Nils Löhndorf

We present a real-world application of a stochastic optimization model for medium-term planning of a cross-linked hydro storage power system in the Austrian Alps. The objective is to maximize the expected total revenue with respect to the German-Austrian EPEX Spot day-ahead market; due to the limited capacity of the ancillary services markets (for primary, secondary, and tertiary control reserve) in Austria, control reserve is taken into account by given global reserve constraints (i.e. not in the objective).

Stochasticity enters the model via uncertain power prices as well as via uncertain hydrologic inflows into the storages and rivers. This consecutive uncertainty is represented by a scenario lattice (recombining scenario tree) with daily branching.

The stochastic inflows are modeled directly by a multi-dimensional Markov chain for the principal components of the detrended and deseasonalized historic inflow time series. It turns out that only few (e.g., three) principal components can explain most of the variation of the highly multivariate original inflow time series. This integral approach (detrending, PCA, Markov chain) is different to the common two-part approach in stochastic programming where scenario tree construction clustering methods are applied to sample paths of some separate time series model.

The resulting stochastic optimization problem is solved by the Quasar Java library of Quantego. This library implements the ADDP method (approximate dual dynamic programming) which is similar to SDDP. It allows, together with the underlying LP solver Sulum, for stochastic optimization of the hydro storage power system with a planning horizon of one or two years in hourly discretization.

3 - Calculation of a power price equilibrium under risk averse trading of futures contracts

Raphael Hauser, Miha Troha

We present a tractable quadratic programming formulation for calculating the equilibrium term structure of electricity prices. Our optimisation problem arises from a game theoretic model of the market for electricity futures in which producers and consumers trade contracts at several periods before maturity under consideration of uncertainty of future prices, trading costs and physical properties of the power plants available for physical power production. Our numerical simulations examine the properties of the term structure and its dependence on various parameters of the model. The proposed quadratic programming formulation is applied to calculate the equilibrium term structure of electricity prices in the UK power grid consisting of a few hundred power plants.

■ TA-28

Thursday, 8:30-10:00 - HS 34

Control theory for supply chain and operations management

Stream: Control Theory
Chair: *Virginia Spiegler*

1 - Dynamic optimal production path in the oil reserves: how upstream contracts distort it? psc perspective

Fazel M.Farimani, Ali Taherifard

To maximize the gain from an oil field, in an economic point of view, the profit function should be maximized, while from an engineering perspective, the cumulative production should be maximized considering the technical features of the reservoir. An economic analysis, in a dynamic optimization framework, produces a time path which shows those amount of production upon which the cumulative profit from the reservoir is maximized, while the engineering modelling generates a time path of production which maximizes the cumulative production. We call the first one economic neutral path and the latter engineering neutral path, very unlikely to match. The economic path might not be practically feasible and the engineering one may not necessarily guarantee the maximum profit. To have both profitable and feasible path we solve a dynamic optimization problem in which the objective

function is the total profit of the field and the constraint is an engineering limit. This problem results in a dynamic optimal production path which is both feasible and profitable and is called in this paper Feasible and Profitable Neutral Path (FPNP). Now we add the ownership to the model; assume that a host government (HC) calls a foreign oil company to develop the field. Consequently, two different optimal economic paths would be generated. We assume a green oil field under production sharing contract. First we find the FPNP and then show how each party find their dynamic optimal production path and how different are their path from the FPNP. Using Optimal Control Theory we show that the main feature in comparing the neutral and parties' optimal path is the relationship between the changes in oil price and the interest rate. The PSC parameters have no effect.

2 - Investigating limit cycles in nonlinear production and inventory control models

Virginia Spiegler, Mohamed Naim, Denis Towill

Purpose: Even in a deterministic setting nonlinearities can yield unexpected dynamic behaviours in an inventory control system, such as rogue oscillations or limit cycles. Utilising a well-known benchmark nonlinear production and inventory control model, we investigate the occurrence of limit cycles. Design: Nonlinear control theory in combination with simulation is used to analyse the effect of discontinuous nonlinearities present in a production and inventory control model. The describing function method is used to predict limit cycle occurrence and their characteristics, such as frequency, amplitude and stability. Findings: Findings suggest that, even for an autonomous system, limit cycles occur. This periodic behaviour is observed in the inventory profile when the feedback gain of the WIP is half smaller than the lead-time. Moreover, we demonstrate the potential of the describing function method to accurately predict limit cycle properties. Value: This paper fills the gap in the literature on nonlinear supply chains by using control engineering methods to explore the dynamic behaviour of inventory profiles. Most studies of supply chain dynamics have focused on linear mathematical models or rely on simulation, which greatly limit the relevancy and/or rigour of published results Research limitations: This research is limited to the dynamics of a single-echelon supply chain system in a deterministic environment. Practical implications: The method suggested in this research for analysing nonlinearities in a real-world setting can be used by supply chain designers to gain more insights into nonlinear systems and provide a mechanism to create a set of systematic experiments for simulation rather than relying on a time-consuming 'trial and error' approach.

3 - Control-theoretic framework for ripple effect and the supply chain structure dynamics

Dmitry Ivanov, Boris Sokolov

Disruptive risks represent a new challenge for supply chain (SC) managers who face the ripple effect subject to structural disruptions in the SC unlike parametrical deviations in the bullwhip-effect. In 2000-2014, SC disruptions occurred in greater frequency and intensity, and thus with greater consequences. Details of empirical or quantitative methodologies differ across the works on SC disruption management, but most share a basic set of attributes: • a disruption (or a set of disruptions) • impact of the disruption on operational and strategic economic performance • stabilization and recovery policies. Within this set of attributes, most studies consider how changes in some structures are rippling through the rest of the SC and impacting on economic performance. We suggest considering this situation the ripple effect in the SC structure dynamics framework, as an analogy to computer science, where the ripple effect determines the disruption-based scope of changes in the system. In SCM settings, the ripple effect should also include recovery strategies which may compensate disruptions and avoid their rippling. The ripple effect describes the impact of a disruption on SC performance and disruption-based scope of changes in the SC structures. Managing the ripple effect is closely related to designing and planning robust and resilient SCs. This study aims at presenting the ripple effect in the SCs in terms of structure dy-namics framework. The SC structure dynamics framework is presented. We show an example of considering the ripple effect and structure dynamics in a SC design and planning obtained in a practical project for a multi-stage production-distribution network. Finally we identify gaps in current research and delineate future research avenues

■ TA-29

Thursday, 8:30-10:00 - SR IÖGF

Robustness in Multiple Criteria Decision Making (c)

Stream: Multiple Criteria Decision Making
Chair: *Silvia Vogel*

1 - First Approaches to Regularization Robustness in Multi-Objective Optimization

Corinna Krüger, Anita Schöbel, Gabriele Eichfelder

In real world applications, multi-objective decision making often has to take place while a part of the data that defines the problem is uncertain. In practice, decision makers often face uncertainty in decision variables, which has to be distinguished from uncertainty in problem parameters. Consideration of uncertainty in decision variables is present whenever a calculated solution can not be put into practice exactly. For instance, in agricultural industries, calculated amounts of peat and fertilizer, which are used to raise plants, can only be realized within some accuracy. Uncertainty in decision variables in single-objective optimization problems is addressed by regularization robustness, see, e.g., Lewis 2002.

In our talk, we present an extension of the framework of single-objective regularization robustness to multi-objective optimization. For each solution, we consider the set of all of its possible realizations instead of the solution itself. Therefore, we have to compare sets instead of points in order to find non-dominated solutions.

Whenever applied to a single-objective problem, the concept presented is identical to the classical single-objective definition of regularization robustness. Moreover, the concept fits into the framework for parameter uncertainty in multi-objective optimization by Ehrgott et al. 2014.

Apart from the concept, we will present first theoretical results about regularization robustness in multi-objective optimization. Furthermore, we will illustrate the close relationship between our concept and set-valued optimization with infima and suprema. We will show first approaches to handle multi-objective regularization robustness as well as special cases of problems where solutions can soundly be determined.

2 - Measuring Robustness in Surrogate Weight Methods

Love Ekenberg, Mats Danielson

Multi Criteria Decision Aid (MCDA) methods have been around for a long time. However, the elicitation of preference information in MCDA processes is problematical in real-life applications. Various proposals on how to eliminate some of the obstacles exist and so called surrogate weights have proliferated for a while in the form of ordinal ranking methods for the criteria weights. At the same time, decision-makers often possess more elaborate information, for example regarding the relative strengths of the criteria, and want to use that. Thus, some form of cardinality often exist that can be utilised when transforming orderings into weights. We have earlier suggested a testing methodology of a set of cardinal ordering methods including to what extent these improve the efficacy of rank order weights and provide a reasonable base for decision making. In this paper, we extend our previous work by introducing the concept of ranking robustness and investigate decision methods regarding different measures of robustness.

3 - Confidence Sets in Multiobjective Optimization

Silvia Vogel

Often decision makers have to deal with an optimization problem with unknown quantities. Then they will estimate these quantities and solve the problem as it then appears - the 'approximate problem'. Thus there is a need to establish conditions which ensure that the solutions of the approximate problem come close to the solutions of the true problem in a suitable manner. Confidence sets can provide important quantitative information. We shall consider decision problems with multiple criteria and derive confidence sets for the sets of efficient points, weakly efficient points, and the corresponding solution sets. We will investigate two approaches: one method needs some knowledge about the true problem, the other can cope without it. The results will be applied to the Markowitz model of portfolio optimization.

■ TA-31

Thursday, 8:30-10:00 - Marietta Blau Saal

Software for Optimization under Uncertainty

Stream: OR Software, Modelling Languages
Chair: *Ronald Hochreiter*

1 - Integrating CMPL with SolverStudio
Mike Steglich, Andrew J Mason

SolverStudio is an add-in for Excel on Windows that allows to build and solve optimisation models in Excel using modeling languages such as AMPL, GAMS or PuLP. One of the languages integrated recently with SolverStudio is CMPL (<Coliop|Coin> Mathematical Programming Language) with its Python API pyCMPL. CMPL is a system for mathematical programming and optimisation of linear optimisation problems using popular solvers such as CBC, GLPK, SCIP, Gurobi and CPLEX. After an overview of the main functionalities of SolverStudio, the main aspects of CMPL's integration with SolverStudio will be described. Furthermore, it will be shown how CMPL and pyCMPL models can be solved within Excel and SolverStudio by presenting several examples.

2 - Introducing new release 5.0 of the MPL Modeling System and the OptiMax Component Library
Bjarni Kristjansson

Maximal Software recently came out with a major new release 5.0 of the MPL Modeling System. This new release represents a major milestone for MPL, and offers numerous new features and enhancements to the software. Among the highlights are new modern directory structure for the MPL installation, completely redesigned documentation with 24 separate user/reference guides in multiple formats, new solver updates for CPLEX 12.6, GUROBI 6.0, SULUM 4.3, MOSEK 7.1, LINDO 9.0, KNITRO 9.0, and IPOPT 3.11, new Reverse Hessian algorithm for faster solving of nonlinear models, automatic feasibility check for the solution returned by the solver, enhanced support for formulating stochastic models

Major updates were also implemented for both the MPL OptiMax Component Library and the MPL Callable Library for deployment, including new callbacks, new exception handlers, and enhanced multi-threaded support. Furthermore, support was added for Visual Studio 2012 and 2013, Python 3.3 and 3.4, and Java 1.8.

In this presentation we will be demonstrating some of the new features of MPL 5.0, with special focus on how to deploy optimization for end-users, both as standalone applications and through online servers or clouds. We will also be describing both the MPL Academic Program and the MPL Free Development Program, which provide access to free full-size versions of the MPL software for academic faculty, students, and even commercial users and consultants.

3 - Open Source Multi-Stage Scenario Tree Generation
Ronald Hochreiter

Most published multi-stage scenario tree generation techniques are masterpieces of mathematical theory and complex notation. However, if one needs to apply a certain methodology for a new stochastic optimization model things turn out to be complicated. It takes a long time to understand and re-engineer the implementation of published methods. In this talk, we remove all esoteric overhead from multi-stage scenario generation and present an open-source multi-stage scenario tree generator. Applications in the field of Finance and Energy are shown.

Thursday, 10:30-12:30

■ TB-02

Thursday, 10:30-12:30 - HS 7

Scheduling Theory (i)

Stream: Scheduling and Project Management
Chair: *Florian Jaehn*

1 - Multistage Online Scheduling
Michael Hopf, Clemens Thielen, Oliver Wendt

We study an online flow shop scheduling problem where each job consists of several tasks that have to be completed in t different stages and the goal is to maximize the total weight of accepted jobs.The set of tasks of a job contains one task for each stage and each stage has a dedicated set of identical parallel machines corresponding to it that can only process tasks of this stage. In order to gain the weight (profit) associated with a job j, each of its tasks has to be executed between a task-specific release date and deadline subject to the constraint that all tasks of job j from stages 1,...,i-1 have to be completed before the task of the i-th stage can be started. In the online problem, jobs arrive over time and all information about the tasks of a job becomes available at the release date of its first task. This model can be used to describe production processes in supply chains when customer orders arrive online.

We show that even the basic version of the offline problem with a single machine in each stage, unit weights, unit processing times, and fixed execution times for all tasks (i.e., deadline minus release date equals processing time) is APX-hard. Moreover, we show that the approximation ratio of any polynomial-time approximation algorithm for this basic version of the problem must depend on the number t of stages.

For the online version of the basic problem, we provide a (2t-1)-competitive deterministic online algorithm and a matching lower bound. Moreover, we provide several upper and lower bounds on the competitive ratio of online algorithms for several generalizations of the basic problem involving different weights, arbitrary release dates and deadlines, different processing times of tasks, and several identical machines per stage.

2 - Resource constraints in scheduling: a unified approach
Sergey Sevastyanov

Resource constraints play an important role in many practical problems of constructing a feasible schedule for a process under investigation. That is why they are presented in formulations of most theoretical problems in Theory of Scheduling (TS). As was found out, there exist resource constraints of different types — such as "renewable' and "nonrenewable', "accumulative' and "non-accumulative'. Later on, new types of resources appeared (e.g., "reproducible' resources, generalizing both renewable and nonrenewable resources). It was interesting to establish, how all these types of constraints relate to each other? It also became clear that an urgent work is needed to eliminate this terminological "mishmash'.

Another source for the mishmash are two "parallel flows' existing in TS — Project Scheduling (PS) and Machine Scheduling (MS) which tend to formulate the same constraints in different terms. For example, MS uses actively such terms as "machine' and "job' without mentioning any resources, while both terms form in PS resource constraints of a "binary' type (which is a special case of the renewable resource). The parallelism often led to duplicating results.

We show that there is no principal difference between all known types of resource constraints – all of them are special cases of the same universal resource. Using this resource in formulations of resource constraints is able to eliminate the existing discord in the resource terminology of TS. We also show that any precedence constraints (even most general) are just special cases of resource constraints. This enables one to investigate more general problems and to derive more general results.

■ TB-03

Thursday, 10:30-12:30 - HS 16

New Scheduling Algorithms and Applications (i)

Stream: Scheduling and Project Management
Chair: *Lennart Zey*

1 - The No-Wait Job Shop with Regular Objective: A Method Based on Optimal Job Insertion

Reinhard Bürgy, Heinz Gröflin

The no-wait job shop problem (NWJS-R) considered here is a version of the job shop scheduling problem where, for any two operations of a job, a fixed time lag between their starting times is prescribed. Also, sequence-dependent set-up times between consecutive operations on a machine can be present. The problem consists in finding a schedule that minimizes a general regular objective function.

We study the so-called optimal job insertion problem in the NWJS-R and prove that this problem is solvable in polynomial time by a very efficient algorithm, generalizing a result we obtained in the case of a makespan objective.

We then propose a large neighborhood local search method for the NWJS-R based on the optimal job insertion algorithm and present extensive numerical results. Specifically, on a large set of well-known benchmark instances, we apply the following objectives: makespan, total flow time, total squared flow time, maximum tardiness, total tardiness, total squared tardiness, and number of tardy jobs.

The obtained results support the validity of our approach. They compare favorably with current benchmarks when available and provide first benchmarks in the other cases.

2 - Designing a Mathematical Model for the Multi-Degree Cyclic Flow Shop Robotic Cell with Multiple Robots

Seyda Topaloglu, Atabak Elmi

This paper deals with the cyclic flow shop robotic cell scheduling problem with multiple robots, where parts are processed successively on multiple machines with standard processing times and the transportation of parts among the machines is executed by the robots. A novel mixed-integer linear programming model for the multi-cyclic flow shop robotic cell scheduling problem has been proposed and solved using a commercial software. The validity of the proposed model is examined by a computational study on a randomly generated problem instance.

3 - Scheduling three co-operating stacking cranes with predetermined container sequences

Lennart Zey, Dirk Briskorn

In recent years the need for efficient processes in sea ports has grown due to the increasing volume of maritime transport. With the help of Automated Stacking Cranes (ASCs) which store and relocate containers in container yards the corresponding storage processes can be improved significantly concering time, costs and productivity. In this paper we develop an algorithm solving the problem of scheduling three cooperating stacking cranes working jointly on a single yard block. We consider a setting with three twin cranes and a setting with two twin cranes and one larger crane. We focus on a subproblem assuming that assignment of container transports to cranes and the sequences of transports assigned to the same crane are predetermined. Since cranes cannot work independent from each other it remains to create collision free schedules deciding priority of cranes when their next operations cannot be processed simultaneously. Our approach aims at finding a collision free schedule minimizing the makespan. First, we represent the problem transforming it into a three dimensional graphical model. Second, we construct an acyclic graph enabling us to determine schedules represented by shortest paths between distinguished nodes by means of dynamic programming. Finally, we discuss the complexity of the problem and give an outlook.

4 - Single machine scheduling to minimize total earliness-tardiness with unavailability period

Gur Mosheiov

We study several versions of a single-machine scheduling problem, where the machine is unavailable for processing for a pre-specified time period. In the basic problem, a common due-date for all the jobs is assumed, and the objective function is minimizing total earliness-tardiness. We consider first the setting that no idle times are allowed. We then extend the problem to general earliness and tardiness cost functions, to the case of job-dependent weights, and to the setting that idle times are allowed. All these problems are known to be NP-hard. We introduce in all cases efficient pseudo-polynomial dynamic programming algorithms.

■ TB-04

Thursday, 10:30-12:30 - HS 21

Integer programming and applications (c)

Stream: Discrete Optimization
Chair: *Marco Lübbecke*

1 - An Experimental Study of Algorithms for Controlling Palletizers

Jochen Rethmann, Frank Gurski, Egon Wanke

We consider multi-line palletizing systems which are used by delivery industry and warehouses, where bins have to be stacked-up from conveyor belts onto pallets. Given are k sequences of labeled bins and a positive integer p. The goal of the FIFO Stack-Up problem 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 corresponding stack-up place becomes available for a pallet of bins of another label. The FIFO Stack-Up problem is computational intractable (Gurski, Rethmann, Wanke, CoRR 2013).

We consider two linear programming models for the problem and compare the running time of our models using GLPK and CPLEX solvers. For lack of benchmark data sets we use randomly generated sequences. We also draw comparisons with a breadth first search solution for the problem (Gurski, Rethmann, Wanke, MCO 2015). Further we discuss the influence of different parameters on the running time needed to solve the problem.

2 - Unbalanced Lagrangean Decomposition for Map Labeling

Luiz A. N. Lorena, Sóstenes Gomes, Glaydston Ribeiro, Geraldo Mauri

Unbalanced Lagrangean Decomposition for Map Labeling

The Cartographic Label Placement Problem refers to the problem of automated label positioning in maps, diagrams, graphs or any graphic object. This is a common problem in Geographic Information Systems (GIS) and is generally addressed by three different features: lines (rivers, roads, etc.), polygons (lakes, districts, buildings, etc.) and points (cities, mountains, etc.).

Mauri, Ribeiro and Lorena (2010) presented a 0-1 linear optimization model to point features, where commercial solvers have difficulties for solving large-scale instances. So, the authors also presented a Lagrangean decomposition that has generated good solutions, outperforming results reported in the literature. For the instances with 1000 points the Lagrangean decomposition has proved the optimality for 5 of 25 instances with an average residual gap of 0.48% and CPLEX cannot prove the optimality for any instances and has presented a gap of 2.71%.

This paper considers the Lagrangean decomposition with unbalanced clustering where it is allowed to the METIS partitioning consider clusters of different sizes. That resulted in better partitions with a reduced number of vertices to clone. The computational results found the optimal solutions to all 25 instances of 1000 points, with small computer times compared to CPLEX and the Lagrangean decomposition with balanced partitions.

Mauri, G.R., Ribeiro, G.M., Lorena, L.A.N., 2010. A new mathematical model and a lagrangean decomposition for the point-feature cartographic label placement problem. Computers & Operations Research 37(12), 2164-2172.

3 - Calculating maximal capacities in gas transportation networks

Christine Hayn, Lars Schewe

The capacity maximization in gas networks is a highly complex task gas transportation network operators are faced with. Mathematically, it results in a three-level optimization problem where the central problem is a mixed-integer nonlinear problem due to gas physics and operating modes. Upper bounds on the demands and supplies at the sinks and sources, respectively, are searched, such that all transportation requests therein can be transported through the given network. These upper bounds are called capacities. We show that the decision variant is already CoNP-hard if a network with linear flow is considered. For solving the capacity maximization problem in the gas context, we propose a two-step solution approach. In a first step, the set of transportation requests is searched for infeasible areas by a refinement algorithm. Then this information is included in a disjunctive master model. Computational results on real-world instances show the capability of the proposed approach.

4 - Robust two-stage network problems

Adam Kasperski, Pawel Zielinski

Many optimization problems arising in practice have a two-stage nature. Namely, a partial solution should be computed in the first stage and completed optimally in the second stage, after a true state of the world reveals. Typically, the first-stage problem parameters are known while the second-stage parameters are uncertain, and specified as a scenario set. The robust min-max approach can be then applied to choose a solution. In this paper we consider a class of network problems. We are given a directed or undirected graph. For each arc of this graph a deterministic first-stage cost and a vector of the second-stage costs under a finite number of scenarios are specified. Our aim is to build an object in this graph such as an s-t path, s-t cut or matching. A partial object (solution) can be built in the first stage. It is then completed optimally in the second-stage after a true state of the world (scenario) occurs. We show several complexity results of this class of two-stage problems. In particular, we show that there is a cost preserving reduction from the robust representatives selection problem to all two-stage network problems discussed in this paper. Hence all these problems are NP-hard for two second-stage scenarios and become strongly NP-hard and also hard to approximate when the number of scenarios is a part of input.

■ TB-05

Thursday, 10:30-12:30 - HS 23

POM applications IV

Stream: Production and Operations Management
Chair: *Raik Stolletz*

1 - Strategic ramp-up planning in automotive production networks

Annika Becker, Raik Stolletz, Thomas Staeblein

In the automotive industry, the frequency of production ramp-ups has increased due to shorter product life cycles and an increased product variety. A rising number of different car model variants (derivatives) is developed based on a common platform. Production takes place at globally dispersed facilities for customers in multiple markets. Therefore, ramp-up planning has to be conducted for a network, considering the interdependencies arising from the knowledge transfer and learning effects. At a German car manufacturer in the premium segment, the ramp-up of a new car model is therefore organized sequentially: A new derivative is first produced in one plant, where processes are improved and workers are trained. Later, the derivative is transferred to other production plants.

The planning problem at hand is to optimize the allocation of derivatives to plants and the timing of ramp-ups and ramp-downs simultaneously with respect to the net present value of the profit. The optimal product flows from plants to markets are derived.

We develop a mixed-integer programming model for this strategic planning problem and conduct a numerical analysis to obtain insights into optimal allocation and timing strategies of production ramp-ups and ramp-downs. Further, we compare the results to other planning approaches, especially regarding the timing decision, and the influence of ramp-up flexibility is shown. We investigate the impact of the time lags between ramp-ups and the influence of sales volumes via a sensitivity analysis.

2 - The allocation of Kanban cards in stochastic and time-dependent production systems

Justus Arne Schwarz, Raik Stolletz

The card allocation in traditional Kanban systems is chosen to compensate stochastic influences such as random processing and repair times. In practice, the parameters describing the stochasticity vary over time, for instance, during production ramp-ups. Thus, we introduce a new mechanism for the Kanban card allocation under stochastic and moreover time-dependent operating environments. In contrast to approaches for systems with time-homogenous parameters, the proposed approach uses information about the future development of the production system to adapt the number of Kanban cards over time. We discuss the corresponding decision problem and preliminary results. Differences and commonalities with the buffer allocation problem are outlined.

3 - Optimal allocation of buffer capacities in stochastic flow lines with limited supply

Sophie Weiss, Raik Stolletz

The supply of flow lines is usually assumed to be unlimited or to follow certain distributions. However, this assumption may not always be realistic because the dependency of raw material consumption and replenishment orders is neglected. Therefore, we model the limited supply in terms of an order policy. To integrate this type of supply in our model, the flexibility of a sample-based optimization approach is exploited. We develop an efficient algorithm to determine the optimal buffer capacities of a flow line. Besides the efficiency of the proposed algorithm, the numerical study demonstrates that the order policy significantly impacts the optimal buffer allocation.

4 - Determining Transient Throughput of Transfer Lines in Pull Systems

Mahmut Ali Gokce

Majority of research on the throughput of transfer lines, concentrate on the steady state results. Current manufacturing trends bring about conditions where transfer lines are not just supposed to be fast but flexible, often working as pull systems. This results in changeover to different parts' production quickly, before enough time passes to reach steady state. For this reason, transient behavior of the system becomes important. Analytical calculations to reach to a closed form for the throughput is very challenging. We show calculations for mean and variance of and interval estimates for transient throughput for a pull type transfer line using simulation and try to generalize results.

■ TB-06

Thursday, 10:30-12:30 - HS 24

Metaheuristics II (c)

Stream: Metaheuristics
Chair: *Patrick Gerhards*

1 - A hybrid approach of optimization and sampling for robust portfolio selection

Omar Rifki, Hirotaka Ono

Dealing with ill-defined optimization problems, where the actual values of input parameters are unknown or not directly measurable, is generally not an easy task. In order to enhance the robustness of the final solutions, we propose in the current paper a hybrid metaheuristic approach that incorporates a sampling-based simulation module. Empirical application to the classical mean-variance portfolio optimization problem, which is known to be extremely sensitive to noises in asset means, is provided through a genetic algorithm solver. Results of the proposed approach are compared with that specified by the baseline worst-case scenario and the two approaches of stochastic programming and robust optimization.

2 - A matheuristic for resource constrained project scheduling problems
Patrick Gerhards, Christian Stürck

Resource constrained project scheduling problems have a wide area of application. Our research focuses on the design of effective metaheuristics to solve various resource constrained project scheduling problems. In particular, we propose a two-phase hybrid approach, using a combination of heuristics and exact methods. In the first phase a feasible solution is generated with a constructive heuristic. The second phase consists of a large neighborhood search where we solve relaxations of MIP formulations to improve the solution. We compare the approach on the benchmark datasets with other existing methods.

■ TB-07

Thursday, 10:30-12:30 - HS 26

Complex Optimization Problems in Logistics (c)

Stream: Logistics and Transportation
Chair: *Sigrid Knust*

1 - Simulation and evaluation of control mechanisms for mobile robot fulfillment systems
Marius Merschformann, Lin Xie, Hanyi Li, Leena Suhl

Our work focuses on automated mobile robot fulfillment systems in distribution centers. From the logistics perspective the main task here is to turn homogeneous item crates into ready-to-ship packages that are send to the customer by using multiple automated transport vehicles. These systems are considered to ensure that these orders are shipped as fast as possible while relieving human order pickers. Our work identifies the main subproblems in such systems as the multi robot path planning, multi agent task allocation, order batching, replenishment batching, item storage assignment and the more uncommon bucket storage assignment problems. In short these decide (in the same order) which paths the robots use, how the tasks are allocated to the different agents, which orders are assigned to which output-station, which incoming items are distributed from which input-station, which new items are put on which bucket and where to park the buckets when bringing them back to the inventory. We present these in the context of the system and draw connections to similar ones in other automated material handling systems. Most of these naturally have to be decided dynamically while they also can be mapped to NP-hard optimization problems. Hence, effective methods have to be evaluated that cooperate best to achieve a globally efficient system. Furthermore, we introduce an extended revision of a previously published framework that allows the integration of different controlling mechanisms in order to compare their performance by simulation. The framework allows a flexible integration of methods capable of solving encapsulated or integrated subproblems. Additionally, we introduce first simple controllers for the identified problem components and discuss them in more detail.

2 - Simultaneous Design of Closed and Opened-Loop Supply Chain Networks
Eren Ozceylan

In this paper, an integrated model that simultaneously optimizes the closed-loop supply chain (CLSC) and opened-loop supply chain (OLSC) networks which use common components is described. A novel mixed integer programming (MIP) model is proposed for the CLSC network that includes both forward and reverse flows and OLSC network that includes only forward flow with multi-periods and multi-components. Our aim is to guarantee the optimal values of transportation amounts of assembled components and disassembled end-products in the CLSC and OLSC -which is also fed by CLSC- simultaneously while determining the location of facilities. The objective function is pertaining to minimization of individual costs that includes transportation, purchasing, collection, disassembling and fixed costs of CLSC and OLSC. Numerical examples are presented using the proposed model and computational results are presented.

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

In practical storage loading problems, the following situation is often encountered: one has to store a set of items into a partly filled storage area with caring on items arriving later so that the utilization of the storage area is optimized. In this talk, we consider such storage loading problems with practical stacking constraints and affection of uncertain data of items arriving later. In order to enhance feasibility of stacking solutions in different scenarios of the uncertain items, we apply the concepts of strict and adjustable robustness. For each type of robustness and uncertainty, we propose three different mixed integer linear programming (MIP) formulations for the respective robust counterparts. Furthermore, we prove that in some particular case the computational effort to find adjustable robust solutions can be significantly reduced. Our experiments on randomly generated instances point out the advantages of each formulation and show that the best performance formulation can solve large instances in reasonable time. Our experimental results also show that adjustable robust solutions outperform strictly robust solutions in terms of objective value.

4 - Optimization models for strategic planning of bike sharing systems under consideration of operative system properties
André Koch, Kathrin Fischer

This work addresses the strategic planning of station-based public bike sharing systems. Two optimization models are developed that can be used to design a system from scratch (model 1) or to restructure an already operating system which is, for example, not able to cope efficiently with increased demand (model 2). The goal of these models is to develop recommendations for the long-term configuration of bike sharing systems which consists of the number and location of stations, their capacities and the size of the bike fleet. To ensure that the resulting systems also suffice operative requirements, the models integrate the hourly movements of the system users as well as dynamic and static repositioning activities of the system operator. The latter are necessary to compensate for asymmetrical bike flows by transporting excess bikes from full to empty stations. The models are solved for different, partially conflicting objective functions. The system operator aims at minimal investment costs for the system erection and a maximum operative result (difference between user fees and operational costs). In comparison, the system users require a sufficient coverage of their origins and destinations as well as a demand-oriented availability of rentable bikes. The models use penalty costs to evaluate these aspects and minimize the resulting costs. Moreover, the different perspectives are simultaneously considered by a combined approach to further enhance the system's viability. The models are solved by a standard solver for a fictitious application example. The findings illustrate the specific solution properties resulting from the different objective functions and show how the current system state can be changed to handle, e.g., increased demand.

■ TB-08

Thursday, 10:30-12:30 - HS 27

Financial Forecasting

Stream: Forecasting
Chair: *Theo Berger*

1 - Psychological Mechanisms Supporting Preservation of Asset Price Characterisations
Daphne Sobolev, Nigel Harvey

Economic systems are extremely complex: they involve millions of investors, and are non-deterministic (Matilla-García and Marín, 2010). Nevertheless, the theoretical justification for many forecasting methods and financial models is that certain parameters of the system are constant. What mechanisms enable financial markets to maintain stability of certain parameters, at least for periods long enough to make forecasts and financial modelling feasible? We suggest that traders' behaviour depends on the way that they perceive financial time series and make forecasts from them. Their perception of, forecasting from, and trading on these series may be one of the mechanisms which stabilise markets. We investigated these ideas in an experiment using fractal time series, which are used to model financial price series (Mandelbrot and Hudson, 2004). Our results revealed that people's forecasts preserve the structure of the given data. In particular, there is a positive correlation between forecast dispersion and measures of the volatility of past data. As Athanassakos and Kalimipalli (2003) have shown that

future volatility is correlated with forecast dispersion, our results suggest that judgmental forecasts enable the use of forecasting methods and financial algorithms.

2 - Medium to Long-Term Prediction of Exchange Rates
Julian Bruns, Sebastian Blanc

The movement of foreign exchange rates has a high impact on the cash flow management of Corporate Finance and the involved risks have to be mitigated. Foreign exchange rate forecasts are an important instrument for multinational companies to reduce the costs of their management of foreign exchange exposure. In this context, forecasts over a short to medium term horizon are needed. Traditional forecasting models focus on a small number of well-motivated predictors based on expected (lagged) relationships amongst the rates and the explanatories. This work proposes to use a larger predictor set first that is then dynamically shrinked to a small set of variables. First, we determine candidate features based on cross-correlation with the exchange rates. Second, time-dynamic model selection based on BIC is used to determine the predictor set. The work also addresses the accuracy—interpretability trade-off by using linear models with transformed variables. Empirical results show that the model method produces a lower test MdAPE compared to commercial benchmarks, and are nearly on par with the random walk, considered the "gold standard' in foreign exchange rate prediction. Interestingly, evidence is found that the quality of the forecast increases when fitting the models on a longer horizon than the real prediction horizon.

3 - Wavelet decomposition and applied portfolio management
Theo Berger

We decompose financial return series into its time and frequency domain to separate short-term noise from long-term trends. First, we investigate dependence between US stocks at different time scales before and after the outbreak of financial crisis. Second, we set up a novel analysis and introduce the application of decomposed return series to a portfolio management setup and model portfolios that minimize the volatility of each particular time scale. As a result, portfolio compositions that minimize short-run volatility of the first scales represent a promising choice, since they slightly outperform portfolio compositions that minimize the variance of the unfiltered return series.

4 - Dynamic Factor Model with infinite-dimensional factor space: forecasting.
Marco Lippi

The paper studies the pseudo real-time forecasting performance of three different factor models. We compare the method recently proposed by Forni et al. (2015) and Forni et al. (2014) with those proposed in Forni et al. (2005) and Stock and Watson (2002a) within a real data forecasting exercise. A large panel of macroeconomic and financial time series for the US economy which includes the Great Recession and the subsequent recovery is employed. In a rolling window framework, we find that the first two methods, based on spectral estimation, outperform the third. Substantial gains from regularized combinations of different inflation forecasts produced with the model in Forni et al. (2015) are also found.

■ TB-09

Thursday, 10:30-12:30 - HS 30

Congestion Games (i)

Stream: Game Theory
Chair: *Max Klimm*

1 - Tight Bounds for Cost-Sharing in Weighted Congestion Games
Grammateia Kotsialou, Martin Gairing, Konstantinos Kollias

We study the price of anarchy and the price of stability of cost-sharing methods in weighted congestion games. We require that our cost-sharing method and our set of cost functions satisfy certain natural conditions and we present general tight price of anarchy bounds, which are robust and apply to general equilibrium concepts. We then turn to the price of stability and prove an upper bound for the Shapley value cost-sharing method, which holds for general sets of cost functions and which is tight in special cases of interest, such as bounded degree polynomials. Also for bounded degree polynomials, we close the paper with a somehow surprising result, showing that a slight deviation from the Shapley value has a huge impact on the price of stability. In fact, for this case, the price of stability becomes as bad as the price of anarchy.

2 - Matroids are immune to Braess paradox
Britta Peis, Satoru Fujishige, Tobias Harks, Rico Zenklusen

The famous Braess paradox describes the following phenomenon: It might happen that the improvement of resources, like building a new street within a congested network, may in fact lead to larger costs for the players in an equilibrium. In this paper we consider general nonatomic congestion games and give a characterization of the maximal combina- torial property of strategy spaces for which Braess paradox does not occur. In a nutshell, bases of matroids are exactly this maximal structure. We prove our characterization by two novel sensitivity results for convex separable optimization problems over polymatroid base polyhedra which may be of independent interest.

3 - Uniqueness of Equilibria in Atomic Splittable Congestion Games
Tobias Harks, Veerle Timmermanns

We present new results on the uniqueness of atomic splittable congestion games. We derive sufficient and necessary conditions for uniqueness of equilibria depending on the combinatorial structure of the allowed set systems as well as the set of allowed cost functions.

4 - Complexity and Approximation of the Continuous Network Design Problem
Max Klimm, Martin Gairing, Tobias Harks

We revisit a classical problem in transportation, known as the (bilevel) continuous network design problem. Given a graph for which the latency of each edge depends on the ratio of the edge flow and the capacity installed, the goal is to find an optimal investment in edge capacities so as to minimize the sum of the routing costs of the induced Wardrop equilibrium and the investment costs for installing the edge's capacities. While this problem is considered as challenging in the literature, its complexity status was still unknown. We close this gap showing that it is strongly NP-hard and APX-hard, even for instances with affine latencies. As for the approximation of the problem, we first provide a detailed analysis for a heuristic studied by Marcotte for the special case of monomial latency functions (Math. Program., Vol. 34, 1986). We derive a closed form expression of its approximation guarantee for arbitrary sets of latency functions. We then propose a different approximation algorithm and show that it has the same approximation guarantee. Then, we prove that using the better of the two approximation algorithms results in a strictly improved approximation guarantee for which we derive a closed form expression. For affine latencies, e.g., this best of two approach achieves a 49/41-approximation which improves on the 5/4 that has been shown before by Marcotte.

■ TB-10

Thursday, 10:30-12:30 - HS 31

Routing Methods I (c)

Stream: Logistics and Transportation
Chair: *Michael Schneider*

1 - Map Partitioning for Accelerated Routing: Measuring Relation between Tiled and Routing Partitions
Maximilian Adam, Natalia Kliewer, Felix G. König

In the automotive industry, onboard maps and routing function on a device in the car and do not crucially rely on cloud infrastructure. The essential navigation as a basic functionality in cars is typically required to work even when not online. Exact and fast onboard routing requires preprocessing, while onboard maps are becoming increasingly modular to facilitate partial map downloads and updates for dynamic routing. Routing preprocessing typically relies on partitioning the street network while minimizing the number of roads crossing the partition, whereas modular maps are typically organized in rectangular tiles. When updating one part of a for routing preprocessed partition all overlapping rectangular tiled data clusters have to be transmitted. Considering this, it is likely that some of the data sent to the devices in tiled data clusters are redundant because they are not covered by the routing area. Even though sending data is costly due to limited bandwidths for data transmission to mobile devices, this problem is not covered by

the literature so far. The goal of this paper consists in gaining insight into the relation between tiled partitions and routing partitions. Therefore we propose different measurement figures and apply them on real street graphs sourced from Open Street Maps. In order to compare different partitions we use a tiled partitioning algorithm and an algorithm based on PUNCH that generates balanced routing partitions. Among other findings the experiments indicate a strong influence of geographical aspects of the underlying maps on the relation of the corresponding partitions.

2 - Route minimization heuristic for the vehicle routing problem with multiple pauses

Alexey Khmelev

In classical vehicle routing problem with time windows we are given a homogeneous fleet of vehicles and a set of geographically dispersed customers with known demands, service times, and time windows. The objective is to find set of routes satisfying capacity and time constraints minimizing travel distance of routes.

In this work, we consider real-world problem, where fleet is heterogeneous in terms of capacity and work shifts. Each shift has time window when driver works and a set of pauses that need to be scheduled in this shift. Each pause has duration and time window. The cost of the route consists of fixed startup cost and variable cost per distance unit. The objective is to minimize total cost of the routes.

Practically, the fixed cost of route is much greater than variable cost, thus the key objective is to minimize the total number of routes. For this reason, we have designed two-stage algorithm. We minimize the total number of routes on the first stage and travel distance on the second stage. We developed local search algorithm for route minimization taking into account multiple pauses. On the second stage, we use iterative local search based on idea of education and repairing. The key optimization module of this algorithm is randomized variable neighborhood descent. For effective evaluation of routes, we developed special dynamic programming method to insert pauses in route.

A delivery company in Novosibirsk provided test instances for computational experiments. Number of customers in these instances were 1000. Experiments show effectiveness of our algorithm. It substantially reduce the fleet and travel distance.

3 - Generating flexible sets of shifts for the days-off scheduling for road transportation

Bastian Stahlbuck

If the days-off scheduling is planned by assigning drivers to explicit given shifts, subsumed in a set of shifts, a preceding set of shifts generation problem results. A set of shifts generation procedure for road transportation has to cope with the following challenges: (1) The demand refers to different transportation types and is characterized by wide fluctuations. (2) The demand is met by the deployment of driver types with different driving skills and their assignment to different vehicle types. (3) Regarding driving hours a comprehensive legislation has to be considered. One opportunity to handle these challenges is the generation of flexibly usable sets of shifts. On the one hand the flexibility of a set is determined by the number and type of included shifts. On the other hand it will be limited by an increasing solution effort with an increasing number of generated shifts, because demand fluctuations cannot be handled immediately. Thus the trade-off between a high number of suitable shifts and an acceptable solution effort has to be balanced by generating reduced sets of suitable shifts. In current literature procedures to generate reduced sets focus mainly on a reduction of solution time. Flexibility aspects are only rudimentary taken into account. Furthermore the above named challenges are considered in just a few approaches and only with respect to one of these challenges. In the planned paper a suitable measuring of the multi-dimensional flexibility of reduced sets of shifts is constituted and a new modelling approach to generate flexible reduced sets respecting different driver, vehicle and transportation types as well as relevant working time rules is formulated. The approach will be tested with test data based on real data of a road transport company.

4 - Design of Granular Solution Methods for Routing Problems with Time Windows

Michael Schneider, Fabian Schwahn, Daniele Vigo

The use of granular neighborhoods is one way to improve the runtime of local-search-based metaheuristics for combinatorial optimization problems without compromising solution quality. So-called sparsification methods are applied to restrict the neighborhoods to include only elements which are likely to be part of high-quality solutions. To provide insights about the design of effective and efficient granular solution methods for routing problems with time windows, we conduct extensive numerical experiments with a granular tabu search (GTS) for the vehicle-routing problem with time windows (VRPTW). We find that sparsification methods using reduced-cost values based on the solution of a linear relaxation of the original problem outperform standard sparsification methods. Furthermore, including additional depot arcs into the restricted arc set (beyond those selected by the sparsification method) improves solution quality. Moreover, for small restricted arc sets, guaranteeing a minimum number of incoming and outgoing arcs per vertex is beneficial. Finally, dynamically altering the size of the restricted arc set can be used to successfully diversify and intensify the search, which has a significant positive effect on solution quality. The usefulness of the gained insights is demonstrated by the performance of the developed GTS for VRPTW, which obtains state-of-the-art results and reaches a considerable computational efficiency. More precisely, with an average run-time of three seconds on a standard desktop computer, our GTS proves to be the fastest method in the literature that is able to find the best-known cumulative number of vehicles of 405 (evaluated as best of five runs) on the well-known Solomon VRPTW instances.

■ TB-11

Thursday, 10:30-12:30 - HS 32

Energy-efficient Mobility II

Stream: Logistics and Transportation
Chair: *Uwe T. Zimmermann*

1 - Railway disruption management

Twan Dollevoet

Railway systems face major disruptions on a daily basis. Whenever such a major disruption occurs, the timetable, the rolling stock schedule, and the crew schedule have to be adjusted. In most current papers on railway disruption management, only one of these three resources is being considered. However, the resource schedules are highly interdependent. For example, if no rolling stock is available for a certain trip, the crew cannot use that trip, either. Furthermore, the trip must be cancelled in the timetable. The development of a decision support system that considers the three resource schedules simultaneously was one of the key goals of the ON-TIME project. Within this EU-funded project, we implemented an iterative algorithm in which the timetable, the rolling stock, and the crew are rescheduled sequentially. The iterative algorithm terminates when the resource schedules are mutually feasible. Our solution framework has been tested on a huge set of disruptions in the network of Netherlands Railways. We consider disruptions where some or all tracks along a link in the network are blocked for a given period of time. Furthermore, we vary both the duration and the start time of the disruptions. The computational experiments show that the iterative framework can reschedule the timetable, the rolling stock, and the crew within several minutes. This indicates that the algorithms for railway disruption management have the potential to be implemented in practice.

2 - Minimizing Total Energy Consumption in Operational Train Timetabling

Anja Hähle, Christoph Helmberg

Given passenger and freight trains with time windows and prespecified routes in a coarsened track network, operational train timetabling asks for feasible schedules of these trains that observe the time windows as well as station capacities and headway times. Freight trains typically have rather large time windows and their energy consumption mainly depends on the number of intermediate stops. Compared to cost functions that favor early arrival of trains, minimizing the total energy consumption over all trains should therefore lead to schedules that place freight trains in between the closely restricted passenger trains so that the number of stops is reduced significantly. We present computational results for real world instances of Deutsche Bahn and study the effect of taking energy consumption into account in the cost function.

3 - Optimizing the Power Load of Railway Timetables

Andreas Bärmann, Alexander Martin

In our talk, we present approaches to optimize train timetables such that high peaks in power usage are avoided. This allows for significant savings in energy costs as electricity contracts for big customers usually incorporate a price component that is proportional to the highest total power drawn at any given point in time. This power component accounts for up to 25 % of the total energy bill, which is as high as 1 billion Euros per year in the case of German railway traffic.

We start with a given raw timetable (before its publication) and shift the train departures at the stations within small time intervals of several minutes to come to the final timetable. This degree of freedom allows us to reduce the maximum power drawn from the catenaries within the planning horizon by desynchronizing too many simultaneous departures. At the same time, we synchronize accelerating trains with braking trains to make better use of the recuperated energy.

Our models are mixed-binary programs with assignment structure whose constraints model the requirements of a feasible timetable. This includes safety constraints as well as constraints to ensure interchanges between the trains at the stations. In our study, we present a hierarchy of possible objective functions with respect to energy and power usage to fit the different needs of the involved players — mainly the railway transport companies and the railway infrastructure managers. We also discuss possible extensions of our approach to incorporate further real-world requirements. The validity of our model is demonstrated on large-scale instances from our partner Deutsche Bahn AG.

■ TB-12

Thursday, 10:30-12:30 - HS 33

Railway Planning II (c)

Stream: Logistics and Transportation
Chair: *Dennis Huisman*

1 - Management of rolling stock on Indian Railways

Narayan Rangaraj, Raveendran Palaniyandi

Indian Railways (IR) is one of the largest integrated rail freight operations in the world, managing over 230,000 wagons, on a large network of terminals and tracks. This paper analyzes the operating structure of the way that the rolling stock resource of rail wagons are managed on this network. This structure is evolving to meet new needs of market competitiveness and cost control and is at a stage where significant changes can take place in the next few years, mainly due to the increased availability of centralized information and the possibility of analytical tools to manage this resource.

IR has 16 operating zones and the current system of management of rolling stock allows zones to plan their internal operations, while also monitoring targets of wagon holding and interchanges with adjacent zones to achieve the global balance that is needed for demand satisfaction. The system is a self adjusting one, which (a) reduces empty running of wagons, (b) allows for stabling of wagons in times of low demand and (c) achieves priority-wise demand satisfaction in periods when demand is high. It permits global priorities to be imposed on the system while respecting local capacity and other constraints in an implementable manner.

The large network that IR controls means that management decisions have to be implemented in a decentralized manner, to take care of local conditions and also to achieve the necessary ownership and performance monitoring. The paper explores how the loosely co-ordinated structure of decision making leads to satisfying global objectives in a sustainable manner. It also points to how improvements can be achieved from time to time without disrupting the entire flow of operations.

2 - The Railway Delay Management Problem — An Overview

Eva König

Passengers travelling by train usually need to change trains on their route. But the given time for changing is regular just a few minutes. If the current train of a passenger is late, it could be that the passenger misses his connecting train and has to wait a long time for the next train. Delay management addresses the question whether the connecting train should wait (or not) for the delayed passengers. If the connecting train waits, delays would get transferred. Some approaches for solving this problem use mixed integer programs that minimize overall waiting times or missed train connections, for example. The other possibility is to use so-called dispatching rules, where wait-depart decisions are made through rule-based strategies. In this talk, an overview on the existing literature is given, and a new classification is introduced. Moreover, limitations of the delay management approaches are discussed and future research opportunities are suggested.

3 - Robust Passengar Orientated Line Planning

Simon Bull, Jesper Larsen, Richard Lusby

The line planning problem for a rail network is a long term strategic level planning problem, with consideration given to operating cost, passenger satisfaction, and robustness in operation and to uncertainty in projected demands. We work with the Danish rail operator, using data for Copenhagen commuters and the self-contained Copenhagen S-Tog train system. We freely route passengers giving each their best route subject to capacity, where each passenger minimizes their travel time including a small fixed penalty for switching lines and a frequency-dependent estimate of the wait time for switching lines. We find line plans that provide all passengers with a route, respect all operational constraints, and minimize passenger travel time given some limit to total operational cost. However we also consider how the robustness of a line plan can be assessed, both from an operator perspective and passenger perspective, and show how those considerations can be included in the planning process.

■ TB-13

Thursday, 10:30-12:30 - HS 41

SC Structure (c)

Stream: Supply Chain Management
Chair: *Jan Trockel*

1 - Optimized adaptive production networks for modular plant designs in the process industry

Dominik Wörsdörfer, Pascal Lutter, Stefan Lier, Brigitte Werners

Producers of fine and specialty products in the process industry are facing new market challenges such as shortened product life cycles, an intense product differentiation and volatile demands in time and location. Conventional plant designs in large capacity scale suffer from large production batches and high investment risks. These production concepts are hardly able to cope with these volatile and uncertain demands. Therefore, modular production concepts implemented in standardized transportation iso-containers are currently in research focus. Due to a high level of standardization, the modular construction offers easily adjustable small scale plant designs with small production batches and a high degree of mobility. This leads to new opportunities regarding supply chain and network structure as a consequence of inherent mobility and scalability. Production locations can be placed directly in customer or resource proximity and plants can be relocated and adjusted in capacity over time in case of demand shifts. Hence, the structure of the production network can be dynamically adapted in accordance to current demands. At each decision step, container modules can either be added or removed from the network, relocated within the network, customers are (re-)allocated to container modules and new locations are set up or existing locations are closed. We propose mathematical optimization to minimize overall production network costs over a given time horizon such that entire customer demands are fulfilled. A single-stage mixed-integer programming model as well as a two-stage decomposition approach are presented to support the production network planning. Both innovative model formulations are compared and evaluated on the basis of real-world data sets of process industry.

2 - Management Coordination for Superstructures of Decentralized Large Scale Supply Chains under Uncertainty

Kefah Hjaila, José M. Laínez-Aguirre, Luis Puigjaner, Antonio Espuña

Current tactical optimization models are usually focused on an overall objective, regardless of the different individual partner objectives to be considered in a decentralized Supply Chain (SC). This work aims to optimize the tactical decisions of decentralized SCs superstructure by setting the best coordination among the participating stakeholders. The interaction between the involved stakeholders and their conflicting objectives is modelled as non-cooperative non-zero-sum Stackelberg game under the leadership of the partner of interest, who tries to find and exploit the win-win potential of the superstructure. For each "leader' possibility, the expectations of the follower SC are optimized, taking into consideration its uncertain external conditions (Monte Carlo simulation) until the Stackelberg payoff matrix is built

for the leader-follower. The performance of the proposed approach is verified on a case study consisting of different providers (follower SCs) around a client (leader SC). In this case, when compared with the standalone case, several win-win opportunities and expected profit improvements are identified, allowing reductions in the uncertainty of the scenarios faced by SC leader and follower. So a new trade-off can be identified, allowing the leader to change its strategy in order to avoid any possible disruptions in the global system, while a win-win situation is maintained. ACKNOWLEDGEMENTS Financial support received from the "Agència de Gestió d'Ajuts Universitaris i de Recerca AGAUR', the Spanish Ministry of Economy and Competitiveness and the European Regional Development Fund, both funding the Project SIGERA (DPI2012-37154-C02-01), and from the Generalitat de Catalunya (2014-SGR-1092-CEPEiMA), is fully appreciated.

3 - Investments in supplier economies of scope with two different products and different supplier characters

Jan Trockel

Self-interests of firms that act in competition prevent a better result than it would be possible in cooperation in a supply chain. The aim of the following analysis based on Chatain/Zemsky (2007) is an introduction of supplier specific economies of scope to improve the situation of the interacting firms. A three-person model is analyzed, whereby one buyer can choose one or two suppliers of a set consisting of not more than two suppliers that are characterized by a specialist and/or a generalist to produce different products. Based on the biform game approach of Brandenburger/Stuart (2007) the model is defined containing two stages. On the first stage the strategic firms can choose to invest in the supplier specific economies of scope. On the second stage the added value of the cooperation occurs and the cooperative solution is considered. Via the best response functions and in dependence of the exogenously given costs all different market situations are calculated and all Nash equilibria are analyzed. It can be shown how parameters influence the selection of the special supplier characters and under which aspects Nash equilibria occur without investments in the relationship.

References: Brandenburger, A., Stuart, H., 2007. Biform Games. In: Management Science, 53 (4), 537-549. Chatain, O., Zemsky, P., 2007. The Horizontal Scope of the Firm: Organizational Tradeoffs vs. Distributor-Supplier Relationships. In: Management Science, 53 (4), 550-565.

4 - How does buyer-supplier relationship operated in the joint venture business environment and affected the performance of the firms?

Weixi Han

The buyer/supplier or vertical partnering relationships of the supply chain is one of the problems which has attracted academic attention over several decades, with the automotive industry as a basis for the development of most studies. Recent dynamics within the global automotive industry have several implications for the academic study of the industry and the Chinese joint ventures are relatively recent developments, which are still to be seriously studied in any depth. Few scholars have researched the interactions between horizational (Joint Venture, JV) and vertical (buyer/supplier) relationship. Therefore, this research is ground breaking.

The goal of this study is to contribute to understanding of buyer-supplier partnering relationship given the role that different foreign nationalities bring to their joint venture processes with Chinese manufacturers set within the specific context of the Chinese automotive industry. This is achieved by analyzing empirical data gathered through a qualitative, case research methodology. The research develops a conceptual framework to inform the data collection and analysis that examines how JV business environment and vertical partnering relationship influence performance in the selected examples drawn from the Chinese automotive industry.

Through in-depth case studies and interview with managers from multiple Chinese and foreign firms, we were able to acquire an understanding of the different dimensions of partnering relationship and measure how this relationship operated in the joint venture business environment and affected the performance of the firms. This study examines the effects of extra and inter—organisational relationships, measured as a historic pattern of exchange on a variety of business outcomes.

■ TB-14

Thursday, 10:30-12:30 - HS 42

Network Design I (i)

Stream: Graphs and Networks
Chair: *Bernard Fortz*

1 - Optimal design of switched Ethernet networks implementing the multiple spanning tree protocol

Martim Joyce-Moniz, Bernard Fortz, Luís Gouveia

We propose and compare different MILP formulations to the Traffic Engineering problem of finding optimal designs for switched Ethernet networks implementing the IEEE Multiple Spanning Tree Protocol. This problem consists in designing networks with multiple VLANs, such that each one is defined by a spanning tree that meets the required traffic demand. Additionally, all the VLANs must jointly verify the bandwidth capacity of the network. Meanwhile the worst-case link utilization (ratio between link's load and capacity) is minimized. Moreover, we also discuss a similar problem, where the objective is to minimize the sum of the traffic flows. This problem can be seen as an extension of the OCSTP (Hu, 74), with link capacitaties and multiple spanning trees.

2 - Modelling fiber/wireless access network planning

Axel Werner, Fabio D'Andreagiovanni, Jonad Pulaj

A recent trend in access network deployment is to combine optical access networks with wireless technology. Benefits are that serving users via wireless links can be realized much easier, quicker and cheaper than deploying fiber connections to these customers, and wireless connections can also act as a backup in case of failures in the fiber-optic network. Access network planning problems that incorporate wireless technology can be formulated as extensions of the k-Architecture Connected Facility Location Problem. Given a graph of the deployment area and possible assignments from customers to facilities, the decision to take is which customers should be served by which facilities using which technology (fiber, copper or wireless) and how to set up a fiber network connecting the facilities with a central office, such that the customer demands are best satisfied and total costs are minimized. Additionally, constraints have to be included to ensure a feasible signal-to-interference ratio for those customers that are served using wireless access links. Variants of the problem account for multi-period planning (when should which customer be connected by which technology), handling uncertain input data (for instance, in the coefficients modelling the propagation of wireless signals), and the use of free-space optic links to replace or backup fiber connections in the network. We present and discuss various models for these problems and show results of computations using realistic instances.

3 - Cooperative Monitoring Problem in Presence of Traffic Uncertainty

Dimitri Papadimitriou, Bernard Fortz

The cooperative monitoring problem refers to the placement and configuration of passive monitoring points (or monitors) to realize a joint monitoring task of time-varying traffic flows. Depending on the routing strategy (e.g., shortest path, minimum-cost multicommodity flow), the objective consists in minimizing the total monitoring cost which combines the installation cost and the configuration cost. defined as the sum of the installation and configuration cost. We formulate the corresponding problem as a mixed-integer program. This formulation can also be dualized to determine the monitoring utility gain obtained when varying the budget constraint imposed on the total monitoring cost. This formulation is also more suited to cope with uncertainty in traffic demands fluctuations which may compromise feasibility and optimality of monitoring placement and configuration solutions. For this purpose, we formulate the robust counterpart by assuming that the traffic demands are uncertain, i.e., their value is not known exactly when the optimization problem is solved and that the uncertainty in traffic data can be modeled by means of box+polyhedral uncertainty sets leading to consider traffic demands within the estimated value and its maximum (positive or negative) deviation around that value. In this paper, we develop different formulations and resolution methods for the resulting problems together with numerical experiments performed on representative instances.

■ TB-15

Thursday, 10:30-12:30 - HS 45

Applied Simulation

Stream: Simulation and Decision Support
Chair: *Heinrich Kuhn*

1 - Enriching scenario analysis with agent-based simulations for planning the prospective market introduction of a smart product

Christian Stummer, Lars Lüpke, Sabrina Backs, Markus Günther

The rule that 'prediction is very difficult, especially about the future' (Nils Bohr) not only applies in physics, but also in innovation management. Market introduction of a novel product constitutes a prominent example — the more so, if the planning horizon lies several years ahead and, consequently, information on customers' needs and/or preferences is scarce. More often than not, scenarios are used in such instances. They can be interpreted as descriptions of journeys to possible (multiple) 'futures' and provide indications on how current trends will unfold, what critical uncertainties will play out, and which factors will become relevant. Once developed, the corresponding 'pictures of the future' can be contrasted with potential (alternative) choices of action and discussed based on gut feelings and/or past experiences. In our talk, we propose to enrich the decision basis with analyses gained from an agent-based (market) simulation that can separately be parameterized for each combination of a scenario and a portfolio of measures for furthering an innovation's market introduction. We have developed such a simulation for the domain of smart products. The corresponding (short-term) scenarios are provided by our cooperation partners from a joint research project embedded in the German Leading-Edge Cluster 'it's OWL'. The applicability as well as the transferability of this hybrid approach is sought to be demonstrated by means of two sample applications for industry partners from the cluster. This is an ongoing research endeavor; still, we can present our agent-based model as well as initial results from the first application case.

2 - Multi-Agent-Simulation of the European Biomass-to-Energy Market

Beatriz Beyer, Jutta Geldermann

Before European energy targets were implemented the energy sources were often limited to fossil sources managed by a few companies. With the increase of renewables energies the respective market became much more diverse. Biomass as an energy source results in a complex market structure by itself due to various biomass types, new technologies and several energy outputs. Additionally, due to different regulations and location factors the energy market across Europe became more heterogeneous. During the ongoing project BIOTEAM, which is co-funded by the EU, project partners of different countries analyse the sustainability of biomass-to-energy pathways as well as the corresponding legislation. A common finding was a disparity between legislative intentions and impacts. In order to give an overview and advice on the market structure and on beneficial regulations, market maps were used. While providing a picture of the structure, market mapping is a descriptive and rigid tool without simulations. Therefore it does not analyse in depth how the market would change e.g. if new laws were implemented or shortages occurred. Multi-Agent-Systems (MAS) for a dynamic simulation purpose can be used instead, with market players being represented by agents. The use of MAS provides them with a greater autonomy as each agent is pursuing its individual goals. Each agent can be defined differently and can react to changes in the environment and interact with other agents. Thereby optimization occurs on an individual level but influences other agents simultaneously. Consequently this approach is more complex and does not necessarily lead to an optimal outcome. Nevertheless, it is closer to reality and therefore can provide a deeper understanding of the market dynamics than existing methods.

3 - Improving Emergency Medical Services (EMS) Performance with Ambulances Dispatching Simulation Models

Jiun-Yu Yu

Emergency Medical Services (EMS) refers to both patient transport and medical support solution for people with illness or injuries. Recent clinical evidence shows that for out-of-hospital cardiac arrest (OHCA) cases the response time, the time spent by the ambulance to arrive at the scene, is critical to the survival rate. However, since the incident occurrence rate is highly irregular in time and in space, it is challenging for EMS authorities to maintain an effective ambulance dispatch policy.

New Taipei City, the most populated region in Taiwan, has the highest demand of EMS in the country. With coastlines on the north and mountains on the east and south, the population, hospitals, and EMS resources in New Taipei City are highly unevenly distributed. The current practice of EMS in the City is that all the ambulances and emergency medical technicians (EMT) stay on-call at their home unit. When an incidence occurs and is reported to 119, the Emergency Medical Dispatch (EMD) Center identifies the situation and the location of the case and then assigns the nearest available ambulance and EMT team to the scene. As the incidence occurrence rates and EMS resources are unevenly distributed across the City, the distribution of the response times is highly skewed.

Based on GIS and statistical analysis, a simulation model is built to examine various ambulance dispatching policies. Different scenarios with potentially feasible ambulance dispatching patterns are investigated via simulation experiments. The preliminary results show that the EMS performance can be significantly improved by re-allocating current resources. It is expected that after completion the results of this study will be able to provide the EMS authority with insightful and practical decision supports.

4 - Patient and impatient pedestrians in a spatial game for egress congestion

Harri Ehtamo, Anton von Schantz

Large crowds evacuating through narrow bottlenecks may create clogging and jams that slow down the egress flow. Especially if people try to push towards the exit, the so-called faster-is-slower effect may occur. In this study, partially based on our article [1], we present a spatial game theoretic model for pedestrian behavior in situations of exit congestion. The options of the agents are either to behave patiently or impatiently. The payoffs of our game are derived from natural assumptions on crowd dynamics, which turn out to result in a hawk-dove game matrix. Nevertheless, the parameters of the game depend on the agents' location in the crowd, and thus, the agents in front of the exit play a different game than the ones further back in the crowd. We apply the best-response learning scheme and study the equilibria of the game. The behavioral game model is coupled with the popular social-force egress simulation model [2]. The individual parameters of the social-force model are set to depend on the agents' strategies. Simulation results show that the model gives an explanation for the clogging occurring at bottlenecks of egress routes under threatening conditions.

[1] Heliövaara, S., Ehtamo, H., Helbing, D., Korhonen, T.: Patient and Impatient Pedestrians in a Spatial Game for Egress Congestion. Physical Review E 87, 012802 (2013) [2] Helbing, D., Farkas, I., Vicsek, T.: Simulating Dynamical Features of Escape Panic. Nature 407, 487-490 (2000)

■ TB-16

Thursday, 10:30-12:30 - HS 46

Public Sector OR and Drug Policy (c)

Stream: Policy Modelling and Public Sector OR
Chair: *Carla Rossi*

1 - Public R&D project selection problem with cancellations

Sinan Gürel, Musa Çağlar

Generally, R&D funding programs use call-based system in which once a call is announced researchers apply to the public organization with their solicited R&D project proposals. After research proposals are examined for eligibility, selected proposals are evaluated scientifically in research panels by peer reviewers. Awarded projects for funding are determined according to panel scores and total available budget constraint. Then, project funding contracts are signed between the organization and grantees. Sometimes a project team fails to comply with their project plan or the terms and conditions of the program. Then the project is terminated. It is estimated that a 5% to 10% of the awarded projects may get into cancellation process. Due to cancellations, organization's budget cannot be fully utilized to create scientific and socio-economic value to society. In this study, we consider the project selection problem given the scores and the budget requirements of the projects. We try to maximize the total score of the selected projects while considering that an estimated number of projects will be

canceled. Our model controls the risk of budget overspend. We propose a mathematical programming formulation for the problem. Using CPLEX, our formulation can be solved for practical size problems in reasonable CPU times. Further, we provide a dynamic programming algorithm which outperforms the mathematical programming formulation.

2 - Analysis of research collaborations in order to support research and innovation policies
Baerbel Deisting

Innovation is a key driver for economic growth and competitiveness within nowadays society. Research activities are core elements in the innovation process. In high tech sectors such as satellite navigation research is often carried out in collaborative structures within regions, across Europe or even globally. Even so there are numerous studies on collaborations the characteristics and evolutions of these research networks are not completely exposed. What are the characteristics of these networks? What can be done from the perspective of research policy to stimulate these networks and therefore to support the creation of innovation? Establishing a model therefore could support research and innovation policies in implementing dedicated activities and framework conditions and hence can contribute to create a pivotal environment for research and the emergence of innovation. In order to answer these questions an analysis on the evolution of research collaborations within a period of several years will be carried out by means of research cooperation in the field of satellite navigation in order to serve as blueprint for other high tech sectors.

3 - Evaluating and modelling drug policy approaches on the basis of new criminal and health indicators.
Carla Rossi

The EU drugs action plan (2009—12) included 'to enhance the quality and effectiveness of drug demand reduction activities, taking account of specific needs of drug users according to gender'. In particular, actions 17 and 19 aimed at 'exchanging good practice guidelines/quality standards for prevention, treatment, harm reduction and rehabilitation interventions and services' and 'to develop an EU consensus on minimum quality standards and benchmarks for prevention, treatment, harm reduction and rehabilitation'. These considerations implied the creation of the Best practice portal by EMCDDA (http://www.emcdda.europa.eu/best-practic) They also fostered EU research projects to provide: a) methodologies and indicators for evaluating interventions, drug laws and policy approaches; b) evidence for the grounds of 'Best drug policies'. The new indicators, provided by several research projects, have been widely used to evaluate various intended and unintended consequences of drug laws and policies; in particular, criminal aspects and health aspects. Considering the behaviour of such indicators, it has been possible to compare different countries providing evidence for improving drug policies. It is now also possible to propose mathematical modelling of the drug policy approach. In the paper, the applications in various countries and to various drug user populations are provided and shown.

■ TB-17

Thursday, 10:30-12:30 - HS 47

Cooperative Games II (c)

Stream: Game Theory
Chair: *Guvenc Sahin*

1 - Determining Collusion Opportunities in Deregulated Electricity Markets
Danial EsmaeiliAliabadi, Guvenc Sahin, Murat Kaya

The primal goal of deregulated electricity markets is to attain a perfect competition among generation companies. Yet, a deregulated market is still prone to threats that may disrupt the competition. A well-known threat is possibility of collusion between generators which induces exorbitance of electricity price for end consumers. Under various trading floors, the independent system organizer, responsible for administering the electricity markets, clears the market driven by the consumer demand and the price bids from the generators aiming to provide the consumer with the lowest cost possible. We use a game theoretic model to represent the market clearance mechanism in order to characterize the sufficient conditions that make it possible for the generators to engage in collusive behavior. We embed these conditions into a bi-level optimization problem where the conflicting objectives of the independent systems organizer and the generators meet. We develop an algorithm for the bi-level problem to show that the optimal behavior of generators are collusive when the sufficient conditions exist. We present numerical examples to illustrate our findings.

2 - A monotonic and merge-proof rule in minimum cost spanning tree situations
Gómez-Rúa María, Juan Vidal-Puga

We present a new model for cost sharing in minimum cost spanning tree problems, so that the planner can identify the agents that merge. Under this new framework, and as opposed to the traditional model, there exist rules that satisfy merge-proofness. Besides, by strengthening this property and adding some other properties, such as population-monotonicity and solidarity, we characterize a unique rule that coincides with the weighted Shapley value of an associated cost game.

3 - New characterizations of the Owen and Banzhaf-Owen values using the intracoalitional balanced contributions property
Silvia Lorenzo-Freire

The main objective of Cooperative Game Theory is the study of solutions for cooperative games with transferable utility (TU-games). These solutions stablish the payoff of each player in the TU-game. The Shapley and the Banzhaf values are two of the best known concepts in this context.

Cooperative games with coalition structure were introduced by Aumann and Drèze. They incorporate the concept of coalition structure to the TU-games. As in the TU-games, it is also interesting to find solutions (coalitional values) in order to obtain a suitable assignment for each player.

The coalition structure can be interpreted by the coalitional values in different ways. Owen defines the Owen and the Banzhaf-Owen values according to a procedure in two stages. In this procedure, the unions play a TU-game among themselves and after that the players in each union play an internal game. Whereas in the Owen value the payoffs in both TU-games are given by the Shapley value, in the Banzhaf-Owen value the Banzhaf value is chosen.

This framework is focused on the study of both coalitional values. To this aim, we consider appealing properties and characterize them, trying to identify the similarities and differences between both coalitional values. All the characterizations make use of the intracoalitional balanced contributions property. It says that given two players in the same coalition, the losses or gains for both agents when the other leaves the game are equal.

■ TB-18

Thursday, 10:30-12:30 - HS 48

(c) Assessment and Valuation

Stream: Energy and Environment
Chair: *Marko Bohanec*

1 - Effects of Different Agricultural Land Valuation Methods on the LandConsolidation Projects
Tayfun Cay, Mevlut Uyan

Land consolidation (LC) is a procedure ofrearrangement of land parcels and their ownership according to developingagricultural technology. LC projects consist of various steps and within thesesteps, land reallocation stage is the core of consolidation. Reallocationquantity depends on the agricultural land valuation. LC projects in Turkey areperformed by different two legal institutions operating under two legalarrangements. However, these institutions use different methods for theproduction agricultural land valuation maps (gradation maps). In this case, twodifferent agricultural land valuation degrees is produced for the same area.

In this study, reallocation process was performedusing agricultural land valuation maps obtained by the two different methodsfor two different legal institutions for same project area. The results of thetwo legal institutions were compared with each other.

2 - Mapping of heating and cooling degree values by multivariate geostatistics
I.Bulent Gundogdu

Evaluating and modeling of the heating and cooling degree (HCD) values are the most important factor to determine of energy consumptions. Energy requirements for heating or cooling will be increased for the future. The consumption is related with all types of buildings. Maps of the consumptions are the base guides for energy sectors. Study area has been modeled by related factors which will affect to HCD values as a secondary variable. Multivariate interpolation techniques have been used to produce the predicted maps. In this study, using 188 stations value which have been integrated into ArcGIS 10.1—ESRI software, heating and cooling degree days for 2014 were calculated for each season and compared with long term (30 years) average value. According to results; while heating requirements have been increasing in Marmara, Aegean, Mediterranean and eastern Turkey because of the above normal temperature; it is decreasing around East of the area due to negative temperature anomalies. Also as parallel with increasing temperature in 2014, especially in Southeastern, cooling degree days have been increased in all over Turkey.

3 - Strategic assesment of electric energy production technologies in slovenia using qualitative multi-attribute and simulation methods
Marko Bohanec, Nejc Trdin, Branko Kontic

Electric energy production is a complex process, which requires strategic planning and management years in advance. This work is aimed at making a transparent and reproducible identification of reliable, rational, and environmentally sound electric energy production technologies in Slovenia by 2050. The appraisal of technologies is based on results of a recent study, which assessed the sustainability of eight technologies using both conventional and renewable energy sources: coal fired, gas fired, biomass fired, oil fired, nuclear, hydro, wind, and photovoltaic. The study identified three main technologies that are most suitable in Slovenia: hydro, gas, and nuclear. Renewable energy sources were found to be limited and less sustainable due to land-use context. The research presented here extends that study in two directions: (1) from assessment of individual technologies to assessment of technology mixtures (i.e., collection of technologies, considering a specific share of each technology in the total installed capacity), and (2) evaluation of scenarios of shutting-down existing old power plants and constructing the new ones until 2050. The first task is based on a qualitative multi-criteria model developed with method DEX. The second task is based on simulation, which runs the DEX model through the years 2014—2050, considering 64 potential management scenarios of shutting-down existing old power plants and constructing the new ones. The simulation is implemented as an on-line decision support system. The results indicate that only mixtures of nuclear, hydro, and gas fired technologies can meet expected energy needs in a sufficiently reliable and rational way. Biomass, wind and photovoltaic sources of energy may provide only 8% to 15% of energy in Slovenia.

4 - Enhancing environmental sustainability of healthcare system - A System Dynamics Approach
Salman Shehab, Afshin Mansouri, Tillal Eldabi, Virginia Spiegler

The demand on Healthcare services is increasing due to population growth and demoghraphical changes. Expansion in healthcare provisions is leading to numerous environmental, economic and social challenges. The major environmental challenges are increase in energy consumption, waste generation and GHG & CO2 emissions. To overcome these challenges, new framework need to be developed to reduce the environmental impacts of healthcare facilities in order to achieve sustainable Healthcare System. System Dynamics Analysis approach is used to mathematically analyzing Healthcare System in Bahrain as a healthcare context.

■ TB-19

Thursday, 10:30-12:30 - HS 50

(c) Planning and Decision Support

Stream: Energy and Environment
Chair: *Martin Densing*

1 - GAMS — Elements, Enhancements, and Examples from the Austrian Power Industry
Franz Nelissen, Wilhelm Ottendörfer, Thomas I. Maindl

The General Algebraic Modeling System (GAMS) has evolved continuously in response to user requirements, changes in computing environments and advances in the theory and practice of mathematical optimization. After introducing some key elements of GAMS, we will look at recent enhancements and will review applications by Verbund, in which optimization is an important element.

2 - Two-stage heuristic approach for solving the long-term Unit Commitment Problem with hydro-thermal coordination
Alexander Franz, Julia Rieck, Jürgen Zimmermann

The increasing share of prioritized renewable energy leads to a major challenge for system operators in German and European power systems. Due to the volatile and stochastic characteristic of the renewable feed-in and residual power demand, the need for highly flexible, but cost-efficient power plant operations arises. Energy storages, mainly hydro storages, are a promising mean to support these flexible requirements by smoothing the residual demand for thermal power plants. Scheduling and coordinating power plants and energy storages results in the well-known Unit Commitment Problem with hydro-thermal coordination (UCP-HT), which typically relies on a mixed-integer linear program (MILP). To substantially reduce the computational effort of the MILP, we present a two-stage heuristic approach for the UCP-HT. The first stage preselects certain plants to fulfill the fluctuating residual demand and spinning reserve requirements without using any energy storages. Moreover, several techno-economic parameters like power output specifications, minimum up- and down-times or time-dependent startup costs are taken into account. A greedy algorithm is hereby applied to get a first solution, which will be stepwise enhanced by local optimization. The second stage improves this solution in consideration of energy storages. The best allocation of them is found again by stepwise optimization replacing committed plants by storage operations to achieve further cost reductions. Finally, the result consists of an hourly dispatch of each thermal and storage unit for e.g., a yearly time-horizon. Within a comprehensive performance analysis, we compare this approach to the MILP and other decomposition techniques (e.g., Benders Decomposition) for large-scale instances derived from real-world data.

3 - Optimal Control of a Battery Train Using Dynamic Programming
Nima Ghaviha, Markus Bohlin, Erik Dahlquist, Fredrik Wallin

Electric propulsion system in trains has the highest efficiency compared to other propulsion systems (i.e. steam and diesel). Still, electric trains are not used on all the routes, due to the high setup and maintenance cost of the catenary system. Energy storage technologies and the battery driven trains however, make it possible to have the electric trains on the non-electrified routes as well. High energy consumption of the electric trains, makes the energy management of such trains crucial to get the best use of the energy storage device. This paper suggests an algorithm for the optimal control of the catenary-free operation of an electric train equipped with an onboard energy storage device (i.e. a battery). The algorithm is based on the discrete dynamic programming and Bellman's backward approach. The objective function is to minimize the energy consumption, i.e. having the maximum battery level left at the end of the trip. The constraints are the trip time, battery capacity, local speed limits and limitations on the traction motor. Time is the independent variable and distance, velocity and battery level are the state variables. All of the four variables are discretized which results in some inaccuracy in the calculations, which is discussed in the paper. The train model and the algorithm are based on the equations of motion which makes the model adjustable for all sorts of electric trains and energy storage devices. Moreover, any type of electrical constraints such as the ones regarding the voltage output of the energy storage device or the power output can be enforced easily, due to the nature of the dynamic programming.

4 - Decision support system for intermodal freight transportation planning: an integrated view on transport emissions, cost and time sensitivity
Andreas Rudi, Magnus Fröhling, Frank Schultmann

As a response to the growing amount of released air emissions from freight transportation, policy makers establish legal frameworks to moderate the society's dependency on fossil fuel and mitigate the release of greenhouse gases into the atmosphere by stimulating the application of intermodal freight transport chains. The evaluation and selection of intermodal routes based on the key objectives, i.e. transit

time, transport emissions and cost, is the main challenge in the design of intermodal networks. It is aim of this talk to present a decision support system for intermodal freight transportation planning which offers methodological contributions to the research on transport mode, route and carrier selection as well as results for industrial practitioners for the assessment of emission abatement potentials with respect to economic and ecological criteria. Core of this approach is a capacitated multi-commodity network flow model considering multiple decision criteria, i.e. costs, time and CO2-equivalents. Two processes are integrated, i.e. transport and transshipment, including the modal shift and/or the carrier change at capacitated terminals or the simple transfer of the material flow. The resulting objective function minimizes the number of transported and transshipped full truck loads assessed by the weighted and normalized criteria taking into account tied in-transit capital and the distance travelled. The decisions support system is validated in an example case study application analyzing the sensitivity of different criteria weightings on optimal route and carrier choice, providing a first assessment of Eurocombis as a new transport means, and investigating the tradeoff between economic and ecological criteria in intermodal freight transportation planning.

■ TB-20

Thursday, 10:30-12:30 - ÜR Germanistik 1

Multistage Mixed Integer Stochastic Optimization (c)

Stream: Stochastic Optimization
Chair: *Laureano Fernando Escudero*

1 - Progressive Hedging and Dual Decomposition

David Woodruff

The PH algorithm proposed by Rockafellar and Wets and the DDSIP algorithm proposed by Caroe and Schultz can both be thought of as primal-dual algorithms and both can be used to address stochastic mixed-integer programs. In this talk I describe work with numerous co-authors to use the two algorithms together. In addition we describe an algebraic modeling language (Pyomo) interface to DDSIP that is useful with, or without, PH.

2 - Assessing the Hydro Production Function modeling on Policies for the Hydrothermal Scheduling

Vitor de Matos, Erlon Finardi, Paulo Vitor Larroyd, Guilherme Fredo

The Hydrothermal Scheduling (HS) plays an important role in power systems that rely heavily on hydroelectricity as its goal is to define a policy for the use of water. The Brazilian system has hundreds of hydro plants and some simplifications are made in their modeling in order to reduce the computational burden.

The HS problem has several important modelling aspects and one of the most relevant is the Hydro Production Function (HPF) which affects directly the amount of energy that can be generated by the hydro plants. There are some modelling options and in this paper we are interested in analyzing two of them: (i) by assuming a constant production factor in such way that the HPF is a function only of the turbined outflow; (ii) a piecewise linear approximation of the original HPF in this case the hydro production may depend on the storage, spillage and turbined outflow. Although the second approach provides a more detailed model for the hydro generation, we are dealing with a huge optimization problem that cannot be solved to optimality due to limited time and computational resources available.

As a result, this paper aims at analyzing the effect that the HPF modeling has on the scheduling policy. We build our policy by means of the Stochastic Dual Dynamic Programming algorithm, which means that the piecewise approximation of the HPF provides "better' cuts whereas the simpler model computes more cuts in the same amount of time. Therefore, it is important to understand which one may result in the best policy given a fixed time limit. We compare both policies by simulating them in the same set of scenarios and considering the best modeling approach for the Brazilian power system.

3 - On risk averse multistage mixed 0-1 optimization modeling under a mixture of Exogenous and Endogenous Uncertainty

Laureano Fernando Escudero, Juan Francisco Monge, Dolores Romero Morales

We present a general multistage stochastic mixed 0-1 problem where the uncertainty appears everywhere in the objective function, constraints matrix and right-hand-side. It is represented by a scenario tree. We consider a non-usually treated uncertainty so named endogenous one, where the modeler decisions can change the weights and / or the outlooks of potential scenarios to occur. The optimization of the objective function expected value subject to Stochastic Dominance (SD) constraints for a set of profiles on a multifunction setting is presented for risk reduction while minimizing the objective function expected value. As a result a bilinear mixed 0-1 model is presented. Given the large-size dimensions of the problem, it is unrealistic to solve the problem up to optimality by plain use of MIP solvers. Instead of it, decomposition algorithms of some type should be used. We consider our Stochastic Dynamic Programming algorithm -the so named SDP risk averse SD. Computsational experience is reported for a three-stage pilot case on resource allocation planning for mitigating disaster's effects.

4 - A bilevel programming problem with stochastic lower level

Rizo Saboiev, Stephan Dempe, Patrick Mehlitz

The bilevel programming problem (BLPP) acts as an optimization problem whose constraint region is determined implicitly by another mathematical programming problem. An ordered hierarchy structure between two decision makers appears, when they have conflicting objectives. The decision maker at the upper level (leader) evaluates his objective function after the possible reaction of the decision maker at the lower level (the follower) is clear. Hereupon, the follower selects his decision under the given decision of the leader. Many real-life problems can be translated into a bilevel programming problem, for instance problems of transportation, management and economics, engineering design, supply chain planning, and health insurance. This paper is dedicated to the study of a certain linear bilevel programming problem eqipped with a two stage stochastic lower level. We transfer the given problem to a single-level optimization problem whose constraints comprise affine complementarity conditions and a variational inequality in order to derive necessary optimality conditions. The global and local relationship of the original bilevel programming problem and the surrogate problem are studied. Results from variational analysis are used to derive stationarity conditions for the mentioned single-level problem and, hence, for the given bilevel programming problem.

■ TB-21

Thursday, 10:30-12:30 - ÜR Germanistik 2

Advances in Stochastic Optimization II (i)

Stream: Stochastic Optimization
Chair: *Huifu Xu*

1 - Data-driven Distributionally Robust Optimization Using the Wasserstein Metric

Daniel Kuhn

We consider stochastic programs where the distribution of the uncertain parameters is only observable through a finite training dataset. Using the Wasserstein metric, we construct a ball in the space of (multivariate and non-discrete) probability distributions centered at the uniform distribution on the training samples, and we seek decisions that perform best in view of the worst-case distribution within this Wasserstein ball. In this paper we demonstrate that, under mild assumptions, the distributionally robust optimization problems over Wasserstein balls can in fact be reformulated as a finite convex program - in many interesting cases even as tractable linear programs. Invoking recent developments in the measure concentration literature, we also show that the proposed solutions enjoy powerful finite-sample performance guarantees.

2 - Risk-Averse Two-Stage Stochastic Program with Distributional Ambiguity

Ruiwei Jiang, Yongpei Guan

We develop a risk-averse two-stage stochastic program (RTSP) taking into account the distributional ambiguity. We derive an equivalent reformulation for RTSP that applies to both discrete and continuous distributions. Also, the reformulation reflects its linkage with a full spectrum of coherent risk measures under varying data availability. Furthermore, we perform convergence analysis to show that the risk-averseness of RTSP vanishes as the data sample size grows to infinity, in the sense that the optimal objective value and the set of optimal solutions of RTSP converge to those of classical TSP.

3 - Sparse grid and QMC quadratures are efficient for linear two-stage stochastic programs

Werner Römisch

Sparse grid and Quasi-Monte Carlo quadratures are considered for solving linear two-stage stochastic programs. Both are efficient for integrands belonging to mixed Sobolev spaces. Unfortunately, linear two-stage integrands are piecewise linear-quadratic and do not belong to those spaces. However, the first two terms of their ANOVA decompositions do if a weak geometric condition on the two-stage model is satisfied. This implies that two-stage models can be solved efficiently by both quadratures if the effective dimension of the integrands is at most 2. We show that this can be achieved in many situations if the underlying probability distribution is normal and principal component analysis is used for decomposing the covariance matrix instead of Cholesky. We present numerical results for a production planning model with normal inputs.

■ TB-22

Thursday, 10:30-12:30 - ÜR Germanistik 3

Accounting (i)

Stream: Accounting and Revenue Management
Chair: *Michaela Schaffhauser-Linzatti*

1 - Do Equity Tax Shields Reduce the Leverage? The Austrian Case

Manfred Fruehwirth

The goal of this article is to analyze the impact of equity tax shields, that were allowed in Austria from 2000 to 2004, on the capital structure of Austrian firms, both at book values and at market values. We see that the choice of the leverage ratio determines whether or not one can find an impact of equity tax shields on the capital structure of firms. Precisely, equity tax shields reduce the long-term liabilities to assets ratio and on the long-term liabilities to long-term capital ratio, but have no impact on the total liabilities to assets ratio. Although the Austrian system granted only a rather small dose of equity tax shields, we find that the tax regime achieved its goal to reduce the leverage (ignoring short-term liabilities). Interestingly, even though it is the book value capital structure that determines the size of equity tax shields, this effect was slightly stronger and more significant for the capital structure at market values than for the book value capital structure. We find that the government could influence the capital structure by changing the level of the equity interest rate allowed. We observe that small firms reduced their capital structure more in response to equity tax shields than big firms. Similarly, we find that firms that were included in the Austrian Traded Index (ATX) did not react to equity tax shields. By contrast, firms that were not included in the ATX strongly reacted to the equity tax shields. Moreover, we find that financial firms did not react to the equity tax shields whereas non-financial firms showed at least some reaction. In addition, with this equity tax shield regime we find strong evidence against the debt substitution hypothesis of De Angelo/Masulis (1980).

2 - The application of a decision support system to calculate consequential costs of hand injuries

Michaela Schaffhauser-Linzatti, Marion Rauner, Beate Mayer

Due to shrinking budgets accident insurance companies focus on cost reduction programmes and prevention measures. Therefore, a series of projects developed a decision support system for consequential cost calculation of occupational injuries for the AUVA, Austria's main social occupational insurance institution. Combining traditional instruments of accounting with quantitative methods such as micro-simulation, this so-called cost calculation tool predicts the subsequent occupational accident costs from the time of an accident and, if applicable, beyond the death of the individual casualty for the AUVA, the companies in which the casualties are working, and the other economic sectors. Decision support systems such as this cost calculation tool represent necessary instruments to identify risk groups and their injured body parts, causes of accidents, and economic activities, which highly burden the budget of an injury company, and help derive countermeasures to avoid injuries. Target-group specific, suitable preventions measures for injuries can reduce accidents in a cost-effective way and lower their consequences. Hence, beside calculation the AUVA also classifies risk groups and derives related prevention campaigns. Currently, it mainly focusses on hand injuries and has already initiated first prevention programmes as hand injuries represent about 38% of all casualties with average costs of about 7,851 Euro/case.

3 - The interaction between Corporate Social Responsibility and Facility Management

Judith Löschl

Today companies are confronted with the necessity to consider "Corporate Social Responsibility" (CSR) in their corporate strategy, because of stakeholders demands but also due to the existing standards and guidelines in Europe. According to the European Commission, CSR is defined as a strategic initiative that should support companies to consider ecological aspects in their decisions and the way they interact with stakeholders. Starting from 2017 CSR reports will be obligatory for large scale enterprises in Europe. The focus of the survey is to analyse the goals of CSR reports and their coherencies and interactions with the activities of Facility Management (FM). The scientific questions of this paper are: How is the interaction between CSR and FM? Do FM- activities help to achieve CSR- goals? Method The following documents are analysed to determine the basic formal principles and goals of CSR: CSR-guideline of the European Commission, European CSR and FM standards and the actual OECD-guiding principles. In a next step exposable CSR- and Sustainability-reports from more than 120 European companies were analysed and compared to show the coherencies and interactions between CSR and FM. Indicators for this coherencies and interaction are defined, these indicators are searched in the reports. Results The results of the analysis of 120 European CSR reports from the period of 2012 to 2014 show a very high coherence and interaction between CSR- and FM goals. For example CO2 and energy savings are the top goals within the CSR reports. These are also in the focus of Facility Management. Both management strategies pursue the objective of a sustainable and corporate governance. To achieve these goals, an intensive cooperation of CSR and FM is necessary.

■ TB-23

Thursday, 10:30-12:30 - ÜR Germanistik 4

Recent Advances in MIP Solving

Stream: Integer Programming
Chair: *Michael Winkler*

1 - LocalSolver: a mathematical optimization solver based on neighborhood search

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

The talk deals with local search for combinatorial optimization and its extension to mixed-variable optimization. Although not yet understood from the theoretical point of view, local search is the paradigm of choice to tackle large-scale real-life optimization problems. Today end-users ask for interactivity with decision support systems. For optimization software, it means obtaining good-quality solutions quickly.

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 modeling formalism of LocalSolver through examples in combinatorial and continuous optimization. We will give the main ideas about how the solver works and illustrate its performance

on various benchmarks. Finally, we will provide an overview of the ongoing developments in the areas of vehicle routing and black-box optimization.

2 - CPLEX keeps getting better
Roland Wunderling, Andrea Tramontani, Pierre Bonami

We present improvements we have recently added to the IBM CPLEX solver with a focus on solving mixed integer nonlinear programming problems. We will discuss algorithmic techniques that were used and analyze their performance impact.

3 - The Impact of Linear Programming on the Performance of Branch-and-Cut based MIP Solvers
Matthias Miltenberger

A major part of the total running time of a branch-and-cut based MIP solver is spent solving LP relaxations. Therefore, one would expect the performance of the underlying LP solver to greatly influence the performance of the MIP solver. Surprisingly, this is often not the case. The solver framework SCIP allows to plug in various LP solvers, including SoPlex, XPRESS, CPLEX, and Gurobi. Using this setup we analyze the behavior and try to answer the question why the performance difference between the LP solvers does not necessarily translate to the MIP solver.

4 - Gurobi - Improvements and New Features
Michael Winkler

The talk covers new features and algorithmic improvements of the upcoming Gurobi release including our new cloud optimization tools. In addition we give a short overview on the performance progress of Gurobi.

■ TB-24

Thursday, 10:30-12:30 - ÜR Germanistik 5

Purchasing & Customer Data (c)

Stream: Analytics
Chair: *Matthias Reisser*

1 - Topological Data Analysis for Extracting Hidden Features of Client Data
Klaus Bruno Schebesch, Ralf Stecking

Computational Topological Data Analysis (TDA) is a collection of procedures which permits extracting certain robust features of high dimensional data, even when the number of data points is relatively small. Classical statistical data analysis is not very successful at or even cannot handle such situations altogether. Hidden features or structure in high dimensional data expresses some direct and indirect links between data points. Such may be the case when there are no explicit links between persons like clients in a database but there may still be important implicit links which characterize client populations and which also make different such populations more comparable. We explore the usefulness of applying TDA to different versions of credit scoring data, where clients are credit takers with a known defaulting behavior, and we compare the role of TDA in the client data context with other information extraction approaches, especially those based on clustering and classification.

2 - Clustering and Decision Tree Analysis of Airline Booking Data
Catherine Cleophas, Sebastian Vock, Laurie Ann Garrow

This talk offers new perspectives on airline booking data by comparing booking distributions from itineraries offered at different times, for different routes, and by different carriers. By mining a data set provided by ARC (Airlines Reporting Corporation), we analyze several hundred origin-destination-carrier combinations and several thousand itineraries. We present a cluster analysis of booking distributions intended as a measurement for market similarity that is capable of overcoming a priori assumptions about market differentiation. Further, we suggest an approach of computing decision trees from these market clusters. These trees offer insight to the relevance of geographic and temporal characteristics.

3 - Segmentation of Purchasing Sequences using Hidden Markov Models
Katerina Shapoval, Johannes Baldinger, Matthias Reisser

Customers of some industries, e.g. financial services industry, were shown to exhibit some specific order of purchased product or service types. Given such logical order within purchasing sequences this information can be employed in next-purchase response modeling in order to increase predictive accuracy. Response modeling is aimed at targeting likely responders to an intended marketing activity like a product offer. However, for enterprises with many products the incorporation of such information is challenging due to the vast amounts of product sequence combinations with little support, impractical for marketing and providing little predictive value.

We propose a segmentation approach for purchasing sequences using Hidden Markov models (HMM). Hidden Markov models allow for a probabilistic clustering of purchasing sequences based on so-called latent states. The intuition thereby is that the unobservable latent states of customers are responsible for the observable purchasing behavior. We interpret these as a certain state of technological maturity of a given customer segment and analyze the resulting purchasing probability of a target product depending on these latent states.

The results of empirical evaluations are based on over 800 thousand purchasing sequences of a telecommunications provider. The resulting customer segments exhibit a logical order of purchases and provide valuable insights into behavior of several types of customers, especially about the probability of purchasing a certain product in a given state. The latter information is of particular interest for marketing campaigns. Additionally, we demonstrate predictive ability of a target product using this segments on a hold-out sample.

■ TB-25

Thursday, 10:30-12:30 - ÜR Alte Geschichte

Statistical Genetics and Bioinformatics

Stream: Bioinformatics
Chair: *Florian Frommlet*

1 - Genome Wide Association Studies with Sorted L-one Penalized Estimation (SLOPE)
Malgorzata Bogdan

Sorted L-one Penalized Estimator (SLOPE) is a new convex optimization algorithm for sparse high dimensional regression. SLOPE is an extension of LASSO designed for the purpose of control of the False Discovery Rate. In this talk we will present the application of SLOPE in the context of Genome Wide Association Studies and compare it to other methods by computer simulations.

2 - Novel genetic matching methods to correct for confounding by population stratification in genome-wide association studies
André Lacour, Tim Becker

Population stratification is a known source of confounding in genome-wide association studies. We propose a novel framework to consider population matchings in the contexts of genome-wide and sequencing association studies. For that we employ pairwise and groupwise optimal case-control matchings and an agglomerative hierarchical clustering, both based on a genetic similarity score matrix. In order to ensure that the resulting matches obtained from the matching algorithm capture correctly the population structure, we employ two ad-hoc stratum validation methods. We also invent a decisive extension to the Cochran-Armitage Trend test to explicitly take into account the particular population structure. We assess our framework by simulations of genotype data under the null hypothesis and by a power study to evaluate type-1 and type-2 error rates. Our results are compared with those obtained from a logistic regression model with principal component covariates. Using the principal components approaches we also find a possible false-positive association to Alzheimer's disease, which is neither supported by our new methods, nor by the results of a most recent large meta analysis or by a linear mixed model approach.

3 - IPO: a tool for automated optimization of XCMS parameters for metabolomics LC-HRMS data processing

Christoph Magnes

We present IPO, a new tool that optimizes XCMS parameter settings for metabolomics LC-HRMS data processing by using isotopologue information. XCMS data processing consists of the steps "peak picking' (PP), "retention time correction' and "grouping'. In the first step "peak picking', parameters are optimized by identifying 13C isotopic peaks and their respective 12C peaks. These isotopologue peaks are considered reliable peaks and lead to the calculation of a peak picking score which is maximized. In the second step, the parameters of "retention time correction' and "grouping' are optimized simultaneously. With respect to "grouping' the definition of 'reliable groups' and 'non-reliable groups' leads to a grouping score used as a target variable. Regarding "retention time correction' relative retention time differences within peak groups are minimized. The target variables of "grouping' and "retention time correction' are combined by applying desirability functions leading to the response variable for our response surface optimization approach. The optimization procedure includes consecutive execution of Design of Experiments (DoE), XCMS data processing, estimation of a full second-order response surface model as an approximation of the assumed non-linear objective function and evaluation of the model, resulting in new parameter specifications for the subsequent DoE. This process is continued as long as the optimum of the estimated objective function can be improved. IPO was evaluated by using a training set and a test set approach. Compared to default settings the number of reliable peaks increased from 5112 to 5439. Reliable groups increased from 314 to 752 in the test set. IPO: https://github.com/glibiseller/IPO.

4 - Modelling and Analysis of High-throughput Data in Cancer Research and in Microbial Ecology

Antoine Buetti-Dinh

Today's high-throughput technologies are increasingly used from clinical research to microbial ecology, and the wealth of data produced by these techniques defies straightforward interpretation. Novel methods and computational tools are necessary to optimize data mining, complement lack of data where necessary and retrieve desired information. This is essential to transfer the information furnished by these new technologies into practical applications such as combined cancer therapy and microbial bioleaching.

Using tools like Bayesian analysis and clustering methods in a data-driven approach, we reverse-engineer experimental datasets into biological interaction networks. We further investigate the results using an in-house developed computational platform for sensitivity analysis of biological networks. Our simulations are based on principles of physical biochemistry and enzyme kinetics to represent activation/inhibition networks under simplifying assumptions that allow to deal with real-life scenarios.

Both in cancer biology and microbial ecology, biological networks are abstracted from an experimental system and modelling is subsequently used to optimize complex processes by controlling key nodes of the network. This allows us to make cancer therapies more specific to drug resistance, or to make the process of copper extraction from mining waste more efficient and ecologically friendly.

This paper is coauthored by Ran Friedman, Mark Dopson(4) and Igor Pivkin.

■ TB-26

Thursday, 10:30-12:30 - SR Geschichte 1

Convex and Nonlinear Optimization

Stream: Continuous Optimization
Chair: *Pál Burai*

1 - Solution methods for black-box optimization problems

Mirjam Duer, Christine Edman

We consider expensive optimization problems, that is, problems, where each evaluation of the objective function is expensive in terms of computation time, consumption of ressources, or costs. This happens in situations where the objective is not available in analytic form, but evaluations are the result of a simulation. In this situation, it is desirable to use as few function evaluations as possible. We discuss response surface methods which use a sophisticated strategy to determine the evaluation points.

2 - Duality-Based Algorithms for Solving the Problem of Locating a Semi-Obnoxious Facility

Andrea Wagner

For several applications of location theory the goal is to locate a new facility which is necessary for social life, but also creates numerous negative effects on the quality of life of people or animals. Such facilities are called semi-obnoxious. This work presents a new approach for solving the non-convex optimization problem of locating such a semi-obnoxious facility. The duality theory by Toland and Singer for d.c. optimization problems is applied for deriving general properties. Based on those properties we formulate algorithms, which determine exact solutions by relating the non-convex optimization problem to a finite number of convex or even linear problems.

3 - On the directional derivative of optimal value functions of nonsmooth convex problems

Robert Mohr

We present a formula for the directional derivative of the optimal value function of a nonsmooth and completely convex parametric problem. The formula is valid at boundary points of the domain of the optimal value function if the direction belongs to a certain conic set. We derive a functional description for this conic set and apply the formula to selected convex problems such as convex semi-infinite problems or problems involving sums and maxima of norms.

4 - Optimality conditions in unconstrained optimization

Pál Burai

The main goal of this talk to show some optimality conditions for unconstrained problems.

Firstly, we use convex analysis tools to derive a necessary and sufficient condition on global optimality.

Secondly, generalized convexity is used to get a similar result.

■ TB-27

Thursday, 10:30-12:30 - SR Geschichte 2

Credit Risk (c)

Stream: Financial Modelling
Chair: *Yuriy Kaniovskyi*

1 - Asset sale, debt restructuring, and liquidation

Michi Nishihara, Takashi Shibata

This paper considers a dynamic model in which shareholders of a firm in distress have a choice of whether to proceed to debt restructuring or liquidation at an arbitrary time. In the model, we show the following results. Less asset sale, lower financing, debt renegotiation, and running costs, a lower premium to the debt holders, a lower cash flow volatility, and a higher initial coupon increase the shareholders' incentive to choose debt restructuring to avoid full liquidation. In the debt renegotiation process, the shareholders arrange the coupon reduction and use equity financing to retire a part of the debt value to the debt holders. The timing of debt restructuring always coincides with that of liquidation without debt renegotiation. The shareholders do not prefer asset sale in debt restructuring even if they face high financing costs. The possibility of debt renegotiation in the future increases the initial leverage ratio in the optimal capital structure. Most of the results are in line with the empirical evidence.

2 - An Efficient Approach for Obtaining Markovian Credit Migration Matrices

Max Hughes, Ralf Werner

Transition matrices, containing credit risk information in the form of ratings based on discrete observations, are published annually by rating agencies. A substantial issue arises, as for higher rating classes practically no defaults are observed yielding default probabilities of zero. This does not always reflect reality. To circumvent this short coming estimation techniques in continuous-time can be applied. However, raw default data may not be available at all or not in the wanted

granularity, leaving the practitioner to rely on given one-year transition matrices from a discrete estimation. Then it becomes necessary, to transform the one-year transition matrix to a generator matrix. This is known as the embedding and uniqueness problem and is numerically not easy to solve. Starting with the optimisation problem of minimising the distance of the exponential of the generator matrix to the annual transition matrix, the newly proposed method applies a homogenisation idea to obtain (almost) globally optimal solutions to the highly nonconvex problem.

3 - Multivariate analysis of short and long-impact indicators for corporate bond market development

Ieva Astrauskaite

An additional instrument or established access to the capital market funding would increase business opportunities for performance, development, growth, channeling financing for sustainable and long-term economic growth and job creation. Capital market and its level of development or further development opportunities are exposed to different factors. Clear identification of them mobilizes the attention of accurate and useful decisions or actions influencing the expected results, their adoption and implementation, monitoring. With the purpose to identify a set of factors influencing the capital market development as well as to introduce a model of their short term and long term impact projections, the ARDL model for the US and Lithuanian cases is introduced. The concluding remarks states on different legal and regulatory framework, banking sector and ICT measures exposures to the different stages of the corporate market development.

4 - Numerical modeling of dependent credit rating transitions with asynchronously moving industries

Yuriy Kaniovskyi, Georg Pflug, Dmitri Boreiko

Two models of dependent credit rating transitions, where each industry can be governed by its own Markovian matrix, are considered. Positive and negative unobserved tendencies, that modify the transition robabilities making the evolutions dependent, are neither synchronized across industry sectors, nor over credit classes: upswing in some of them can coexist with a decline of the rest. The models are tested on a Standard and Poor's data set. The corresponding maximum likelihood estimates obtain by MATLAB optimization software. An analysis of correlations between the hidden tendencies shows that the considered industries evolve asynchronously. Estimated by Monte - Carlo simulations distributions of defaults, exhibit lighter, than for the known coupling models, tails for schemes with asynchronously moving industries.

■ TB-28

Thursday, 10:30-12:30 - HS 34

(c) Dynamic Games and Optimal Control

Stream: Control Theory
Chair: *Reinhard Neck*

1 - Differential Games with (A)symmetric Players and Heterogeneous Strategies

Benteng Zou

One family of heterogeneous strategies in differential games with (a)symmetric players is developed in which one player adopts an anticipating open-loop strategy and the other adopts a standard Markovian strategy. Via conjecturing principle, the anticipating open-loop strategic player plans her strategy based on the possible updating the rival player may take. These asymmetric strategies frame non-degenerate Markovian Nash Equilibrium, which can be subgame perfect. Except the stationary path, this kind of strategy makes the study of short-run trajectory possible, which usually are not subgame perfect. However, the short-run non-perfection provides very important policy suggestions.

2 - Together we are strong - divided still better? Strategic aspects of a fiscal union

Reinhard Neck, Dmitri Blueschke

In this paper we present an application of dynamic tracking games to a monetary union. We use a small stylized nonlinear two-country macroeconomic model of a monetary union for analysing the interactions between two fiscal (governments) and one monetary (common central bank) policy makers, assuming different objective functions of these decision makers. Using the OPTGAME algorithm, we calculate numerical solutions for cooperative (Pareto optimal) and non-cooperative games (feedback Nash). We show how the policy makers react upon demand shocks according to these solution concepts. To this end we introduce a negative asymmetric demand side shock aimed at describing the macroeconomic dynamics within a monetary union in a situation similar to the economic crisis (2007-2010) and the sovereign debt crisis (since 2010) in Europe. We investigate the welfare consequences of three scenarios: decentralized fiscal policies by independent governments (the present situation), centralized fiscal policy (a fiscal union) with an independent central bank, and a fully centralized fiscal and monetary union. For the latter two scenarios, we investigate the effects of different assumptions about the joint objective function corresponding to different weights for the two governments in the bargaining process assumed to precede the design of the common fiscal policy. We show the crucial importance of these weights for the macroeconomic outcomes of the resulting games.

■ TB-29

Thursday, 10:30-12:30 - SR IÖGF

Group Decision Making and Negotiation (c)

Stream: Multiple Criteria Decision Making
Chair: *Rudolf Vetschera*

1 - A New Hybrid Decision Making Model for Tourism Destination Selection

Erdem Aksakal, Metin Dagdeviren

Tourism can be described as the activities of people for travelling or staying outside from the usual place for recreation, leisure, family or business purposes usually for a limited time. In today's world, tourism becomes a dynamic and competitive industry which forms due to the customers' needs and desires. According to the changing needs, the customer's satisfaction varies according to some criteria. The way to have a nice travel or stay passes through having a good decision-making and planning processes. Selection process can be differing for each person. The aim of this study is to provide a decision making model for tourism destination selection problem. To select the appropriate destination, the criteria were selected with the help of experts and the literature review. The expert group consists of 4 people who are two academicians and two professional tour guides. The decision process formed of two stages. In the first stage, the region preference is determined under the given criteria. In the second stage the country selection process structured due to the finding region in the first stage. The decision process consists of eight criteria as; climate, cost of travel, destination (easy to get), language, culture, food, safety and events (activities). The regions and the countries identified from World Tourism Organization's (UNWTO) data. AHP method and TOPSIS method used as hybrid to find the appropriate destination selection. AHP method is used for to get the preference of the regions. TOPSIS method is used for to find the appropriate destination selection through countries.

2 - Prioritization of University Choice Dimensions using Fuzzy DEMATEL

Raja Rub Nawaz, Sajjida Reza

ABSTRACT Marketing in higher education has yet to prove its mettle in its theoretical models applications albeit, instances of application of marketing concepts are growing. This study is an effort to present an application of consumer choice behavior model in higher education with one of the tools of Fuzzy Multiple-Criteria Decision-Making (FMCDM) sphere, specifically, Fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) method was used. Five university choice dimensions, based on consumer choice model in the realm of higher education in Pakistan, were chosen for the purpose of prioritization of these dimensions from the higher management perspective of several local and regional universities. The resultant digraph of fuzzy DEMATEL method showed that "University Competence' as a dimension was highest on importance axis and "University History' was the lowest as a dimension. On relationship axis of digraph, all the four dimensions "University Competence', "Market Worth', "Value-added Activities', and "Amenities Offered' were the causal factors having a concomitant effect on the fifth dimension "University History'. The importance with cause and effect relationship

digraph also enabled us to look into the structural framework that was inherent by studying the cause and effect groups of university choice dimensions. The prioritization of criteria/dimensions also elicits the steering factors for higher management of any university as what dimensions must be concentrated and focused on while formulating and implementing marketing strategies in higher education domain.

3 - A systemic approach to supporting the ill-structured negotiation problems

Jerzy Michnik

Situation when the negotiation space and template are not clearly defined is very likely in negotiations. If it also happens that criteria cannot be regarded as independent, any approach based on weighted additive scoring is not suitable for evaluating the negotiation template and building the offers scoring system. This is area where other approaches with less limiting assumptions can prove their usefulness. It is proposed to apply the general systemic procedure for supporting the ill-structured negotiation problems. The procedure consists of two stages. In the introductory stage the negotiating team builds a common network of concepts and their relations representing the negotiation problem. This structure resembles the cognitive or causal map. The bottom nodes represent potential alternatives (offers) while the top nodes represent objectives (issues). The number of intermediary nodes link alternatives with objectives. This stage helps the negotiation team to structure the problem and supports learning and comprehension. The main stage involves the use of WINGS (Weighted Inuence Non-linear Gauge System) — a quantitative method that allows to build the ranking of the compromise solutions. The WINGS method is a general systemic approach that helps solving complex problems involving interrelated factors. In particular it can be used to evaluate alternatives when interrelations between criteria cannot be neglected. *This work was supported by the grant from Polish National Science Center DEC 2011/03/B/HS4/03857.

■ TB-31

Thursday, 10:30-12:30 - Marietta Blau Saal

Decision Support in Disaster Management

Stream: Health and Disaster Aid

Chair: *Marion Rauner*

1 - Network Design to Anticipate Selfish Evacuation Routing

Kerstin Seekircher, Alf Kimms

When a disaster occurs the population of the endangered zone must be evacuated as fast as possible. In this case, a large number of vehicles move through a street network to reach safe areas. In such a situation it might be impossible to communicate the routes to the evacuees they have to choose to optimize the traffic flow, moreover it is difficult to ensure that the evacuees take the communicated routes. With our approach we optimize the traffic routing without determining optimal routes for every evacuee. In the developed method, the street network for a given traffic flow is optimized. With the blockage of street segments we reach an improvement of traffic distribution what leads to a better traffic flow and results in a faster evacuation. To integrate human behaviour every evacuee is modelled as an independent acting agent that chooses a route dependent on her preferences. So the individual behaviour of the evacuees and also the structure of the street network are integrated in the solution. In a computational study we compare our solution with the results from the unmodified network and with a solution where the optimal routes for every evacuee are given. The results of the computational study indicate that our approach reduces the negative influence of selfish routing on the evacuation.

2 - Pre-disaster planning of retrofitting, response and recovery decisions

Alper Döyen, Yasemin Arda

Disaster management mainly composes of four components: mitigation, preparedness, response and recovery. A disaster preparedness plan becomes much more effective when it takes into account the interrelations between all of these phases. In this manner, we consider a comprehensive disaster management model that incorporates critical decisions related with pre- and post-disaster situations. We formulate a two-stage stochastic programming model where earthquake occurrence is the random event that separates the planning horizon as the first and second stage. Building and road retrofitting decisions constitute the binary first-stage variables, while relief flows and shortage amounts are the continuous second-stage variables. Retrofitting decisions are limited by a specific budget. The proposed model considers the time dimension such that the time of earthquake occurrence affects all of the decision variables. Minimizing the total costs of relief logistics, relief shortage and retrofitting is the objective of the model. An effective integer L-shaped method is presented to solve the problem. Experimental results show that the proposed method performs well on a large set of test instances.

3 - Decision support for health care emergency management: interlinking emergency interventions, responders, and equipment/materials

Marion Rauner, Helmut Niessner, Lisa Sasse, Kristina Tomic

For a successful emergency management (EM) it is crucial that all stakeholders, especially health care emergency responders, use the same terminology. For this reason, we developed the S-HELP UNI-VIE wiki that provides main glossary terms, definitions, and standards for strategic disaster management. It was implemented for the FP7-EU S-HELP (Securing Health.Emergency. Learning.Planning) project coordinated by Dr. Karen Neville, University College Cork, Ireland which develops a Decision Support (DS) tool for EM (http://www.fp7-shelp.eu/).

As a next step, we established a skills taxonomy template to interlink emergency interventions/tasks and emergency responders/skills. Furthermore, we provided an overview which emergency interventions/tasks can be covered by EU Civil Protection Modules by incorporating availability, start of operation, self-sufficiency, and operation time. Next, the resource taxonomy template contained the linkage of emergency interventions/tasks and emergency responders/skills to emergency equipment/materials needed. The skills and resource taxonomy templates considered the complex and multi-disciplinary nature of health services in emergency preparedness, response, and recovery.

These taxonomies are currently implemented and integrated into the S-HELP Decision Support Tool for emergency responders by University College Cork, Ireland. They are also used for health care responder training. A future improvement step of our taxonomies is the integration of special emergency equipment/materials, responders/skills, and interventions/tasks used in the disaster scenarios (flooding, chemical spill, epidemic). For the interoperability, we will investigate in detail specific main core emergency responders of selected European countries.

4 - Integrating delivery time assessment in disaster relief decision support

Christian Wankmüller, Gerald Reiner, Nathan Kunz, Thomas Wurzer

Disaster management includes the organization of efficient and effective logistics processes that serve to satisfy basic food and health care needs of affected people in disaster areas. For improving the quality of disaster management, scientific literature offers different disaster relief preparedness strategies, such as pre-positioning of life-saving relief supplies in disaster prone areas as well as investing in disaster management capabilities to reduce the response time in case of catastrophic events. One possibility to analyze the performance of disaster relief preparedness strategies is to apply process simulation based on empirical data, i.e. empirical quantitative modelling. For this reason, the motivation of our paper is to provide an instrument to appropriately assess the temporal dimension of transport processes according to different situational factors. The main objective of our study is the integration of transport to increase the quality of the provided decision support. In this regard, important influencing factors related to transport means are speed, transport capacity and availability. Further factors are transportation distances, volume of traffic, road/track/inland waterway as well as air traffic control conditions and airport availability. Thus, traditional Geographic Information Systems will be complemented by transport capacity restrictions and related risks. The developed model serves as a decision support system that enables relief organizations to choose the appropriate preparedness strategy and type of transport under consideration of supply process characteristic in order to be better prepared and to improve decision making for disaster relief operations.

Thursday, 14:00-15:30

■ TC-02

Thursday, 14:00-15:30 - HS 7

Scheduling in Logistics (i)

Stream: Scheduling and Project Management
Chair: *Jenny Nossack*

1 - A dynamic programming approach for the aircraft scheduling problem with general airport runway configurations
Alexander Lieder, Raik Stolletz

We present a dynamic programming approach for the aircraft scheduling problem at an airport, that is to assign a runway and an operation time to a set of pending aircraft take-offs and landings. Between all pairs of operations, sequence-dependent separation requirements have to be considered. The objective is to minimize the total costs incurred by delayed operations.

We take constraints incurred by the airport's runway configuration into account: Schedules for closely-spaced parallel runways have to consider additional diagonal separation constraints and not all runways can accommodate all kinds of operations.

Solution approaches presented in the recent literature are mostly heuristic, approximate, or restricted to solving very small problem instances. We present an approach that can solve comparatively large problem instances to optimality within short computation times.

2 - The Windy Rural Postman Problem with a Time-Dependent Zigzag Option
Jenny Nossack, Bruce Golden, Erwin Pesch, Rui Zhang

In this research, we focus on the windy rural postman problem with the additional option to zigzag street segments during certain times of the day. If a street is narrow or traffic is light, it is possible (and often desirable) to service both sides of the street in a single pass by zigzagging. However, if a street is wide or traffic is heavy, we must service the street by two single traversals. For some streets, we further impose the restriction that they may only be zigzagged at specific times of the day, e.g., in the early morning when there is virtually no traffic. Real-life applications arise, among others, in trash collection and newspaper delivery. This specific arc routing problem combines two classes of problems known from the literature, arc routing problems with zigzag options and arc routing problems with time dependencies. We present and discuss two (mixed) integer programming formulations for the problem at hand and suggest exact solution approaches. Furthermore, we analyze the effects of zigzag and time window options on the objective function value and test our solution approaches on real-world instances.

■ TC-03

Thursday, 14:00-15:30 - HS 16

Sequencing in Production Planning and Logistics (i)

Stream: Scheduling and Project Management
Chair: *Dirk Briskorn*

1 - Synchronous flow shop problems with dominating machines
Sigrid Knust, Stefan Waldherr

A synchronous flow shop is a variant of a non-preemptive permutation flow shop where transfers of jobs from one machine to the next take place at the same time. The processing is organized in synchronized cycles which means that in a cycle all current jobs start at the same time on the corresponding machines. Then all jobs are processed and have to wait until the last one is finished. Afterwards, all jobs are moved to the next machine simultaneously. As a consequence, the processing time of a cycle is determined by the maximum processing time of the operations contained in it. Furthermore, only permutation schedules are feasible, i.e. the jobs have to be processed in the same order on all machines. The goal is to find a permutation of the jobs such that the makespan is minimized. Motivated by a practical application we investigate special cases where the processing times of the cycles are only determined by a subset of so-called dominating machines. Besides complexity results we present exact and heuristic solution algorithms.

2 - Loading parallel stacks to minimize the number of blockages
Simon Emde, Nils Boysen

This presentation treats an elementary optimization problem which arises whenever an inbound stream of items is to be intermediately stored in a given number of parallel stacks such that blockages during their later retrieval are avoided. A blockage occurs whenever an item to be retrieved earlier is blocked by another item with lower priority stored on top of it in the same stack. Our stack loading problem arises, for instance, if containers arriving by vessel are intermediately stored in a container yard of a port or if, during nighttime, successively arriving railcars are to be parked in multiple parallel dead-end rail tracks of a tram depot. We formalize the resulting basic stack loading problem, investigate its computational complexity, and present suited exact and heuristic solution procedures.

3 - Finding optimal schedules for inland shipping
Stefan Bock

In this talk a specific ship scheduling problem in a real-world transportation network of water ways is considered. It is assumed that the underlying network is acyclic and possesses a tree like structure. Due to existing deadline restrictions at the ports and varying waiting times, a robust time schedule of a considered inland cargo ship is sought. This problem is shown to be strongly NP-hard by a reduction from 3-PARTITION. In order to efficiently solve the considered scheduling problem, a new Branch&Bound procedure is proposed. This procedure explores the solution space in a best-first manner and applies various dominance rules. The efficiency of the Branch&Bound procedure and its applied bounds and domination rules is validated by a computational study.

■ TC-04

Thursday, 14:00-15:30 - HS 21

Cutting and packing problems (c)

Stream: Discrete Optimization
Chair: *Torsten Buchwald*

1 - LP-based Relaxations of the Skiving Stock Problem
John Martinovic, Guntram Scheithauer

We consider the one-dimensional skiving stock problem (SSP) which is also known as the dual bin-packing problem in literature. In the classical formulation, different (small) item lengths and corresponding availabilities are given. We aim at maximizing the number of objects with a certain minimum length that can be constructed by connecting the items on hand. Such computations are of high interest in many real world application, e.g. in industrial recycling processes, wireless communications and politico-economic questions. For this optimization problem, we give a short introduction by presenting different modelling approaches, particularly the pattern-based standard model and the position-indexed arc flow model, and discuss their relationships. Since the SSP is known to be NP-hard a common solution approach consists in solving an LP-based relaxation and the application of (appropriate) heuristics. Practical experience and computational simulations have shown that there is only a small difference (called gap) between the optimal objective values of the relaxation and the SSP itself. Hence, we will present some results and upper bounds for the gap of the SSP also providing instances where the (modified) integer round-down property can be proved. Besides the continuous relaxation, we will focus on the proper relaxation and aim at introducing a proper arc flow model of pseudo-polynomial complexity. Moreover, first results regarding the proper gap will be delivered.

2 - Using contiguous, 2D feasible 1D cutting patterns for the 2D rectangular strip packing problem
Isabel Friedow, Guntram Scheithauer

The 2D rectangular strip packing problem consists in packing rectangles into a strip of fixed width and unrestricted height without overlapping while minimizing the strip height needed. In our case rotation of rectangles is not allowed. A relaxation of that problem is the 1D horizontal bar relaxation, the LP relaxation of the 1D binary cutting stock problem. To represent a solution of the strip packing problem, a solution of the horizontal bar relaxation has to satisfy, among others, the vertical contiguous condition. That means there must exist such an ordering of the 1D cutting patterns that all items representing one rectangle are located in consecutive patterns. To strengthen the bar relaxation with respect to that vertical contiguity we formulate inequalities that are based on the knowledge of y-coordinates of rectangles in a corresponding 2D packing. The inequalities ensure that if a 1D cutting pattern is used in the solution there exists at least one cutting pattern with usage greater than zero that continues that pattern. Additional to the vertical contiguous condition a solution of the bar relaxation must ensure that all items representing one rectangle have the same x-position in each pattern. The considered 1D cutting patterns do not provide any information about the location of the items contained. Because of that the following two strategies are integrated in the process of column generation: modification of the slave problem to generate only 2D feasible cutting patterns and identification and exclusion of 2D infeasible cutting patterns. We tested our approach used in an exact as well as in a heuristic algorithm for different sets of test instances and compare our computational results with other methods proposed in literature.

3 - Creating worst-case Instances for upper and 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 heuristics 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 heuristic. Therefore, we model the solution obtained by the heuristic 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 heuristic. We introduce this new model for the Next-Fit Decreasing-Height, the First-Fit Decreasing-Height and the Best-Fit Decreasing-Height heuristic. Furthermore, we provide an opportunity to use this idea to create worst-case instances for lower bounds.

■ TC-05

Thursday, 14:00-15:30 - HS 23

Lotsizing and Inventory Management II

Stream: Production and Operations Management
Chair: *Christian Almeder*

1 - Monolithic Models for Production Planning - beneficial or not?
Tom Vogel, Bernardo Almada-Lobo, Christian Almeder

The hierarchical planning concept is commonly used for production planning. Dividing the planning process into subprocesses which are solved separately in the order of the hierarchy decreases the complexity and fits the common organizational structure. However, interaction between planning levels is crucial to avoid infeasibility and inconsistency of plans. Furthermore, optimizing subproblems often leads to suboptimal results for the overall problem. The alternative, a monolithic model integrating all planning levels, has been rejected in the literature due to several reasons, such as different planning horizons with different level of detail and different degrees of data uncertainty. In this study we show that those arguments are not valid any longer. We develop models for both approaches considering two levels, Aggregate Production Planning (APP) and Master Production Scheduling (MPS). On the aggregate planning level major capacity adaptations and inventory levels for product types are determined on a monthly basis and forwarded to the level of MPS. There the more detailed production plan for product families is determined on a weekly basis. Computational tests show that it is possible to solve the monolithic model and that it outperforms the hierarchical approach if only a single planning step is considered. However, additional experiments reveal that on a rolling horizon basis the monolithic model is no longer superior and thus, not beneficial.

2 - Online Algorithms for the Newsvendor Problem
Esther Mohr

This work considers the dilemma of a newspaper salesman - how many papers should he purchase each day to resell when he doesn't know the demand? Due to the fact that the newsvendor problem is simple but rich enough to capture the fundamentals of many operations management problems it serves as the building block for numerous models in inventory control, supply chain coordination, revenue management, and scheduling. Typically, the objective of the newsvendor is either to maximize the expected profit or to minimize the variance of profit, which is appropriate when the probability distributions of the market demands are fully known. However in practice, demand distributions are often unknown to the newsvendor, in particular for products with short life-cycles. For example, most retailers are not able to forecast their customer's demand with accuracy due to few historical data or volatility. Hence, decision-makers to seek for alternative solutions to the newsboy problem that work with limited demand information. We present and analyze online algorithms that determine the newsvendors' optimal order quantity for the case where only sets of constants are available to characterize the demand, but no probability distributions. Our results indicate that online algorithms perform comparably, and to some extend better than stochastic approaches.

3 - Price and Quantity Optimization in the Risk-sensitive Newsvendor Problem with Isoelastic Demand
Javier Rubio-Herrero, Melike Baykal-Gursoy

We present the optimization of price and quantity in the single-product, single-period newsvendor problem. The newsvendor is risk-sensitive and seeks the maximization of profit via a mean-variance analysis. The demand is assumed to be price-dependent, multiplicative, and isoelastic. We propose several results based on different scenarios, namely, risk-neutral, risk-averse, and risk-seeking. We compare these results to others previously obtained by other authors that used different risk measures.Finally, we introduce numerical examples.

■ TC-06

Thursday, 14:00-15:30 - HS 24

Metaheuristics III (c)

Stream: Metaheuristics
Chair: *Ivan Davydov*

1 - Two-dimensional nesting problem: A new approach to genetic algorithm
Mehmet Hacibeyoglu, Mohammed Ibrahim

The nesting problem is commonly encountered in numerous industries such as furniture, garment, footwear and sheet metal. It is a combinatorial optimization problem in which a set of regular and irregular objects must be placed on one or more pieces of a rectangular sheet without overlap. The purpose of the nesting process is increasing the sheet use efficiency by minimizing the waste. The search space of the nesting problem is very large so to find the optimal solution is very difficult and long process. Therefore, metaheuristic algorithms are often used for solving this problem. In this paper a new approach to genetic algorithm is proposed for the nesting problem. In this new approach, crossover and mutation processes are implemented with novel techniques. The proposed algorithm analyzed, implemented and tested on several datasets. The experiments demonstrate the achievement of the proposed genetic algorithm.

2 - On Solving The Power Generalized Extreme Value Distribution By Using The Metahuristic Algorithm — A Case Study Of Flood Data.
Seyyed Hassan Taheri, Ali Saeb

The six types of power normalized stable laws that introduced by Pancheva (1984) may all be represented as members of two families which called log generalized extreme value distribution (lgevd) and negative log generalized extreme value distribution (nlgevd).

In this article, we introduce the power generalized extreme value distribution and we also demonstrate a metaheuristic algorithm to estimate the parameters of lgevd and nlgevd. We compare this algorithm by using on flood data set as a case study. The results show the efficiency of our algorithm to solve lgevd and nlgevd problems.

3 - Tabu search heuristic for the competitive base stations location problem

Ivan Davydov

We consider the base stations location problem. Two competitive operators, which we refer to as a leader and a follower, compete to serve clients by installing and configuring 5G networks. We are given a set of sites, suitable for antenna installation and a set of clients locations. Location of the leaders base station is also known. Follower can set up his base stations on a free sites, or use the leaders base stations to deploy his antennas as well as on the sites, occupied by the leader. In the latter case the follower have to pay the rent price. After the deployment of all base stations, users sign a contract with the leaders or followers network. The choice of each user is dependant of the average quality of the network. The quality of a signal between the user and the base station depends on distance, noise and interference. Noise in the band together with an interference between base stations decreases the power of signal. We assume, that traffic demand is a constant in the network that operators wish to serve. In every location there is a certain demand, generated by users. This demand is statistical and can be shared by the leader and the follower or not served at all. Physical data rate, provided by the base station depends on the signal power and amount of the demand served. Users prefer the network, which provides higher average data rate. The problem is to find an optimal location of the follower base stations, providing maximal total income for the follower. We provide a mathematical model for this problem in terms of nonlinear mixed-integer programming. We suggest a tabu search based heuristic for this problem. The numerical test results are discussed.

■ TC-07

Thursday, 14:00-15:30 - HS 26

Fixed-parameter-tractable and online algorithms (c)

Stream: Discrete Optimization
Chair: *R. Hildenbrandt*

1 - Parameterized Complexity of Multi-Portfolio Capital Budgeting Problems

Frank Gurski, Jochen Rethmann, Eda Yilmaz

We consider a capital budgeting problem on several portfolios. A firm is given a set of n financial instruments X and a number m of portfolios. Every instrument has a return and a price. Further for every portfolio there is capacity. The task is to choose m disjoint portfolios from X such that for every of these portfolios the prices do not exceed the given capacity and the total return of this selection is maximized. From a computational point of view this problem is intractable, even for m=1. Since the problem is defined on inputs of various information, we study the fixed-parameter tractability of the problem. The idea behind fixed-parameter tractability is to split the complexity into two parts - one part that depends purely on the size of the input, and one part that depends on some parameter of the problem that tends to be small in practice. We show that for our problem the number of instruments, the threshold value of the return, and the sum of all capacities can be chosen as a parameter such that the problem is fixed-parameter tractable. Thus for a lot of small parameter values we obtain efficient solutions for the capital budgeting problems on several portfolios. We also consider the connection between these parameterized problems to approximation and pseudopolynomial algorithms.

2 - Fixed-Parameter Tractability of Change-Making Problems

Steffen Goebbels, Frank Gurski, Jochen Rethmann, Eda Yilmaz

The change-making problem is the problem of representing a given amount of money with the fewest number of coins possible from a given set of coin denominations. In the general version of the problem, an upper bound for the availability of every coin value is given. Even the special case, where for each value an unlimited number of coins is available, is NP-hard. This motivates to study the fixed-parameter tractability of these problems. The idea behind fixed-parameter tractability is to split the complexity into two parts - one part that depends purely on the size of the input, and one part that depends on some parameter of the problem that tends to be small in practice. Our results consider the connection of parameterized change-making problems to linear programming and pseudo-polynomial algorithms.

3 - An operations research problem for conversions of machines modelled as a k-server problem

R. Hildenbrandt

In this talk we consider a generalized k-server problem which was initiated by an operations research problem that consists of optimal conversions of machines or moulds in order to produce parts of different types. In this problem we must decide which machine is to be converted into which state in each stage. If we disregard a probability distribution for the requirements of parts we obtain an online problem. More precisely, it is a generalized k-ser-ver problem with parallel requests where several servers can also be located on one point. In this talk we will introduce this problem and present new results. Among other things we consider the Harmonic k-server algorithm in relation to the generalized k-server problem. By an example we verify that the potential function which was introduced by Y. Bartal and E. Grove [2000] is not helpful in order to prove competitiveness in the general case. That's why we will present the "compound Harmonic algorithm" for the generalized problem and show that this algorithm is competitive.

■ TC-08

Thursday, 14:00-15:30 - HS 27

Computational and Experimental Economics

Stream: Computational and Experimental Economics
Chair: *Ulrike Leopold-Wildburger*

1 - Finding Binary Rules for Purchase Intention in e-Commerce

Arik Sadeh

There are many factors that affect purchase intention in e-commerce. In this study the main focus is to define such factors and to find what combinations of these factors' values lead to better purchase intention. Two product oriented factors and three site oriented factors are considered: price attractiveness, product's quality, site's disclosure, accountability and security and safety. Each factor has two levels, low and high; consequently, there are 32 possible combinations of values of these five factors. 128 respondents gave information about their purchase intention of 2048 combinations. The methodology used is based on finding the minimal number of rules that detect as many combinations as possible that are associated with high level of purchase intention. It was found that e-consumer give more attention to site conduct. The methodology can be adopted to other cases of management and operations research.

2 - Team Collaboration and Research Productivity: the case of economics publications

Boontarika Paphawasit

Scientific knowledge production has changed dramatically over the past few decades from a small research team to a larger project gathering many researchers into a single team. This shift leads a question of how collaboration of author-team impacts the quality of scientific publication. What differentiates influential publications from obscure articles? This study aims to examine what demographic characteristics of author-team (i.e., gender, nationality, seniority, academic rank, and team size) affect publication productivity in economics and how they impact the research outcomes measuring from citation counts, journal ranking lists, and journal impact factor (JIF). The analysis employed cross-sectional data of 1,512 publications published in 2012 from 16 economics journals listed in Association of Business Schools (ABS) Journal Quality Guide 2010. Results from normality tests confirmed

that all variables were not normally distributed; hence spearman correlation and quantile regression were used to analyse the data. The findings showed a significantly positive effect of team size on the possibility of being a productive publication, whereas there was a negative relationship between female dominated team and research productivity. In other words, the larger teams with male dominated collaborators have produced higher quality of publication. Regardless of gender dominated contributors' issue, the analysis showed a significantly negative relationship between gender diversity and research productivity, that is, single-gender teams have produced better research. Seniority and nationality diversity also has a negative connection with research productivity and academic rank has a positive relationship; however, they were not statistically significant.

■ TC-09

Thursday, 14:00-15:30 - HS 30

Scheduling and games

Stream: Game Theory
Chair: *Rob van Stee*

1 - Vector scheduling and packing games

Leah Epstein, Elena Kleiman

We study the multidimensional vector scheduling problem and the multidimensional vector bin packing problem with selfish jobs or items. The players correspond to jobs or items that have multidimensional vectors associated with them. In the first problem, there are m identical machines, each player or job is interested in minimizing its cost. The cost is based on the load vector of the machine which the job is assigned to, and the load of a machine is the sum of the vectors of the jobs assigned to it. In the second problem, each player or item is to be packed into a bin. There is a supply of bins whose components are equal to 1, and its goal of a player is to maximize the volume of the bin where it is packed. We provide improved bounds on the price of anarchy and the strong price of anarchy for both problems, and discuss other kinds of equilibria.

2 - Minimization load balancing scheduling problems: a unified approach for designing EPTASs

Asaf Levin, Ishai Kones

We consider a common generalization of many minimization variants of the load balancing in parallel machines scheduling problems. These can be used for modelling problems such as processor scheduling and transmitting video streams. In particular, each machine can be activated to one of a subset of types associated with it. Activating a machine to a given type incurs an activation cost and any activation of machines to types must obey a bound on the total activation cost. When a job is scheduled to a machine of a given type, it takes on a processing time vector unique to itself and the type. For each machine we sum these processing time vectors to get a machine's work vector. The machines each have a speed and dividing a machine's work vector by its speed we get the machine's load vector. Then the objective of our problem is to minimize a multidimensional function, which generalizes the lp norm and makespan, over these load vectors.

This problem (as well as many of its special cases) is strongly NP-hard and so neither an optimal solution nor a fully polynomial time approximation scheme can be given for it (assuming P is not equal to NP). Instead, we provide an efficient polynomial time approximation scheme.

3 - Coordinating Selfish Players in Multi-Job Scheduling Games

Fidaa Abed, José Correa, Chien-Chung Huang

We consider the unrelated machine scheduling game in which players control subsets of jobs. Each player's objective is to minimize the weighted sum of completion time of her jobs, while the social cost is the sum of players' costs. The goal is to design simple processing policies in the machines with small coordination ratio, i.e., the implied equilibria are within a small factor of the optimal schedule. We work with a weaker equilibrium concept that includes that of Nash.

We first prove that if machines order jobs according to their processing time to weight ratio, a.k.a. Smith-rule, then the coordination ratio is at most 4, moreover this is best possible among nonpreemptive policies. Then we establish our main result. We design a preemptive policy, EX, that extends Smith-rule by adding extra delays on the jobs accounting for the negative externality they impose on other players. For this policy we prove that the coordination ratio is 2.618, and complement this result by proving that this ratio is best possible even if we allow for randomization or full information. Finally, we establish that this externality policy induces a potential game and that an epsilon-equilibrium can be found in polynomial time. An interesting consequence of our results is that an epsilon-local optima of the problem for the jump (a.k.a. move) neighborhood can be found in polynomial time and are within a factor of 2.618 of the optimal solution. The latter constitutes the first direct application of purely game-theoretic ideas to the analysis of a well studied local search heuristic.

■ TC-10

Thursday, 14:00-15:30 - HS 31

Routing Methods II (c)

Stream: Logistics and Transportation
Chair: *Karl Doerner*

1 - Investigations on network flow-based mathematical models for vehicle scheduling and vehicle routing with deliveries and pickups and loading constraints

Taieb Mellouli

At a first glance, the vehicle routing and the vehicle scheduling problems (VRP, VSP) seem to share a very common structure, since both chain nodes (locations/trips) into routes/rotations. As state-of-the-art methods for practical constraints and instances are based on mathematical programming for the second, large instances for routing problems are still solved heuristically. A network with space resp. time-space nodes and explicit arc connections is acyclic only for VSP due to irreversible time progress.

Connections can be represented implicitly by introducing connection (time) lines, leading to more efficient vehicle flow models for VSP. In order to solve hard versions of VSP and rotation building (multiple types and depots for buses, cyclic maintenance requirements for trains), the author developed crucial techniques for aggregating deadhead trips and resource paths based on computing latest-first-matches between connection lines and introducing resource-state dependent connection lines. This led to competitive network-flow models being in productive use, also for crew scheduling by aggregating flows of same crew states. As vehicle flow models for VRP suffer of subtours and lot of symmetry, a model allowing structure exploitation is chosen for first experiments: Coupling commodity flows for types of loads to the vehicle flow, techniques modeling practical requirements (linehauls strictly or preferably before backhauls, restricted mixture of deliveries and pickups avoiding shuffling problems, LIFO strategy for pickup-and-delivery-pairs) are implemented and tested. Preliminary results for up to 100 nodes using Gurobi show that restricted versions are solved more efficiently, suggesting to break symmetry for weaker versions by imposing some degrees of tour quality.

2 - Optimization Approaches for Recreational Bicycle Tour Planning

Benedikt Klocker, Günther Raidl, Matthias Prandtstetter

Exercising is important to stay healthy. Therefore, we develop an algorithm for finding nice recreational bicycle tours with the goal of making exercising by cycling more attractive.

We formulate this challenge as a mathematical optimization problem similar to the arc orienteering problem (AOP) on a directed multigraph. The objective is to maximize the attractiveness of a route under the condition of not exceeding a maximal tour length. It allows multiple usage of streets, but penalizes it such that the attractiveness or score of the route decreases. The problem is NP-hard and developing practically effective algorithms running in reasonable time is therefore crucial.

Three mixed integer linear programs are provided for solving the given problem exactly. The first program uses a classical cut formulation as sub tour elimination, the second a flow formulation and the third the combination of the first two.

Testing the implementations of the three mixed integer linear programs using CPLEX reveals that the flow formulation is for our purposes more efficient than the other two formulations. Compared to other exact algorithms solving similar problems like the AOP, our implementation of the flow formulation is faster up to a factor of 1000. If we compare our implementation with heuristic approaches for similar

problems, we get the result that for some instances our implementation finds the optimal solution in short time and the heuristic approaches do not find the optimal solution. However, the heuristics scale better for large instances. On the countryside the algorithm is applicable for routes up to 60 km and in urban areas for routes up to 13 km, which seems to be enough for our intended practical purposes.

3 - The Lateral Transhipment Problem for A Priori Routes and Piecewise Linear Profits

Martin Romauch, Richard Hartl, Thibaut Vidal

We propose exact solution approaches for the lateral transhipment problem with a-priori routes. For any given route, an optimal inventory redistribution plan is sought, considering travel costs, profits (dependent on the local inventory levels) and holding costs. Constraints on trip duration and vehicle capacities are also imposed. This problem, with fixed routes, arises when enumerating solutions of a vehicle routing problem for lateral transhipments with piecewise linear profits, during heuristic resolution. The same formulation is also encountered when dealing with lot sizing applications, in the presence of setup costs and equipment requalifications. To address this problem, we introduce a pure dynamic programming approach and a branch-and-bound framework that combines dynamic programming with Lagrangian relaxation. Expensive experiments are conducted to determine the most suitable resolution approach for different instances, depending on their size, vehicle capacities and duration constraint. The performance is compared to Gurobi as one representative of a commercial optimization solver. The proposed branch-and-bound and Lagrangian relaxation approach, in particular, solves problems of up to 100 delivery locations in less than one minute on a modern computer, outperforming Gurobi for most benchmark instances.

■ TC-11

Thursday, 14:00-15:30 - HS 32

Energy-efficient Mobility III

Stream: Logistics and Transportation
Chair: *Christoph Helmberg*

1 - Energy Efficient Freight Train Composition and Scheduling

Frederik Fiand, Uwe T. Zimmermann

Based on a real world problem we optimize energy efficiency in rail freight transportation. Given a set of shipment requests and predefined freight train schedules that allow some local time shifts, our goal is to find optimal transportation plans. Here it is the main objective to minimize the energy consumption under consideration of several business rules like demand satisfaction, capacity constraints and release and due dates. The requirements result in a highly complex large scale problem based on tremendous time expanded networks. We develop a tailor made preprocessing, mainly based on shortest path computations, and provide a compact MIP formulation that fits in a highly customizable rolling horizon framework. The obtained results for real world instances provided by our industrial partner DB Mobility Logistics are promising. The corresponding project "e-motion' is funded by the German Federal Ministry of Education and Research (BMBF).

2 - Time-expanded ILP formulations for finding optimal locations for charging stations in an electric car sharing network

Georg Brandstätter, Markus Leitner, Ivana Ljubic

Due to their high efficiency in urban settings, electric cars are prime candidates for use within a city-wide car sharing network. Thanks to recent developments, their use on a commercial scale is becoming more feasible. However, the range of most electric cars is still fairly limited, which necessitates recharging throughout the day. To facilitate such recharging, charging stations must be placed throughout the operational area of the car sharing network. Obviously, their locations within the network have a significant impact on the amount of potential customer demand that can be covered, as well as on the network's operational efficiency. In our work, we develop integer linear programming formulations to solve the problem of finding optimal locations for these charging stations, as well as determining their optimal size. Customers can walk to any nearby station that has been opened to pick up a car (if one is available at that station) and return that car at any such station within the network with a free charging slot at the conclusion of their trip. To model the state of the car sharing network at different time intervals, we use time-expanded graphs. Our objective is to maximize the number of trips covered by our stations, given a limited budget for constructing stations and charging slots. We also discuss preliminary experimental results for our models, both for artificial and realistic instances.

3 - Electric vehicle routing with stochastic energy consumption

Henning Preis, Stefan Frank, Karl Nachtigall

The operation of battery electric vehicles (BEV) in commercial fleets, as it is recommended in projects of sustainable mobility, requires different extensions in modelling vehicle routing decisions. Here the strong limitation of driving range is addressed to be the major issue. The paper introduces an extension of the vehicle routing problem that takes into account the estimation of energy consumption on each section, stochastic influences and recharging stops. The objective is to find a set of routes with minimal average energy consumption subject to different constraints to ensure energetic feasibility. Therefor a vehicle flow formulation is presented, appropriate test instances are introduced and computational results are shown. Furthermore the paper investigates the trade-off between distance-based and energy-based vehicle routing as well as convenient penalty formulations for integrating energy issues in typical metaheuristic approaches.

■ TC-12

Thursday, 14:00-15:30 - HS 33

Railway Scheduling (c)

Stream: Logistics and Transportation
Chair: *Kirsten Hoffmann*

1 - Optimization of railway timetable by allocation of extra time supplements

Takayuki Shiina, Susumu Morito, Jun Imaizumi

In Japan, there is high demand for travel by railway, and this is especially true during weekday rush hours, when the trains become highly congested due to commuters who work in the metropolitan areas. There is a positive correlation between the congestion rate and the times at which travelers embark and disembark at train stations. On the other hand, it is important to determine an appropriate supplement to the running times between stations and arrival times at each station, in order to create a schedule that is robust against unanticipated delays. In the present study, we develop a mathematical model to distribute the running time supplement in such a way that the train can operate according to the schedule, in spite of delays. A previous study by Vekas et al. (2012) examined the optimal way to allocate the running time supplement for a train. The uncertain disturbances were modeled as a random variable. In their model, it was assumed that there was an upper limit to the total supplement, but its allocation was not restricted. In this paper, we suggest an improvement to the previous model and present a new mathematical programming model in which there is a constraint on the running time supplement allocated to each trip; this is done in order to minimize the expected delay. In addition, we compare the expected total delay for each model and examine the differences in the delay ratios.

2 - Models for Train Timetabling Problems with Configuration Based Ordering Constraints

Frank Fischer

In the train timetabling problem (TTP) one is given an infrastructure network and a set of trains with predefined routes running in this network. The goal is to find schedules for the trains so that certain operational constraints like station capacities and headway times are satisfied.

One of the most widely used integer programming models is based on time expanded networks. Each train is associated with a network and the schedule is represented by a path in this network. Coupling constraints ensure the operational constraints. If the variability of the schedules of the trains is not too large, e.g. due to restricted deviations from an ideal timetable or because of existing and fixed trains running in the network, these models work quite well.

However, if the schedules of the trains are rather free, the linear programming bounds of these models become quite weak. One reason is that ordering relations between trains caused by combinatorial properties of the network are not covered well in these models.

In this talk we present a new approach bringing ordering conditions into these models. Based on the so called configuration network based formulation for headway times, we extend these models so that additional constraints allow to formulate ordering conditions between trains running on the same track. We present some computational results illustrating the improved bounds obtained by our new approach.

3 - A hybrid solution approach for railway crew scheduling problems with attendance rates

Kirsten Hoffmann

The railway crew scheduling problem is to find an allocation of train services to crew members satisfying legal requirements and operating conditions in order to minimize total costs. Previous crew scheduling models and solution approaches mostly deal with covering all trips of the given train timetable. The diminishing importance of operational tasks and increasing cost pressure, however, force responsible authorities in Germany to reduce the deployment of conductors. Therefore, transportation contracts defining all frame conditions for different transportation networks determine one or more percentage rates of trains or kilometers that have to be attended by conductors. Typically, these rates are distinguished between product types, lines, track sections, or time windows.

In this talk, we present a model for railway crew scheduling problems dealing with such rates. For real-world instances, this model contains millions of feasible duties and, thus, variables. To avoid generating all duties a priori, the problem is decomposed in a master and a pricing problem. After solving the restricted master problem with an initial schedule, dual values are used to generate new feasible duties iteratively (pricing problem). The most common approach to solve the pricing problem is to find a shortest path according to resource constraints. As we have to find good crew schedules for planning periods of two weeks or even one month in a few hours in practice, we present a genetic algorithm as a faster solution approach for the pricing problem. Based on a set of real-world instances, we compare our hybrid solution approach with the enumeration approach with respect to resulting total costs and computation time.

■ TC-13

Thursday, 14:00-15:30 - HS 41

Hierarchical Demand Fulfillment (i)

Stream: Supply Chain Management
Chair: *Herbert Meyr*

1 - Multi-period Deterministic Hierarchical Demand Fulfillment

Jaime Cano Belmán, Herbert Meyr

In manufacturing environments with a hierarchical sales organization and heterogeneous customers the optimal matching of available resources (i.e. capacity and inventory) with demand can be 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 decentral, aggregate information only. Decentral, deterministic linear and nonlinear programming models are proposed approximating the first-best benchmark of a central, multi-period allocation planning with full information. First insights will be presented.

2 - Managing Scarce Supply in Customer Hierarchies with Service Level Agreements

Konstantin Kloos

Companies typically structure their customers in a hierarchical manner, often based on sales channels or regional structure. Based on a bottom-up aggregation of forecasts companies plan their overall supply. The available supply is then disaggregated hierarchically (top down) and allocated to lower level organizational entities where it is consumed by customers. In current practice, this top down allocation is done by simple rules (rank based, fixed split or per commit) or based on aggregated measure of profitability. As Vogel (2014) points out, these allocation mechanisms often lead to suboptimal results in terms of overall profitability. Our research addresses a scenario in which customers are hierarchically structured, but differ in their service level agreements. We propose a single period model, where overall supply is scarce and has to be allocated to local warehouses. Each warehouse serves multiple customer groups with stochastic demand and differing service level requirements. Here, inventory rationing strategies can be employed to account for the heterogeneity in customer requirements. However, due to the overall shortage, at least some customers' expected service level is lower than what was promised. Using multiple approaches (eg. penalties, goal programming) to balance deviations from the service level requirements of different customer groups, we derive conditions for optimal allocations to the warehouses under central planning and partitioned allocation. Subsequently, the insights obtained for central planner are used to derive procedures for a hierarchical, decentralized planning process to generate near optimal solutions. Furthermore, we extend these approaches to incorporate more elaborated rationing strategies such as standard and theft nesting.

3 - Profit-maximizing stochastic demand fulfillment in customer hierarchies

Maryam Nouri Roozbahani, Moritz Fleischmann

Customers differ in their profitability or importance to the firm. In order to maximize expected profits, considering limited resources, companies commonly divide the 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. This presentation reports on a research project that addresses the demand fulfillment problem in a make to stock environment, considering such hierarchically structured customer segments. Allocation decisions that match supply and current demand depend on information on future demand for the same supply which is, in general, uncertain. In order to deal with such uncertainties a stochastic planning approach will be developed which maximizes expected profits.

■ TC-14

Thursday, 14:00-15:30 - HS 42

Network Design II

Stream: Graphs and Networks
Chair: *Markus Leitner*

1 - Optimal Design of Shared Networks: From Bioinformatics to Telecommunications.

Martin Luipersbeck, Eduardo Álvarez-Miranda, Ivana Ljubic, Markus Sinnl

In the minimum-k-labeling Steiner tree problem (MKLSTP), we are given an edge-weighted undirected graph, k labels associated to potentially overlapping subsets of nodes (referred to as terminals) and a root node. A feasible solution corresponds to finding a subgraph containing a subtree per label that connects the label's terminals to the root, i.e., a labeling of edges where each edge is assigned the labels of each subtrees it is part of. The goal is to find a feasible solution of minimum cost, where cost is defined as the weighted-sum of the subgraph cost and each label's subtree costs.

The problem arises naturally in biological network analysis, where protein-protein interaction networks are used to describe related interaction processes between protein activity determined in multiple experiments. Another application lies within the area of telecommunication network design, when multiple services are to be provided to customers over a shared infrastructure.

Multiple solution methods have been implemented and compared in computational experiments. Our methods are based on ILP formulations and include a compact flow formulation known from related literature, as well as two new approaches, one based on the classical directed-cut formulation for the Steiner tree problem and one based on Benders decomposition.

2 - Nature Reserve Design with Connectivity and Buffer Requirements

Markus Sinnl, Eduardo Álvarez-Miranda, Ivana Ljubic

The design of nature reserves is becoming, more and more, a crucial task for ensuring the conservation of endangered wildlife. In order to guarantee the persistence of species and a general ecological functioning, the designed reserves should typically verify a series of spatial requirements. Among the required characteristics, practitioners and researchers have pointed out two important characteristics: (i) connectivity, to avoid spatial fragmentation, and (ii) the presence of buffer zones surrounding (or protecting) so-called core areas.

In this talk, we present general Integer Linear Programming models, which, for the first time, address both requirements simultaneously. Moreover, the incorporation of proximity requirements is also investigated. Based on our models, we developed a branch-and-cut algorithm. Extensive experimental results on synthetic and realistic instances show the effectiveness of our algorithm in providing optimal solutions in short computing times. The capacity of the models in producing solutions that exhibit other desired spatial properties, such as compactness, is also discussed.

3 - Integer Programming Formulations for Survivable Hop Constrained Network Design

Markus Leitner, Luís Gouveia, Ivana Ljubic

We consider the k-edge Survivable Hop Constrained Network Design Problem (k-HCNDP). Given is an undirected graph, with nonnegative edge costs, a set of commodities, two hop limits for each commodity pair, and a parameter k specifying the required redundancy. Solutions of the k-HCNDP are subgraphs containing a path of length at most H for each commodity pair and a path of length at most H' between its nodes after removing at most k edges. We first observe that solving this problem is not equivalent to designing a network containing a number of disjoint paths of length at most H and H', respectively, between each relevant node pair (the hop-constrained survivable network design problem (HSNDP) for which different integer programming formulations and solution algorithms have been proposed for the case H = H'). The reason for this is that Mengerian-like theorems do not hold for paths with hop constraints, i.e., designing a network including k edge disjoint paths with at most H hops between two nodes is not equivalent to designing a network guaranteeing the existence of a path with at most H hops between them after the failure of k-1 edges. Besides showing that the solutions to the problem can be different from the ones of the HSNDP, we propose integer programming formulations for the case of a single failure (i.e., for k=1) and analyze whether the solutions are really different from those obtained from considering the classical HSNDP.

■ TC-15

Thursday, 14:00-15:30 - HS 45

Simulation in Aeronautics and Transportation

Stream: Simulation and Decision Support
Chair: *Dirk Christian Mattfeld*

1 - Scheduling trucks with blocking constraints in a tank terminal

Evert-Jan Jacobs, Jannes Verstichel, Tony Wauters, Greet Vanden Berghe

At a tank terminal, tanks provide storage for liquids and gases, while pipelines connect these tanks to loading racks. At each truck arrival, the truck scheduler assigns the vehicle to a position at the loading rack connected to the tank selected beforehand. Due to the loading processes on their routes, the assignment can result in blocked trucks, increasing the total transit time at the terminal. The transportation between client and terminal is outsourced to external contractors. Therefore, the transport costs will increase when the total transit time exceeds a particular threshold. Thus, reducing the waiting time increases client satisfaction. The objective is to minimize average and maximum waiting times for the trucks. Before dispatching a truck, the algorithm computes the shortest route to the loading position. When the product is loaded, the route to the exit is calculated. Using simulation, the variable processing times and tank failure are modelled. Input data was provided, including the definition of the tank terminal and truck information. The definition includes the escape routes, the positions of the equipment and their connections with the tanks. After analyzing the truck data, probability functions used for generating datasets have been defined. These generated datasets, as well as real world data, are important to test the efficiency of the algorithms. Comparison between the original transit times and the calculated times show the possibility for a huge improvement. The truck scheduling will later be extended with berth allocation at the quay side of the terminal. The algorithm will adapt to resource unavailability when a barge is loading from one of the tanks.

2 - Modeling Airline Activity in Staged Queues for Airport Capacity Planning

L. Douglas Smith, Jan Fabian Ehmke, Dirk Christian Mattfeld

Concentration of traffic at major U.S. hub airports has dramatically altered activity and caused airport planners to reconsider how to manage airport assets. We present a discrete event simulation model for that purpose. The model uses staged queuing networks as its conceptual foundation and reveals the potential impact on system performance of stressful weather events, delays due to traffic congestion at major hub airports, changes in airline schedules, gate allocations, ground traffic control procedures, etc. We describe multivariate statistical models for setting dynamic parameters and validating the model itself. We also describe features of the simulation model and illustrate its application for strategic analysis.

3 - Development of a consistent approach for inventory control of Unit Load Devices (ULD) in international air transportation

Stephan Buetikofer, Christoph Hofer

Unit Load Devices (ULDs) are standard equipment for loading baggage and cargo in airplanes. The maintenance of one's own ULD stock is a non-negligible cost factor for airlines. In recent years, therefore, many airlines have outsourced the management of their ULD's to independent ULD-providers. As part of an applied research project, we develop for an ULD provider simulation based decision support: - To determine the daily safety stock levels in order to guarantee a service level for a fixed planning horizon, and - To control safety stock levels at the stations.

We will discuss the approach to determine the daily safety stock level and show results from several test airports. This approach is implemented at the moment by our industrial partner. The modelling of the decision support for the ULD control is still in progress. We will present intermediate results there.

■ TC-16

Thursday, 14:00-15:30 - HS 46

OR and Public Health

Stream: Policy Modelling and Public Sector OR
Chair: *Doris Behrens*

1 - Two approaches to cooperative covering location problem and its application to ambulance deployment

Hozumi Morohosi, Takehiro Furuta

This study proposes two approximation methods for defining coverage probability used in a cooperative covering problem, which was proposed by Berman et al. as an extension to classical covering problems. Classical covering models consider a demand point is covered if a given coverage condition, usually based on the distance between demand point and facility, is satisfied by at least one facility, but uncovered otherwise. Under the constraint given by such "all or nothing' condition on covering, they look for the location maximizing covered demand.

In some problems, such a covering condition in classical setting might be too restrictive and not suit a real situation. For example, thinking of emergency medical service, it would be reasonable that responding to an emergency call can be made by not a single fixed ambulance, but several ambulances possibly.

Cooperative covering model takes into account of the probability by such a group covering. A key ingredient of the model is the estimation of coverage probability by multiple facilities, which is a difficult task suffering from a complicated interaction between demand and facility. We propose two methods for calculating it approximately. One goes to straightforward calculation of covered probability, while another makes indirectly use of uncovered probability. Since they use a different approximation scheme, they give slightly different probability, therefore different solution. We report and discuss about two solutions which obtained from the computation using simulation and actual data.

2 - Modelling policies for healthcare workforce management using system dynamics: alleviating the Canadian rural care gap
Jennifer Morgan, Anna Graber

The concentration of healthcare professionals in urban areas mainly is a concern in many countries, including Canada. During many years, it has driven large number of government led initiatives to address the rural care gap. This research seeks to examine the efficacy of such policies on the workforce in the long term. A small system dynamics model is employed to simulate the distribution of general physicians at a jurisdictional level. The model represents the transition of general practitioners to provide insight into the dynamics of care provision over time. The movement, and competition, between rural and urban areas is modelled to explore in detail the proposed measures to alleviate the care gap. This small system dynamics model is developed for Canada's reality, but its simple nature lends itself to easy application to other countries that experience a similar problem.

3 - Using Systems Thinking to Model Health and Social Care
Doris Behrens, Jennifer Morgan

The aim of this research is to develop a robust hospital and social care policy evaluation tool for health care managers in Wales to explore system impact. The tool results from the comparison between two models (A and B) developed from two different sources: the received literature and expert judgement. It is motivated by concerns, when considering the relationship between hospital and social care, the current view of the system boundary is too narrow and that there is a need to broaden this to capture the dynamic responsiveness of the system.

A structured literature analysis identified the core system entities and the existence of relationships between them to create the first model (model A). Interactive model-building workshops with experts created the second model (model B). These two models will be compared to highlight commonality and contradiction. This paper describes work to date.

■ TC-17

Thursday, 14:00-15:30 - HS 47

Optimization and Games (c)

Stream: Game Theory
Chair: *Jasper de Jong*

1 - Bi-Allocation Games — Cooperative Games with Multiple Utilities
Igor Kozeletskyi, Alf Kimms, Ana Meca

In this presentation a new class of non-transferable utility games is introduced. This class of games describes multi-objective cooperative situations where every player follows two objectives: his individual objective and a common objective for all players. The individual objective is defined as a non-transferable utility and the common objective is considered as a transferable utility. For bi-allocation games we present a solution concept, defined as an extension of the Shapley NTU value and state that this value always exists. For this solution concept a computation algorithm based on iterative search and multi-objective optimization was developed. We evaluate the performance of this algorithm using a multi-objective extension of linear production games.

2 - The Sequential Price of Anarchy for Atomic Congestion Games
Jasper de Jong, Marc Uetz

The price of anarchy measures the additional costs that are caused by the lack of central coordination. More formally, in games with selfish players, it relates the quality of any Nash equilibrium to the quality of a global optimum. Instead of assuming that all players choose their strategies simultaneously, we consider games where players choose their strategies sequentially. The sequential price of anarchy (SPoA) then relates the quality of any subgame perfect equilibrium of such a game to the quality of a global optimum. The idea was introduced by Paes Leme, Syrgkanis, and Tardos. The effect of sequential decision making on the quality of equilibria, however, depends on the specific game under consideration - it can be both positive or negative. We analyze the sequential price of anarchy for atomic congestion games with linear cost functions. We derive several lower and upper bounds, thereby showing that in special cases, sequential decisions mitigate the worst case outcomes for the classical price of anarchy found by Christodoulou and Koutsoupias. Our main point is the counterintuitive result that the sequential price of anarchy is unbounded, even in the special case of symmetric network congestion games. Next to the bounds on the sequential price of anarchy, an interesting aspect of our work is a new proof technique using ILPs for games with a finite number of players.

■ TC-18

Thursday, 14:00-15:30 - HS 48

(c) Investment and Expansion Planning

Stream: Energy and Environment
Chair: *Valentin Bertsch*

1 - Multistage Expansion Planning of Distribution Networks Including DG and EV Charging Stations
Pilar Meneses, Javier Contreras

This paper deals with the joint expansion planning of a distribution system considering all the investments in the network, distributed generation (DG) and electric vehicle (EV) charging stations. Network expansion comprises several alternatives for the new transformers, feeders, DG and charging stations. The optimal expansion plan selects the best alternative, location and stage for each asset. The model is a multistage stochastic programing minimizing the net present value of the overall costs, which contains investment, maintenance, production, losses and unserved energy costs. The motivation of this proposal is to incentive distributor planners in the current situation driven by the increased penetration of DG and EV in order to invest efficiently. This model explicitly uses uncertainty from demand and renewable energy sources. A k-means clustering technique is proposed to address this uncertainty maintaining the correlation between load, wind and photovoltaic generation. EVs have become quite significant due to the increased social awareness of environmental issues and the desire to rely on fossil fuels. For this reason, optimal siting and sizing of charging stations are taken into account in the optimal planning. Moreover, the model can allocate charging capacity among candidate charging station sites optimally and expand an existing one. Another feature is that, with the new penetration of DG, radiality constraints related to fictitious demands are incorporated into the model. Also, the cost of energy losses is linearized by a piecewise linear approximation so the formulation is a mixed integer lineal programming (MILP) in order to guarantee optimality. Numerical results on an IEEE 24-bus system show the effective performance of the proposed model.

2 - Risk-adapted capacity determination of flexibility investments for distributed energy resource systems
Katrin Schulz

Distributed energy resource (DER) systems are composed of different small to medium sized energy generators that are sited near consumers. Considering a DER system with power and district heat, micro CHP plants play a central role. The volatile supply from renewable energies requires a flexible operation of CHP plants which can be further increased by flexibility investments such as heat storages. For investment planning, the economically optimal capacity of the flexibility investment over its entire lifetime has to be determined. Due to increasing uncertainties regarding the development of the DER system, the investment's lifetime is divided into two sections: The planning horizon is determined as the time period for which uncertainty can be modeled with scenarios. In contrast, the remaining lifetime is characterized by fundamental uncertainty. To consider the investment's benefit for the amortization of the investment expenditures in both time periods, the amortization time is not limited to the planning horizon but is adapted according to the decision maker's risk attitude. Here, the two-stage stochastic programming model optimizes the operation of the DER system and the capacity of the flexibility investment for the planning horizon simultaneously. Applying a minimax regret and an expected value approach, risk averse and risk neutral decision makers are explicitly taken into account. The calculated investment capacities are evaluated by considering the possible future operation and adaptability of the CHP plant with heat storage. An exemplary case study illustrates the advantage of the approach taken here.

3 - A multi-objective approach for time segment selection in power generation and transmission expansion planning models
Viktor Slednev, Valentin Bertsch, Wolf Fichtner

The complexity of large scale long-term energy system models often necessitates a simplified representation of time and the choice of a suitable temporal resolution. Nowadays, mainly simple heuristic approaches are utilised for the selection of time slices. In case of traditional energy systems, with a low share of generation from renewable energy sources (RES) and negligible grid restrictions, such simplified approaches may be justified. An adequate decision support related to power systems planning with a high RES share, however, requires preserving the complex intra-period and intra-regional links within and between the volatile electricity supply and demand profiles. Especially in case of an optimal operation and expansion planning of electricity generation and transmission, often conflicting requirements for the selection of the relevant time segment have to be considered. To resolve the target conflict between model complexity and accuracy we propose a model-based approach for the time segment selection based on the solution of a two-step multi-objective integer optimisation problem with a subsequent sensitivity analysis using multi-attribute value theory (MAVT). Our target is to provide a time segment selection which accounts for both, typical and extreme demand and RES profiles on a nodal and global level. Our approach therefore minimises the hourly deviations between the modelled and observed profiles subject to the requirement of including extreme situations at a certain confidence level. The model is applied in an analysis based on a regional model of the hourly RES generation and demand in Germany. We are able to show that even an amount of less than 300 time segments may be sufficient for the modelling of a whole year, if chosen carefully.

■ TC-19

Thursday, 14:00-15:30 - HS 50

Energy Finance

Stream: Energy and Environment
Chair: *Raimund Kovacevic*

1 - A structural model for coupled electricity markets
Rudiger Kiesel

European Electricity Markets changed rapidly in recent years. Due to market coupling the markets became more interconnected and at the same time due to the rising share of renewable energy more decentralised. We will introduce a multi-market structural model for coupled electricity markets and discuss ist main properties.

2 - Bilevel oligopolistic electricity market models: The case of Switzerland and surrounding countries
Martin Densing

Despite efforts for a common wholesale market of electricity in Central Western Europe, domestic policies and the interests of individual countries influence the capacity expansion of electricity generation, and power production utilities will likely stay domestically centered. As an example of the past, the large deployment of photovoltaic generation in Germany was an unilateral decision of Germany, as well as the nuclear strategy of France. We present an oligopolistic capacity-expansion and market-clearing model for Switzerland and the surrounding countries. The model uses a closed-loop formulation, and features transmission constraints between the players and decision-making under uncertainty. We represent numerical results. In particular, we are interested whether reported findings in the literature on closed-loop models translate to this real-world setup, and we test proposed solution algorithms for the bilevel equilibrium problem.

3 - Valuation and Pricing of Electricity Delivery Contracts - the Producer's View
Raimund Kovacevic

Summary. This paper analyzes the valuation and pricing of physical electricity delivery contracts from the viewpoint of a producer with fixed production possibilities and storage capacity. Using stochastic optimization problems in discrete time with general state space, the duals of production problems are used to derive no-arbitrage conditions for fuel and electricity prices as well as superhedging values and prices of OTC electricity delivery contracts. In particular we take the perspective of an electricity producer, serving contractual deliveries but avoiding unacceptable losses at the end of the planning horizon. The resulting no-arbitrage conditions, stochastic discount factors and superhedging prices account for typical frictions like limitation of storage and production capacity and for the fact that it is possible to produce electricity from fuel, but not to produce fuel from electricity. Similarities, but also substantial differences to purely financial results can be demonstrated in this way. Finally, using acceptability measures we analyze capital requirements and acceptability prices for delivery contracts, where the producer accepts some risk.

■ TC-20

Thursday, 14:00-15:30 - ÜR Germanistik 1

Optimal Valuations (c)

Stream: Stochastic Optimization
Chair: *Rüdiger Schultz*

1 - Valuating complex options with kernel-based approximate policy iteration
Tobias Jung

This talk deals with the modeling and valuation of assets and associated derivative products which arise in the trading of natural gas. Our focus is on scaling up existing stochastic dynamic programming techniques developed for standard multiple exercise options with single time-integral constraints, such as standard gas swing and storage contracts, to allow the treatment of non-standard and complex options, such as long term supply contracts, which resemble swing options with multiple overlapping time-integral constraints, complex price formulas, multiple delivery points, and multiple markets. Modeled as a Markov decision process, these complex options, unlike standard options, come with both a high-dimensional exogenous and endogenous state and vector-valued decisions and hence suffer from all three curses of dimensionality together. The common industry approach to valuate standard options is the so-called least squares Monte-Carlo method, a form of approximate value iteration, which uses simulated price paths as sample locations both to evaluate the Bellman operator in and to approximate the expectation; and uses least squares regression to represent the value function iterates in terms of a monomial (or other) basis. The approach we present here on the other hand is built around approximate policy iteration and solves a projected form of the Bellman equation in a regularized kernel ridge regression setting. Our approach also uses simulated price paths; to cope with the high computational complexity of kernel ridge regression (growing cubically in the number of paths), we employ a partial Gram-Schmidt like orthogonalization scheme in the kernel space, reducing computational complexity to something that asymptotically only depends linearly on the number of paths.

2 - Value of a Firm with Suspension and Exit Options
Carlos Oliveira, Manuel Guerra, Cláudia Nunes

We consider the problem of the optimal strategy for a company that adapts to random fluctuations in demand by suspending/restarting its activity, having also the possibility of irreversible cessation. Activity and temporary suspension incur specific running costs, while change in status have specific spot costs. We discuss the structure of the optimal strategy and present some examples.

3 - Optimal Value of a Firm Investing in Exogenous Technology
Pedro Pólvora, Cláudia Nunes, Manuel Guerra

In this work we study the optimal value for a Firm whose value is function of an exogenous technology level. At any point in time the Firm can invest in a new technology, incurring in an immediate cost and in return it will become able to use that technology yielding profit through a given profit flow function. The technology is modelled by a discrete stochastic process with a time-dependent arrival rate. We study the optimal stopping time that will correspond to the point in time when the firm will invest. We use a dynamic programming approach, finding the Hamilton-Jacobi-Bellman equation whose solution gives us the optimal value of the firm. We particularise for two cases, one with a constant arrival rate and the other with a time-dependent and non-monotonic arrival.

■ TC-21

Thursday, 14:00-15:30 - ÜR Germanistik 2

Multistage Stochastic Optimization (i)

Stream: Stochastic Optimization
Chair: *Alois Pichler*

1 - Existence of Nash equilibrium for Chance Constrained Games

Abdel Lisser

We consider an n-player strategic game with finite action set and random payoffs for each player. The payoff vector of each player follows a multivariate elliptically symmetric distribution. We assume that each player uses satisficing payoff criterion defined by a chance-constraint, i.e., players face a chance-constrained game. In this talk, we show that there always exists a mixed strategy Nash equilibrium for this game.

2 - Monotonic Bounds and approximation in multistage stochastic programs

Francesca Maggioni, Georg Pflug

Consider multistage stochastic programs, which are defined on scenario trees as the basic data structure. The computational complexity of the solution depends on the size of the tree, which itself increases typically exponentially fast with the number of decision stages. For this reason approximations which replace the problem by a simpler are of importance. In this talk we study several methods to obtain lower and upper bounds for multistage stochastic programs both in linear and non-linear cases. Chains of inequalities among the new quantities are provided and proved in relation to the optimal objective value, WS and EEV. Numerical results on a multistage inventory problem and on a real case transportation problem are provided. Complexity considerations for the computation of the proposed lower bounds as function of tree depth and branching factor are also discussed.

3 - Scenario Trees based on sample paths observed

Alois Pichler

Scenario trees are the basic data model for stochastic optimization problems. Unfortunately, they cannot be observed. What can be observed eEmpirically, are sample paths. We demonstrate how to construct scenario trees out of observed sample paths by employing classical means from nonparametric statistics, as density estimation.

■ TC-22

Thursday, 14:00-15:30 - ÜR Germanistik 3

Simulation and Managerial Accounting (i)

Stream: Accounting and Revenue Management
Chair: *Stephan Leitner*

1 - A dynamic model for cash flow at risk

Luca Gentili, Dario Girardi, Martino Grasselli, Bruno Giacomello

We consider a version of the dynamic budgeting model introduced by Girardi et al (2013) where parameters are constant. Assuming that the dynamics of the balance sheet can be represented through a system of difference equations, we first investigate the implications of the constant parameters assumption on the liquidity process, which in our framework has a precise meaning and can be expressed in closed form. What is more, using the notion of average in the sense of Chisini and exploiting the properties of the double entry, we find the set of constant parameters that matches the results of the general model at each financial statement. Thanks to the previous results we can deeply investigate the fundamental relationship between cash flows and firm risk capacity, i.e. the ability of the firm to deal with challenging business conditions. A numerical exercise based on a real case allows us to analyse how the company's financial resources would develop in a wide range of future scenarios: this is extremely useful in order to evaluate how the firm would be able to support its growth and face its business stress. This approach leads to the introduction of a natural risk measure on the firm liquidity dynamics that takes into account the cash flows due to the company's investing and financing activities.

2 - Transfer pricing — heterogeneous agents and learning effects

Arno Karrer

In this paper we analyze the impact of heterogeneous agents and learning effects on negotiated transfer prices and the consolidated profit resulting at firm level. An agent-based simulation is employed to show potential results implied by learning and interaction effects between negotiating profit centers. In particular, in the model intra-company profit centers can choose to trade with each other or with independent parties on an external market, which is technologically as well as demand independent. Since the profit centers have incomplete and heterogeneous information about this external market, they are involved in a bargaining process with diverse outside options. To achieve a maximized comprehensive income it may be favourable on profit center level or even on firm level to choose outside options. In the long run the intracompany option should be favourable on all levels, as it excludes the profit orientated external market. We investigate our agents' behaviour under different parameter settings regarding the incentive system set by the company-wide management. Potential results show how learning and interaction effects may affect the decision making process with respect to the firm's overall objective.

3 - Interaction Effects of Different Data Quality Categories in Managerial Decision Making

Peter Letmathe, Benjamin von Eicken

More and more decisions are based on an increasing amount of data. However, data is mostly assumed to be accurate and consequences of poor data quality are often not considered. We categorize different categories of data quality (completeness, timeliness, correctness, semantic accuracy) and analyse interaction effects of poor data quality related to these categories.

We define a cost minimizing production model enriched with different kinds of low quality data. This model is used to compute different problem instances. For each category of data quality, we simulate erroneous input data for different error levels. By solving these problem instances, we can analyze the consequences of poor data quality. The resulting costs allow to compare non-error runs with runs based on faulty data. It will be shown that the cost consequences depend on the error levels and on interaction effects of the different categories of data quality defects. As a result, we derive problem-specific strategies to mitigate negative effects of poor data quality.

■ TC-23

Thursday, 14:00-15:30 - ÜR Germanistik 4

Vehicle Routing and Hypergraph Separation (c)

Stream: Integer Programming
Chair: *Michael Bastubbe*

1 - On the formulation of subtour elimination constraints

Bolor Jargalsaikhan, Kees Jan Roodbergen

In this talk, we discuss various integer programming formulations of traveling salesman problem (TSP)/vehicle routing problem (VRP). In particular, we revisit the subtour elimination constraints of TSP and VRP. One of the classical formulations given by Dantzig, Fulkerson and Johnson (DFJ) provides a relatively strong linear programming (LP) relaxation, but consists of exponentially many constraints. Another formulation due to Miller, Tucker, Zemlin (MTZ) is known to have a weaker LP relaxation than DFJ's but has an advantage of being easily reformulated as VRP constraints such as capacity, time window etc. We give a novel formulation which aims to incorporate both MTZ and DFJ constraints. Furthermore, we compare and analyze our model with other approaches.

2 - The vehicle routing problem with multiple deliverymen: exact and hybrid approaches
Pedro Munari, Aldair Álvarez, Reinaldo Morabito

Vehicle routing problems have been widely studied by the Operations Research community. The contributions in the literature follows many different directions. Some of them focus on proposing new variants of the problem, which incorporate practical requirements such as time windows imposed by customers, pickup and delivery requests and crew assignment, to cite only a few. Other contributions focus on proposing solution methods such as heuristics, metaheuristics, exact methods and hybrid combinations of them. In this talk, we address the vehicle routing problem with time windows and multiple deliverymen (VRPTWMD), a variant that has been recently proposed in the literature. It includes the decision of how many deliverymen should be assigned to each route, in addition to the typical routing and scheduling decisions. To the moment, only a few heuristic methods have been proposed to solve the VRPTWMD, as the currently available formulations challenges the state-of-the-art optimization solvers. Even instances with a small number of customers cannot be solved to optimality. Hence, we propose a set partitioning formulation and develop a branch-price-and-cut method to solve the VRPTWMD. This branch-price-and-cut method is based on central primal-dual solutions that are obtained by an interior point method. Also, a strong branching strategy is incorporated in the method in order reduce the number of nodes exploited. Finally, fast meta-heuristics are combined with the branch-price-and-cut method with the purpose of finding good incumbent solutions. The computational results indicate that the proposed methodology is able to quickly obtain relatively good solutions for instances available in the literature. Also, some previously unsolved instances are solved to optimality.

3 - A Branch-and-Price Algorithm for the Capacitated Hypergraph Vertex Separator Problem
Michael Bastubbe, Martin Bergner, Alberto Ceselli, Marco Lübbecke

In this talk we consider the following optimization problem: Given a hypergraph, a capacity and a maximum number of components, the task is to find a minimum cardinality subset of vertices whose removal yields a hypergraph with a feasible number of (not necessarily connected) components with cardinality not exceeding the capacity such that no hyperedge spans vertices of different components. We present an integer programming formulation solved by a Branch-and-Price algorithm. The pricing problem, interesting on its own, has a decomposable structure that can be exploited. Furthermore, we introduce a branching scheme working on (aggregated) sums of variables that does not change the structure of the pricing problem. Moreover, we introduce a (randomized) primal heuristic that uses fractional solutions to provide good integer solutions even in the root node. Additionally, we use exchange vectors that may improve the convergence of the dual values. In our computational experiments we will investigate the impact of the above techniques and compare the performance with the existing exact algorithms. Preliminary results suggest that our approach performs well for a higher (>4) number of components.

■ TC-24

Thursday, 14:00-15:30 - ÜR Germanistik 5

Revenue Management Applications (i)

Stream: Accounting and Revenue Management
Chair: *Jochen Gönsch*

1 - Demand-oriented integrated scheduling for point-to-point carriers
Jochen Gönsch, Oliver Faust, Robert Klein

Optimizing an airline schedule usually comprises multiple planning stages. These are the choice of flights to offer (schedule design), the assignment of fleets to flight legs (fleet assignment), and the construction of rotations under consideration of maintenance constraints (aircraft maintenance routing). Moreover, the airline must assign crews to all flights (crew scheduling). Traditionally, these scheduling stages are either solved sequentially or an existing schedule is modified in order to cope with the arising complexity issue. More recently, some authors have developed models that integrate adjacent stages. In this paper, we consider the case of a small to medium-sized point-to-point airline with a homogeneous fleet. Hence, fleet assignment is omitted, which offers the possibility to solve schedule design and aircraft maintenance routing simultaneously. Our approach explicitly accounts for passengers' return flight demand and for marginal revenues declining with increasing seat capacity, hence, anticipating the effects of capacity control in revenue management systems. In order to solve the arising integrated mixed-integer problem, a branch-and-price approach and a column generation-based heuristic have been developed. An extensive numerical study, using data from a major European airline, shows that the presented approaches yield high quality solutions to real-world problem instances within reasonable time.

2 - A Revenue Management Approach for the Process Industry
Johannes Fichtinger, Andreas Mild, Michael Schuh

We study a revenue management model for a wholesaler of diesel who offers the product under spot and term contracts. Selling prices for spot and term are based on fluctuating daily average industry prices plus a mark-up resulting in around 50% higher spot than term prices. For any customer, signing a yearly framework agreement is required in order to buy under a term contract. This agreement defines monthly quantities to be fulfilled by both the buyer and the seller. Customers place orders for diesel and pick it within a specified time window. If the company has sufficient diesel available for selling, customers can also buy and pick the product on the spot market on the same day without any long term contractual agreement. Currently any term quantity sold is reserved until it is picked by the customer. However, company statistics show that around 50% of orders are picked after the replenishment lead time. Therefore, sales to spot market customers could be increased by overbooking on-hand inventory instead of reserving it for term customers.

In this paper we propose a revenue management model for a combined make-to-order and make-to-stock environment in the process industry. We allow overbooking of on-hand inventory within the replenishment lead time. We model and solve the problem using stochastic dynamic programming. The decisions include booking limits for term and spot customers and the reorder point for replenishment by the wholesaler. We analytically analyse the optimal policy and provide sensitivity results with respect to the parameters of the term contract and product prices. Finally, we compare the current company practice with the policy proposed in this paper and show the benefits of using revenue management models in the process industry.

■ TC-25

Thursday, 14:00-15:30 - ÜR Alte Geschichte

Fuzzy Expert Systems

Stream: Neural Networks and Fuzzy Systems
Chair: *Thomas Spengler*

1 - Interpretability vs. Predictability with Neural Networks
Ralph Grothmann, Hans Georg Zimmermann

Interpretability is an intellectual concept while predictability is a measurable feature in forecasting. In this talk we will see, that these properties are mutual excluding. Because of their rich modeling power this is especially true for neural networks. Even for high dimensional nonlinear feedforward neural networks it is not easy to formulate such an interpretation. For large recurrent neural networks a traditional analysis is seldom possible - but these models are superior in predictability. Reasons are, that these models do not have explicit input-output connections and time is bidirectional.

2 - Deeper insights in the use of a fuzzificated Datar-Mathews approach
André Mangelsdorf, Thomas Spengler

So far path-dependency in interfirm-networks havent been covered in literature in depth and we lack in the evaluation with real-options in this field of interest both in an uncertain and in a fuzzy environment at all. By regarding networks as sequence of single investments, in financial theory well known option-pricing theory can be applied. For the determination of change in value of a network-entrance by emerging path-dependency, a fuzzy approach will be used for evaluation and thus giving decision support. For this purpose, a fuzzy version of the Datar-Mathews approach will be applied, once with and once without considering path-dependent processes. The use of the Datar-Mathews

approach first relaxes the stringent assumption of evaluation via an escapist riskless market interest rate. Instead, according to network-specific characteristics and in relation to the exercise date of the examined options, differentiated interest rates are used. In addition, the effects of arising path-dependency on the payoff distribution and, hence, the corresponding realoption-value of a project can be examined by applying a fuzzy methodology. Thereto, we can use fuzzy numbers and intervals as well as linguistic variables. Fuzzy numbers and intervals are employed for arithmetical calculation, linguistic variables for rule-based determination of the option-value. Whereat, the corresponding fuzzy factors can refer to all determinants of the option-value (e.g. cashflows, scenario probabilities). In terms of work in progress we continue our last year's topic "Evaluating path-dependency in networks — a fuzzy realoption approach' and extend it by in depth considerations concerning a fuzzificated Datar-Mathews approach.

3 - Fuzzy Logik basierte Asset Allocation
Reiner North

In diesem Beitrag wird vorgestellt, wie auf der Basis von Konzepten der Fuzzy-Logik ein individualisierbares Modell für die Asset Allokation aufgebaut werden kann, welches alle relevanten quantitativen als auch qualitativen Merkmale eines Anlagevorhabens realitätsgerecht abbilden und aggregieren kann und dadurch zu vergleichbar guten Empfehlungen wie ein Experte gelangt. Dabei laufen alle Rechenschritte transparent und reproduzierbar ab. Um die Vorgehensweise zu verdeutlichen und die Vorzüge des Verfahrens zu illustrieren, wird ein Pilot-Modell entwickelt. Dieses unterstützt einen Berater bei der Asset Allokation, indem es nach einer Analyse der Merkmale des Anlageziels und der Markterwartungen die Vorteilhaftigkeit mehrerer Anlagestrategien bewertet und die Schritte zu deren Bewertung nachvollziehbar aufzeigt. Anhand von Fallbeispielen werden die Ergebnisse des Pilot-Modells mit bekannt guten Empfehlungen verglichen.

■ TC-26

Thursday, 14:00-15:30 - SR Geschichte 1

Nonsmooth Convex Optimization

Stream: Continuous Optimization
Chair: *Radu Ioan Bot*

1 - An accelerated optimal first-order method for large-scale convex optimization
Masoud Ahookhosh

We propose an accelerated optimal first-order method for solving convex optimization problems in simple domains. More specifically, we accelerate the Nesterov-type optimal methods by improving the linear model using a two-point gradient technique and combining the schemes with a nonmonotone line search. Using the two-point gradient step we improve the quality of the local linear model approximating the objective function, which uses an approximation of Hessian of the objective. Hence the schemes do not need to know about a Lipschitz constant of gradients. It is known that the sequence of function values of Nesterov-type optimal methods are nonmonotone. Therefore, we combine a backtracking line search with a nonmonotone term to improve the computational efficiency of the schemes. In addition, we adapt the scheme for solving nonsmooth convex optimization problems with composite objectives. The complexity analysis of the new schemes is investigated. Numerical results regarding experiments with some applications in signal and image processing and inverse problems involving big data are reported, which show the efficiency of the proposed schemes.

2 - Regularizing inverse problems by alternating direction method of multipliers
Qinian Jin

Alternating direction method of multipliers (ADMM) is a very powerful method for solving structural optimization problems due to its decomposability and superior convergence properties. When applying to inverse problems, ADMM is usually used to solve a regularized minimization problem in which the regularization parameter is assumed to be chosen properly and its convergence depends on the solvability of the dual problem. It is natural to ask if it is possible to apply ADMM to solve inverse problems directly. In this talk we will confirm this by proposing an iterative method using ADMM strategy. We will discuss its regularization property and give numerical simulations. This is a joint work with Y. Jiao, X. Lu and W. Wang.

3 - A forward-backward-forward differential equation and its asymptotic properties
Sebastian Banert, Radu Ioan Bot

In this talk, we approach the problem of finding the zeros of the sum of a maximally monotone operator and a monotone and Lipschitz continuous one in a real Hilbert space via an implicit forward-backward-forward dynamical system with nonconstant stepsizes of the resolvents. Besides discussing existence and uniqueness of strong global solutions for the differential equation under consideration, we show weak convergence of the generated trajectories and, under strong monotonicity assumptions, strong convergence with exponential rate. In the particular setting of minimizing the sum of a proper, convex and lower semicontinuous function with a smooth convex one, we present a rate for the convergence of the objective function along the ergodic trajectory to its minimum value.

■ TC-27

Thursday, 14:00-15:30 - SR Geschichte 2

Financial Modelling

Stream: Financial Modelling
Chair: *Alex Weissensteiner*

1 - Where would the EUR/CHF exchange rate be without the SNB's minimum exchange rate policy?
Michael Hanke, Rolf Poulsen, Alex Weissensteiner

Since its announcement made on Sept. 6, 2011, the Swiss National Bank (SNB) has been pursuing the goal of a minimum EUR/CHF exchange rate of 1.20, promising to intervene on currency markets to prevent the exchange rate from falling below this level. We use a compound option pricing approach to estimate the latent exchange rate that would prevail in the absence of the SNB's interventions, together with the market's confidence in the SNB's commitment to this policy.

2 - Currency Pegs: Cases For Baskets
Rolf Poulsen

We analyze criteria for and effects of a country pegging (tying) its currency to a basket of foreign currencies. We demonstrate that there can be considerable benefits associated with this. As empirical cases we look at Turkey, Denmark, Greece, and Bangladesh. We and that (a) Turkey has a large idiosyncratic exchange rate risk and thus has a lot to gain from pegging its currency, the lira, to a basket representing its trade composition, (b) an insurance cost minimization-case can be made for the Danish krone keeping its peg to the euro, (c) if Greece leaves the euro but pegs its new currency to a trade weighted basket, the exchange rate risk costs are small, and (d) the cost-optimal basket peg for Bangladesh is a well-diversified portfolio (that isn't exactly the trade weights) and switching to that gives an economically (as well as statistically) significant gain.

3 - Analyzing the Swiss National Bank's euro exchange rate policy: A latent likelihood approach
Alex Weissensteiner, Rolf Poulsen, Michael Hanke

On Sept. 6, 2011 the Swiss National Bank (SNB) announced the goal of a minimum EUR/CHF exchange rate of 1.20, promising to intervene on currency markets to prevent the exchange rate from falling below this level. We model the observed exchange rate as the sum of the latent exchange rate (that would have prevailed in the absence of the SNB's minimum exchange rate policy) and an American put option written by the SNB. The aim of this paper is to estimate the latent exchange rate using a maximum likelihood approach. The estimated latent exchange rate (at varying time-points) is between half a percent and ten percent below the observed exchange rate over the period September 2011 to July 2014; lowest in June 2012 and about three percent over the last part of the sample. From mid-2013 the credibility of the guarantee as perceived by the market has increased significantly.

■ TC-28

Thursday, 14:00-15:30 - HS 34

(c) Population Control and Epidemiology

Stream: Control Theory
Chair: *Markus Thäter*

1 - Bicriteria Optimal Control
David Willems, Karunia Putra Wijaya, Thomas Götz, Stefan Ruzika

A wide variety of different numerical methods have been developed to compute the trajectories of optimal control problems on the one hand and to approximate Pareto sets of multiobjective optimization problems on the other hand. However, so far only few approaches exist for the combination of both problems leading to multiobjective optimal control problems. In this contribution we study a biobjective optimal control problem that arises in the modeling of Dengue Fever: the population of Aedes mosquitos or other vectors is minimized as one criterion and, as a second, the cost of the vaccination or other types of control are taken into account. The computation of the Pareto set allows best-possible information in an a posteriori decision making process. However, computing all Pareto solutions is not possible for this continuous problem. Therefore, we adopt the sandwich algorithm of Burkard, Hamacher and Rote to approximate the Pareto set. This approximation comes as an upper and lower approximation serves as a substitute of the Pareto set in the decision making process. The lower and upper approximations are utilized to control the approximation's quality based which confident decisions can be made.

2 - Optimal control for a harmful population model
Narcisa Apreutesei

We study an optimal control problem associated to a reaction-diffusion system that models the dynamics of a harmful invasive population. Assume that the population is composed by normal females and males and some genetically modified organisms. The last ones are considered as supermales and feminized supermales. Mating with them produces only males and supermales. In time the number of normal females decreases, thus finally leading to the extinction of the population. This is also a way to eradicate a harmful invasive species.

Regarding the problem as an optimal control one, our goal is to minimize the female population, maximize the male population, and to minimize the rate of introduction of the feminized supermales. The existence of an optimal solution is established and some optimality conditions are found.

3 - Optimal vaccination strategies for an improved SEIR model
Markus Thäter, Kurt Chudej, Hans Josef Pesch

An improved SEIR model for an infectious disease is presented which includes logistic growth for the the total population. The aim is to develop optimal vaccination strategies against the spread of a generic desease in a city on the one hand and in rural areas on the other hand. These vaccination strategies arise from the study of optimal control problems with various kinds of constraints including mixed control-state and state constraints and, for the two different area-types, a quadratic respectively a linear cost functional is used. After presenting the new models and implementing the optimal control problems by means of a first-discretize-then-optimize method, numerical results for the scenarios are discussed and compared to an analytical optimal control law based on Pontrygin's minimum principle respectively by a switching-function-method that allows to verify these results as approximations of candidate optimal solutions.

■ TC-29

Thursday, 14:00-15:30 - SR IÖGF

Group Decision Making and Preference Modeling (c)

Stream: Multiple Criteria Decision Making
Chair: *Tomasz Wachowicz*

1 - A new preference voting method using complementary slackness condition and discriminant analysis for solving multiple criteria decision making problem
Mohammad Izadikhah

DEA, is a mathematical technique based on linear programming and was first proposed by (Charnes, Cooper and Rhodes, 1978) in evaluating the efficiency of an educational center in USA. The aggregation of preference rankings has wide applications in social choice, committee election and voting systems. By using DEA, (Cook and Kress 1990) have proposed a method for estimating preference scores without imposing any fixed weights from the outset. This paper presented a new method for ranking aggregation preferences in voting system using complementary slackness condition and discriminant analysis, in which each candidate seeks to maximize its own eciency. Then, the proposed method applied for selecting the best option from a multiple criteria decision making problem. For this purpose, first the weighting decision matrix is constructed by using the Shannon's Entropy concept. Then the obtained matrix is considered as the voting matrix. After that, by the proposed method for ranking voting system we can select the best alternative. The main contributions of the proposed approach can be expressed as: Our integrated method combined the discriminate factor of Cook and Kress, complementary slackness conditions and discriminate analysis; The proposed approach not only ranks all candidates, but also yields a single efficient candidate; For the first time, we applied the proposed voting method for selecting the best alternative of a MCDM problem. In the proposed methodology, we use the results of criteria (based on the weighted decision matrix) as the votes of some decision makers. Then by using the proposed method for ranking voting system, we can select the best option and rank the alternatives with respect to the votes of decision makers.

2 - Plant Location Selection With Utility Range Based Interactive Group Decision Making Method
Halil Şen, Hüseyin Fidan

Enterprises want to select the plant location which maximize business capacity or capacity utilization level and minimize production and marketing costs as much as possible. Because of the high investment costs, too much attention is given on decision-making ability. Determination of precise plant location takes place the work done though some stages. First of all, a specific problem of the existing general theory or formula should be known about it cannot be applied directly. Contribution of such general formula is only guiding the operation. Each plant location problem carries its own characteristics. These methods of solving the problem affects even necessitate the discovery of new methods. Analysts suggested that mathematical analysis for the economic feasibility of alternative locations as a first step. Then, evaluation can be made less tangible the other factors. The complexity of the structure, such as location selection decisions hosting uncertainty and the lack of information and can be occurred in together. Minimizing the costs associated with plant location selection, or by maximizing the benefits obtained from the placement result, you need to find the optimal point. The optimal location selection is one of the most important decisions for newly established enterprise. This is about the solution of complex problems aimed at maximizing the benefits of the enterprise; we use utility range based interactive group decision making process. By using this multi criteria group decision making process, enterprise managers as decision makers, in accordance with the criteria defined by, choose location which brings the expected maximum utility.

3 - MARS — a hybrid approach for holistic analysis of MCDM problem
Tomasz Wachowicz, Ewa Roszkowska, Dorota Górecka

In this paper a new multi-criteria decision making method — MARS — is presented. MARS (Measuring Attractiveness near Reference Solution) derives from the disaggregation (regression) paradigm and employs some notions of ZAPROS and MACBETH methods to elicit the decision maker preferences over some reference solutions by means of pairwise comparisons. It allows DMs to define their preferences verbally and provides a straightforward but effective algorithm for analyzing the trade-offs between the alternatives using selected reference alternatives only (the ZAPROS-like approach). The elements of the MACBETH algorithm applied in our method allow to determine the cardinal scores for the alternatives and to identify potential inconsistencies in defining the preferences by the negotiators in the classic ZAPROS approach. The MACBETH-like approach also extends the classic ZAPROS functionality by allowing the DMs not only to declare if one alternative is preferable over another, but also to specify verbally by how much it is better or worse. We have provided the theoretical foundations of MARS and discussed the advantages and disadvantages of the approach proposed as well as illustrated its application to the analysis of a multiple criteria decision making problem.

(This research was supported by the grant from Polish National Science Centre (DEC-2011/03/B/HS4/03857)).

■ TC-31

Thursday, 14:00-15:30 - Marietta Blau Saal

Humanitarian Logistics

Stream: Health and Disaster Aid
Chair: *Lena Silbermayr*
Chair: *Gerald Reiner*

1 - Funds Allocation in NPOs: The Role of Administrative Cost Ratios

Tina Wakolbinger, Christian Burkart, Fuminori Toyasaki, Michael Fearon

Performance measurement of Non-Profit Organizations (NPOs) is of increasing importance for aid agencies, policy-makers and donors. A widely used benchmark for measuring the efficiency of NPOs is the overhead cost ratio, consisting of the total money spent on administration and fundraising relative to the budget. Such easily accessible measurements face severe criticism, since variations of overhead costs are not necessarily linked to changes in the impact achieved. Additionally, the focus on such information can lead to increasing pressure to reduce expenses, with potential negative effects on administrative capacities. Unlike fundraising expenses, administrative costs do not help advertise the actions of an NPO, but account for the majority of overhead costs. Reducing administrative expenses is a logical consequence from a financial viewpoint and might, hence, not only negatively affect NPOs but also beneficiaries. This phenomenon is known as "Nonprofit Starvation Cycle". This work provides an analytical framework for analyzing NPO decision making concerning administrative costs. It builds upon a compound utility function, containing budget and impact maximizing properties. The paper provides answers to important recent research questions on the optimal level of administrative spending, the influencing factors and the effects of available information on NPOs and beneficiaries. Our results indicate that the donation amount received by an NPO has no influence on the optimal level of the administrative cost ratio, while the information level has a negative impact on this ratio as well as on the utility created in an environment of high marginal efficiency gains of administrative expenditures.

2 - Decision-support for coordinated last-mile distribution during disasters

Christian Fikar, Manfred Gronalt, Patrick Hirsch

Disaster relief requires coordinated actions of various organizations to reduce damages and to support victims effectively. However, due to the involvement of multiple actors in the relief process, coordination is difficult to achieve. We present a simulation and optimization based decision-support system (DSS), which assists decision-makers in analyzing and planning actions concerning the last-mile distribution of goods. In particular, we focus on facilitating relief organizations to bridge the transportation of goods through affected areas in order to deal with panic buying and stockpiling. The DSS selects and optimizes a limited number of transfer points where transshipments are performed and routes the available vehicles dedicated for this service. Three different modes of transportation are included; air, road and off-road transportation. Roads which are open and closed to traffic during a disaster are modeled to support rerouting and reconsiderations of location decisions across the planning horizon, which further enables an extensive analysis of various disaster scenarios. To test the DSS, we investigate the region of Krems in Austria, an area which was recently struck by major river floods in the Danube River Basin. Results highlight the potential of coordination and of optimization to improve decision-making and last-mile distribution during disasters.

3 - Disaster Relief Inventory Management: Horizontal Cooperation between Humanitarian Organizations

Lena Silbermayr, Fuminori Toyasaki, Emel Arikan, Ioanna Falagara Sigala

Cooperation and coordination among humanitarian organizations (HOs) has attracted increasing attention to enhance effectiveness and efficiency of relief supply chains. Our research focuses on horizontal cooperation in inventory management that is currently implemented in the United Nations Humanitarian Response Depot (UNHRD) network. The UNHRD provides its members with free of charge standard services and special services on the basis of full cost recovery. Our research follows a two-step research approach, which combines collection of empirical data and quantitative modeling to examine and overcome the coordination challenges of the network. Through a series of the interviews with members of the network, our research has identified several managerial issues for sustainable cooperative inventory management that the UNHRD network pursues. Using a newsvendor model in the context of non-cooperative game theory, our research has explored member HOs' incentive of joining the network, a coordination mechanism that achieves system optimality, and impacts of members' decisions about stock rationing. Our results indicate that delicate coordination is necessary for sustainable operations of the network.

Thursday, 16:00-16:45

■ TD-04

Thursday, 16:00-16:45 - HS 21

Semi-plenary: Prekopa

Stream: Semi plenaries I
Chair: *Georg Pflug*

1 - Moment Problems: Important Source of Ideas in Optimization
Andras Prekopa

The problem of linear programing, can be thought of as a special bounding moment problem, where the unknown measure is not normalized and its support is a known discrete set. Despite of this fundamental relationship, it was essentially stochastic programming, where moment problems played important role in their initial development. The desire to come up with spectacular applications and the fascinating interaction with the emerging computer science in the 1950s made the researchers less interested in distant mathematical theories,but in stochastic programming bounding moment problems. The situation changed when computerized optimization reached an advanced level, new optimization problems came up, like semi-infinite programming and some classical probability bounds have been discovered as optimum values of special bounding moment problems, essentially linear programming problems. We briefly summarize the history of optimization in the 19th century, which includes the early history of the moment problems (Fourier, Lagrange, Ostrogradsky, Farkas, Chebyshev, Markov, Stieltjes and others). Then we present the main results from the history of bounding moment problems in the 20th century, together with the numerical solutions of the relevant problems. Special attention will be paid to the univariate and multivariate discrete moment problems, initiated by the author, the main theoretical and computational results in this respect and their numerous practical applications. We show that bounding discrete moment problems provide us with better insight into the continuous counterparts and help to solve their problems efficiently. We also show that there is a big potential in this novel methodology to handle big data, discover hidden and missing information in big data sets.

■ TD-13

Thursday, 16:00-16:45 - HS 41

Semi-plenary: Huisman

Stream: Semi plenaries II
Chair: *Alf Kimms*

1 - Developments and Experiments in Crew Rescheduling at Netherlands Railways
Dennis Huisman

The railway industry is a rich area for interesting Operations Research problems. Netherlands Railways (NS) operates about 4,700 trains per day, and employs about 2,700 drivers and 3,000 guards. These crew members operate from 28 bases spread over the country and a duty typically starts and ends in a crew base and takes about 8 hours. In this talk, we will consider the railway crew rescheduling problem, both in case of disruptions and in case of a modified timetable. In railway disruption management, crew rescheduling is one of the most challenging tasks. During a disruption, dozens of crew duties have to be rescheduled satisfying numerous labor rules and within at most a few minutes of computation time. Crew rescheduling is also important when another timetable is operated on one or more days. This is, for instance, the case when heavy winter weather is predicted or during construction works on some part of the railway network. In this case, the constraints are usually tighter than during a disruption, but a computation time of a few hours is possible. During the last 10 years, a lot of research has been done on inventing algorithms. Moreover, much time has been spent on implementing these algorithms in IT systems and incorporating the use of these algorithms in the daily operations of NS. In this talk, we review the models and algorithms that have been developed to solve the railway crew rescheduling problem. Moreover, we discuss some of the challenges we faced during the implementation of these algorithms in practice. Finally, we will discuss some of the remaining challenges in this area.

■ TD-17

Thursday, 16:00-16:45 - HS 47

GOR science award

Stream: Semi plenaries IV
Chair: *Leena Suhl*

■ TD-19

Thursday, 16:00-16:45 - HS 50

Semi-plenary: Brandeau

Stream: Semi plenaries III
Chair: *Marion Rauner*

1 - Optimization and Disease Control: Investment in Public Health Interventions
Margaret L. Brandeau

Appropriate investment in public health programs can save lives and improve health for millions of people. However, determining which disease control programs to invest in and which population subgroups to target is complicated by the dynamics of disease and effects of control programs, as well as limited public health budgets. This talk describes several models for optimal control of diseases including optimal dynamic allocation of a budget for epidemic control; optimal dynamic mix of screening and contact tracing for a communicable disease; cost-effective level of disease control over time; and optimal information collection in ongoing disease control programs. We conclude with discussion of promising areas for further research.

Friday, 8:30-10:00

■ FA-02

Friday, 8:30-10:00 - HS 7

Proactive/Reactive Project Scheduling (i)

Stream: Scheduling and Project Management
Chair: *Erik Demeulemeester*

1 - An exact algorithm for the chance-constrained resource-constrained project scheduling problem
Patricio Lamas, Erik Demeulemeester

The chance-constrained resource-constrained project scheduling problem (CC RCPSP) is the problem of finding a non-preemptive schedule of minimum makespan, such that it is feasible with respect to the precedence and the resource constrains, for a given probability (or confidence). One of the main attributes of this problem is that it generates a robust proactive schedule which is independent of any reactive policy that is planned to be applied. The drawback is its computational tractability: the well-known (theoretical and practical) computational intractability of the (deterministic) RCPSP is amplified in this case. Here, we present an exact branch and bound (b&b) algorithm for solving the CC RCPSP. It is based on upper and lower bounds obtained by solving the RCPSP. Thus, our method does not depend on integer programming (IP) formulations of the RCPSP that in general perform worse than ad-hoc methods, i.e. methods that are not based on linear programming relaxations. We provide results of computational experiments that clearly show the practical benefits of our algorithm over an alternative IP approach: our algorithm was able to solve more instances to optimality for small confidence levels; its optimality gaps were smaller for all confidence levels; it requires less memory; and it does not have precision problems. Finally, we believe that this research is a contribution to the general chance-constrained programming (CCP) literature since all theoretical and algorithmic results can be extended to general CCP problems.

2 - An iterative method to solve stochastic resource-constrained project scheduling problem
Morteza Davari, Stefan Creemers, Erik Demeulemeester

The resource-constrained project scheduling problem (RCPSP) has been widely studied the last few decades. In real world projects, however, not all information is known in advance and uncertainty is an inevitable part of these projects. The stochastic resource-constrained project scheduling problem (SRCPSP) is one of the most studied problems dealing with uncertainty. In this article, Markov chain and Lagrangian relaxation are combined to shape a new and efficient procedure that can solve instances of stochastic resource-constrained project scheduling problem. In this article, we combine the concepts "Markovian decision system' and "Lagrangian relaxation'. We exploit a Lagrangian-relaxation based lower bound and a heuristic upper bound to determine an optimality gap for the minimum expected-makespan of resource-constrained projects with stochastic activity durations. Within many iterations, we opt to reduce the gap to zero. A computational experiment shows that our approach works best when solving medium to large-sized problem instances. Moreover, Our method optimally solves many instances in PSPLIB for which the optimal solutions were not known.

3 - A sequential bidding model for public-private partnerships: theory versus laboratory
Dennis De Clerck, Erik Demeulemeester

Public-private partnerships are globally gaining importance in the construction industry. The risk transfer from the contracting government towards the private entity has important repercussions on the tender. Contractors need to carefully prepare the bid proposal and need to make an assessment of the project risk. These investigations require expensive investment efforts that might go down the drain in case the bidder loses the tender. A second choice relates to the requested mark-up that reflects the profit aims and the risk premium. The competitive context might be an inhibitor for players to participate in the tender process. The research project develops a sequential procurement model to imitate the PPP market. We consider a set of equivalent project opportunities in a finite project pipeline and a set of players entering the tender. The bidders are heterogeneous in their experience, so that more experienced contractors have a cost advantage and, additionally, they are able to more accurately estimate the project cost. Besides, winning a project results in an experience increase. The Markov perfect equilibrium of this sequential game is heuristically approximated by a best response mechanism. We experimentally show that the introduction of a pipeline results in fiercer competition from a mark-up perspective. Nevertheless, including future project opportunities does not necessarily lead to a greater investment willingness. Consequently, triggering the increased bid proposal efforts might require the introduction of bid cost reimbursements. The study also reports on the findings from a laboratory experiment with 180 business students in this PPP setup. The students consistently underbid compared to the theoretical equilibrium, which inflates the risk of default.

■ FA-03

Friday, 8:30-10:00 - HS 16

Operations Management and Scheduling (c)

Stream: Scheduling and Project Management
Chair: *Seyda Topaloglu*

1 - A multi-objective Cat Swarm optimization for workflow scheduling based on energy-aware in cloud computing environment
Khaled Sellami, Pierre F Tiako

Cloud computing is viewed as a new model of service provisioning in distributed systems that encourages researchers to take advantage on executing scientific applications such as workflows. One of the most important issues in clouds is the optimal workflow scheduling, i.e., scheduling resources when each resource may be used by more than one task, and may be needed at different points in time by satisfying the QoS requirements of the users. Existing heuristic and evolutionary algorithms mainly focus on optimizing the time and cost without paying much attention to energy consumption. In this paper, we propose a new approach based on the use of the BI heuristic to optimize the scheduling performance by (a) formulating a model for task-resource mapping to minimize the overall energy consumption using the dynamic voltage scaling (DVS) technique; and (b) designing a heuristic that uses the multi-objective cat swarm optimization to solve task resource mapping based on the proposed model. Our approach is validated by simulating a complex workflow application.

2 - An Adaptive Local Search Algorithm for Tour Scheduling Problem with Start-time Bands
Mustafa Avci, Seyda Topaloglu

Nowadays, due to global competition, timeliness and flexibility in satisfying changing customer demands have gained importance for organizations. In this context, many companies encounter the problem of determining personnel schedules. These schedules must not only fulfill the variable customer demands over a week, but also must allow enough time for rest between subsequent working days for employees. In this study, a labour tour scheduling problem involving start-time bands is adressed. In order to solve the problem, an adaptive local search algorithm which involves a non-monotone threshold accepting function is developed. The algorithm is applied to a set of randomly generated problem instances. The performance of the approach is evaluated according to the results.

3 - The quay crane scheduling problem: an exact solution approach
Ali Diabat

As the maritime industry grows rapidly in size, more attention is being paid to to a wide range of aspects of problems faced at ports with respect to the efficient allocation of resources. A very important seaside planning problem that has received large attention in literature lately is the quay crane scheduling problem (QCSP). The problem involves the creation of a work schedule for the available quay cranes at the port to empty the containers from a vessel or given set of vessels. These optimization problems can be very complex and since they involve a large number of variables and constraints, the use of a commercial solver is impractical. In this paper, we reformulate a problem currently available in the literature to a Dantzig-Wolfe formulation that can be solved by column generation. We then develop a branch-and-price algorithm, which is an exact method, to effectively solve mixed integer programs with very large instances. The algorithm is first tested on a formulation currently available in literature with a small instance and will then be tested on large instances.

■ FA-04

Friday, 8:30-10:00 - HS 21

Routing and network design problems (c)

Stream: Discrete Optimization
Chair: *Frank Meisel*

1 - The Active-Passive Vehicle-Routing Problem, Part I: Solution by Column Generation

Christian Tilk, Nicola Bianchessi, Michael Drexl, Stefan Irnich, Frank Meisel

Recently, Meisel and Kopfer (2014, OR Spectrum) introduced the Active-Passive Vehicle-Routing Problem (APVRP). Therein, two classes of vehicles are required to fulfill pickup-and-delivery requests: Non-autonomous passive vehicles such as containers transport the cargo from its pickup to its delivery location. Autonomous active vehicles such as trucks can carry passive vehicles from one to another location. In the basic version we consider, each passive vehicle can load only one request at a time and each active vehicle can transport only one passive vehicle at a time. Each request must be executed by the same passive vehicle, while different active vehicles can be involved. For example, one active vehicle may deliver a passive to a pickup location and another active may later transport the passive from the request's pickup to its delivery point. Therefore, synchronization of active and passive vehicles is required. In this first part, we present a new column-generation formulation for the APVRP. We define an extended network in such a way that only the routing of active vehicles is necessary, while the routing of passive vehicles is implicitly specified by the routes of the active vehicles. The corresponding subproblem is a Shortest Path Problem with Time Windows and Linear Node Costs (SPPRC-LNC), which is solved using a labeling algorithm with ng-tour relaxation. To the best of our knowledge, we present the first approach that applies ng-tour relaxation to solve a linear node cost problem.

2 - The Active-Passive Vehicle-Routing Problem, Part II: Comparison of Column-Generation Subproblem Solvers

Stefan Irnich, Nicola Bianchessi, Michael Drexl, Frank Meisel, Christian Tilk

Recently, Meisel and Kopfer (2014, OR Spectrum) introduced the Active-Passive Vehicle-Routing Problem (APVRP). Therein two classes of vehicles are required to fulfill pickup-and-delivery requests: Non-autonomous passive vehicles such as containers transport the cargo from its pickup to its delivery location. Autonomous active vehicles such as trucks can carry passive vehicles from one to another location. In the basic version we consider, each passive vehicle can load only one request at a time and each active vehicle can transport only one passive vehicle at a time. Each request must be executed by the same passive vehicle, while different active vehicles can be involved. For example, one active vehicle may deliver a passive to a pickup location and another active may later transport the passive from the request's pickup to its delivery point. Therefore, synchronization of active and passive vehicles is required. A column-generation algorithm is used to solve the APVRP, where the subproblem is a Shortest Path Problem with Time Windows and linear node costs (SPPRC-LNC). In this second part, we compare different solution methods for the SPPRC-LNC. The baseline approach is a labeling algorithm capable of solving the ng-tour relaxation bidirectionally. We compare is with a direct MIP-formulation, in which routing and resource variables are coupled without big-M technique. Moreover, the SPPRC-LNC can be solved with a column-generation algorithm giving rise to an overall nested column-generation algorithm.

3 - Branch-and-Price-and-Cut for a Service Network Design and Hub Location Problem

Ann-Kathrin Rothenbächer, Michael Drexl, Stefan Irnich

In the context of combined road-rail freight transport, we study the integrated tactical planning of hub locations and the design of a frequency service network with fixed costs for each service to offer. We consider a number of real-world constraints such as multiple transshipments of requests at hubs, transport time limits for requests, request splitting and outsourcing possibilities. To our knowledge, the combination of problem features we deal with has not been described before. We present a path-based model and solve it with a branch-and-price-and-cut algorithm. Computational experiments show that large realistic instances from a major German rail freight company can be solved close to optimality within one hour on a standard desktop computer, allowing our algorithm to be used for practical planning purposes.

■ FA-05

Friday, 8:30-10:00 - HS 23

Assembly lines

Stream: Production and Operations Management
Chair: *Heinrich Kuhn*

1 - An Alternative MILP Model for Makespan Minimization on Assembly Lines

Sel Ozcan, Deniz Türsel Eliiyi, Levent Kandiller

The Simple Assembly Line Balancing Problem-2 (SABLP-2) is defined as partitioning tasks among stations so as to minimize the cycle time given the number of stations. SALBP-2 myopically considers minimizing the makespan of a single order quantity, and reduces to the identical parallel machine scheduling problem with makespan minimization (PmCmax) when the precedence relations are ignored. In this respect, PmCmax provides a lower bound for SALBP-2. For minimizing makespan, product units revisiting the same station over consecutive tours might be preferable in a tandem cyclic layout setting. In this study, the tradeoff between the makespan values obtained from SALBP-2 and PmCmax as a function of total order quantity is analyzed. In our study, an alternative model formulation is developed and the whole spectrum between the solutions of SALBP-2 and PmCmax is searched with respect to makespan. The results of our computational experiment indicate that SALBP-2 outperforms for small quantities, whereas PmCmax yields the best results for larger quantities.

2 - Managing an Assemble-To-Order System with After Sales Market for Components

Mohsen Elhafsi, Essia Hamouda

In this paper, we consider an assemble-to-order manufacturing system producing a single end product, assembled from n components, and serving an after sales market for individual components. Components are produced in a make-to-stock fashion, one unit at a time, on independent production facilities. Production times are exponentially distributed with finite production rates. The components are stocked ahead of demand and therefore incur a holding cost rate per unit. Demand for the end product as well as for the individual components occurs continuously over time according to independent Poisson streams. In order to characterize the optimal production and inventory rationing policies, we formulate such a problem using a Markov decision process framework. In particular, we show that the optimal component production policy is a state-dependent base-stock policy. We also show that the optimal component inventory rationing policy is a rationing policy with state-dependent rationing levels. Recognizing that such a policy is generally not only difficult to obtain numerically but also is difficult to implement in practice, we propose three heuristic policies that are easier to implement in practice. We show that two of these heuristics are highly efficient compared to the optimal policy. In particular, we show that one of the two heuristics strikes a balance between high efficiency and computational effort and thus can be used as an effective substitute of the optimal policy.

3 - Level Scheduling in Automotive Assembly Lines and its Real Effect on In-House Logistics Costs

Heinrich Kuhn, Dominik Wörner

Part-oriented level scheduling approaches in sequencing of assembly lines are generally used as substitutional model for the underlying economic objective as a leveled distribution of the materials requirements does not necessarily contribute directly to this objective.

We therefore analyze the level scheduling strategy in respect of its real effect on the consumption of critical in-house resources at a major German automotive company.

We conduct a case study selecting relevant part families whose consumption is currently unequal distributed. An extensive simulation study then quantifies the effects on resource consumptions in respect of various factors. As a result we can define prerequisites under which part-oriented level scheduling is a suitable approach minimizing resource consumptions of material supply.

■ FA-06

Friday, 8:30-10:00 - HS 24

Remanufacturing I

Stream: Production and Operations Management
Chair: *Maria Mavri*

1 - How many times to remanufacture in a Schrady-type reverse logistics model

Imre Dobos, Grigory Pishchulov

An integrated production—recycling system is investigated. A constant demand can be satisfied by production and recycling. The used items might be bought back and then recycled. The not recycled products are disposed of. The model examines and minimizes the EOQ related cost. This basic model was examined by one of the authors in a previous paper (Dobos-Richter (2004): A production/recycling model with quality consideration). This paper extends the model for the case of quality consideration: it is asked for the quality of the bought back products. In the former model we have assumed that all returned items are serviceable, but not asked, how many times to remanufacture. We assume that it is known, how many times a returned product was remanufactured before. Now we want to determine the optimal number of remanufacturing, after that the inventory related costs are increasing and these products will be disposed of. Which one of the control systems are more cost advantageous in this case? The research was supported by OTKA K 105888.

2 - An Optimal Piecewise-linear Programming Model for Stochastic Disassembly Line Balancing Problem

F. Tevhide Altekin

Disassembly lines are widely used in recovering both economic and ecological value residing in collected end-of-life products while meeting environmental legislation. Due to the nature of the disassembly operations, disassembly tasks exhibit higher levels of uncertainty. So as to incorporate the variability in task times while designing disassembly lines, this paper deals with the stochastic disassembly line balancing problem with the objective of minimizing number of stations. A chance-constrained piecewise-linear mixed integer programming model is proposed to model and solve the problem. Task times are assumed to be normally distributed random variables with known means and standard deviations. The precedence relations among the disassembly tasks and subassemblies are represented using an AND/OR graph. The computational results that incorporate different levels of task time variability demonstrate that the proposed method is capable of solving practical-sized problems.

3 - Additive Manufacturing versus Classic Manufacturing?

Maria Mavri

Additive manufacturing refers to technological procedure that turns computer digital files into solid objects. These solid objects are first designed using computer software, or a 3D scanner scans them, and they are fabricated using a 3D printer. Since 1970, two philosophies have monopolized the production scheme: materials requirement planning (MRP) and just in time (JIT) systems. As is already known, the heart of MRP is the production plan. This plan specifies the number of each item, the exact timing of the production lot sizes, and the final schedule of the competition. The JIT philosophy is used for production lots of small sizes, and it is used in order to ensure that products are produced only as they are needed.Although it is risky, in this study we assume that production using 3D printers is more familiar with the JIT philosophy than the MRP philosophy. The goal of this paper is to examine the transformation of traditional approaches via additive manufacturing to production operation problems. Managing incoming orders, managing demand paths, managing service levels, pricing these new products are some issues which are related to manufacture procedure and have to be defined.

■ FA-07

Friday, 8:30-10:00 - HS 26

Cooperation and Coordination in Transport (c)

Stream: Logistics and Transportation
Chair: *Mario Ziebuhr*
Chair: *Kristian Schopka*

1 - Collaborative Transportation Planning with Forwarding Limitations

Mario Ziebuhr, Herbert Kopfer

In collaborative transportation planning, independent forwarders align their transportation plans by exchanging requests within a horizontal coalition. The goal of the coalition members is to increase their profitability and flexibility in competitive markets with high demand fluctuations. In recent publications, it is assumed that each request can be fulfilled by any coalition member. However, in practice some requests are not allowed to be forwarded due to contractual agreements. These requests are known as compulsory requests. The contribution of this presentation is to identify the increase of costs by considering compulsory requests of a pickup and delivery collaborative transportation planning problem. To analyze the impact of compulsory requests an existing column generation based heuristic is modified. The applied column generation is suitable for linear programming with many variables, where the original problem is divided in a subproblem by generating vehicle routes and a master problem by selecting vehicle routes. To handle compulsory requests two solution strategies are proposed. One strategy proposes the consideration of compulsory requests during the subproblem (strict generation procedure) while the other one considers compulsory requests during the master problem (strict compulsion procedure).

2 - Cost allocations for horizontal carrier coalitions by approximating the Shapley value

Kristian Schopka, Herbert Kopfer

Due to a small portfolio of resources for disposal and a weak market position, it is difficult for small and mid-sized carriers (SMCs) to create cost-effective plans for modern transportation and shipping. To improve competitiveness, SMCs ally in horizontal carrier coalitions for request exchange. Fairness of the cost allocation among the involved participants is a crucial aspect for the stability of long-term coalitions. The principle of the Shapley value gives a scheme for a cost allocation in the core, if the core is not empty. Since both calculating the Shapley value and generating transportation plans are NP-hard, strategies that approximate the Shapley value are beneficial. This presentation proposes a new sampling procedure for approximating the Shapley value. This procedure, called 3-Sampling, enables a fair cost allocation for horizontal coalitions with numerous SMCs (agents) in less computing time. The basic idea of the 3-Sampling is to calculate the marginal contribution of each agent in every sub-coalition with three agents. Based on the sum of the calculated marginal contributions the coalition costs are allocated among the agents. In an extensive computational study on the collaborative traveling salesman problem with time windows, the presented 3-Sampling procedure is compared with a state of the art sampling procedure. This study identifies the deviation among the two sampling procedures and their deviation to the actual Shapley value, while also the required computing time is analyzed.

3 - Loading dock coordination by core-selecting package auctions

Paul Karänke, Martin Bichler, Stefan Minner

Congestions at loading docks can cause severe delays in logistics processes and cause increasing bottlenecks for truck routes. For warehouses, uncoordinated arrivals of trucks make appropriate staffing difficult and congestions can interfere with other processes at the facility. To mitigate congestions at loading docks, we propose package auctions to allocate time slots to trucks.

The contribution of this research is the application of core-selecting package auctions to address the loading dock congestion problem. We propose a bidding language and a core-selecting package auction for this setting based on existing literature. Core-selecting payment rules can avoid drawbacks of the Vickrey—Clarke—Groves (VCG) mechanism with Clarke pivot rule, e.g., low perceived fairness of prices.

We evaluate our proposal by means of simulation and assess (i) the potential for waiting time reduction compared to uncoordinated arrivals as well as sharing of historical waiting times, (ii) the empirical complexity of the computational problem for scenarios of varying complexity, and (iii) the relation of VCG and bidder-Pareto-optimal core payments. Our findings provide evidence that loading dock auctions can alleviate congestion substantially and that the core-pricing rule is well-suited to address the price fairness and low seller revenue problems in this setting.

■ FA-09

Friday, 8:30-10:00 - HS 30

Voting, Tournament and Inspection Games (c)

Stream: Game Theory
Chair: *Jochen Schlapp*

1 - Representation Compatible Power Indices

Serguei Kaniovski, Sascha Kurz

We use average representations of a weighted voting game to obtain four new indices of voting power for this type of voting games. The average representations are computed from weight and representation polytopes defined by the set of winning and losing coalitions of the game.

These average representations come remarkably close to fulfilling the standard criteria for a coherent measure of voting power. They are symmetric, positive, efficient and strongly monotonic. The dummy property, which assigns zero power to powerless players, can be imposed by restricting the polytopes. The resulting restricted average representations are coherent measures of power.

Further properties can be imposed by tailoring the polytope. Restrictions based on the equivalence classes of voters defined by the Isbell desirability relation lead to another pair of power indices, which ascribe equal power to all members of an equivalence class. These indices are strictly monotonic in voting weight.

The defining property of the four new indices is representation compatibility, which ensures proportionality between power and weight. We believe that proportionality makes the new indices ideal measure of power for voting institutions, in which the votes are distributed to the voter based on their contribution to a fixed purse.

2 - The effects of trust variations on inspection procedures

Günter Fandel, Jan Trockel

In our paper we expand the considerations of Fandel/Trockel (2011) to an analysis of a dynamic trust behavior of the strategic players. The trust parameters that determine the level of the additional payoffs in the case of trust are now time-dependent with respect to the number of repeated rounds of the inspection game. The basis of modelling is a logistic function that describes the trust expansion among the strategic players. Unfortunately there exists the hazard that the inspectee will prey the inspector's trust if the inspector's trust level increases and exceeds a threshold. The inspector wants to prevent this situation. This is modelled by a stochastic term which expresses the percentual loss of trust of the inspector that may occur, so that a reasonable boundary of a threatened exploitation is not realized. However if this occurs, the calculated equilibrium in the next round of the repeated game will be the Nash solution without any trust. In the following rounds trust will maybe increase again and develop in a similar way as before. Based on a simulated structure of the chronology of the players' payoffs one can estimate the level of mistrust the inspector should never underbid, so that error-free payoff-series without trust variations occur that dominate the Nash solution in games without trust, but simultaneously decrease the value of hazard the inspector may be exploited by the inspectee.

3 - Feedback in Innovation Tournaments

Jochen Schlapp

Tournaments have become a popular tool for firms to source innovative ideas from a broad set of potential innovators. While tournaments are already widely used in practice, our understanding of how to manage such tournaments is rather limited. This paper investigates whether a host firm should give interim performance feedback to the tournament participants, and if so, what kind of feedback: public or private? To address this question, we build a two-stage game theoretic model, where participants can adjust their second-round efforts according to the received feedback on their first round performance. We demonstrate the crucial role of the host firm's ex ante commitment to a particular feedback strategy. We also characterize the participants' equilibrium behavior and show that public feedback is never optimal. The choice of private or no feedback depends on the uncertainty in the innovation problem. For low uncertainty, the host firm prefers to give no feedback, whereas a large uncertainty demands private feedback.

■ FA-10

Friday, 8:30-10:00 - HS 31

Multi-Compartment Vehicle Routing (c)

Stream: Logistics and Transportation
Chair: *Alexander Hübner*

1 - A Branch-and-Price Algorithm for The Multi-Compartment Vehicle Routing Problem

Samira Mirzaei

Despite the vast amount of literature about vehicle routing problems, only little attention has been paid to multi compartment vehicle routing problem that investigate transportation of different commodities on the same vehicle, but in different compartments. Due to complexity of this class of routing problem, heuristics and meta-heuristics approaches are proposed in the most of the related papers, but in many cases, there is no available proof that shows us the quality of these solution methods. In this project, we investigate the Multi-Compartment Vehicle Routing Problem that consists of customers with demand for different commodities and vehicles with several compartments and different capacities to co-transport these commodities. The problem is formulated as a Set Partitioning model, solved by a Branch-and-Price algorithm. The acceleration heuristics are adopted in each node in the branching tree to find good feasible routes quickly as well as for providing an initial set of columns for the Branch-and-Price algorithm.

2 - A multi-compartment vehicle routing problem for livestock feed distribution

Levent Kandiller, Bahar Turan, Deniz Türsel Eliiyi

In the well-known Vehicle Routing Problem (VRP), customer demands from one or more depots are to be distributed via a fleet of vehicles. Various objectives of the problem are considered in literature, including minimization of the total distance/time traversed by the fleet during distribution, the total cost of vehicle usage, or minimizing the maximum tour length/time. In this study, we consider a multi-compartment VRP with incompatible products for the daily solution of a livestock feed distribution network, where each livestock farm requests one type of feed from a single depot and the vehicles have several compartments. The objective is to minimize the total cost of distribution. Although VRP is a well-studied problem in literature, multi-compartment VRP is considered only by few authors, and our problem differs from the existing ones due to special operational constraints imposed by the situation on hand. We formulate a basic mathematical model for the problem and present possible extensions. We design a computational experiment for testing the effects of uncontrollable parameters over model performance on a commercial solver and report the results. The proposed model can easily be adapted to other distribution networks such as food and fuel/chemicals.

3 - Food distribution with multi-compartment trucks: An extended vehicle routing problem

Alexander Hübner, Manuel Ostermeier

Distribution of grocery is subject to temperature control. Grocers typically organize their flow of goods based on temperature requirements and distribute in temperature-specific trucks. Some retailers, however, started to pilot multi-compartment vehicles (MCV) with different temperature-specific compartments to integrate transportation flows. We identify in an empirical study the MCV relevant costs. Loading costs increase with additional handling processes at the warehouse. Transportation costs need to factor in the higher investment costs for MCVs and the changes in routing, whereas unloading costs reduce with a lower number of stops at stores.

Vehicle routing problems with multi-compartments (VRPMC) mainly find their application in fuel distribution with fixed compartment sizes. However, the capacities per temperature zone for food-MCVs can be adjusted. Derigs et al (2011) investigate different algorithms for the VRPMC. However, they only minimize distances. We develop therefore a VRPMC taking into account also loading, transportation and unloading costs. This allows investigating the efficiency of truck types. Our solution approach is based on a construction heuristics using a parallel savings algorithm, followed by a large neighborhood search. The latter follows the idea of a heuristic based on the Shaw removal and regret insertions that turned out to be most suitable for VRPMCs distance minimization problems.

We show that our model results in up to 10.3% lower logistics costs than a pure distance minimization. The magnitude mainly depends on average order size, distances between stores and loading and unloading process costs. We apply the model to real-life case study.

■ FA-11

Friday, 8:30-10:00 - HS 32

Facility location (c)

Stream: Logistics and Transportation
Chair: *Luca Maria Gambardella*

1 - Rectilinear distance to a facility in the presence of a square barrier

Masashi Miyagawa

This work examines the barrier distance to a facility in the presence of a square barrier. The barrier distance is defined as the length of the shortest path not intersecting the interior of barriers. Measuring the barrier distance is important in location problems with barriers. The distribution of the barrier distance is derived for two regular patterns of facilities: square and diamond lattices. Distance is measured as the rectilinear distance. The distribution demonstrates how the location and size of the barrier affect the barrier distance to the nearest facility, and thus is useful for facility location problems with barriers. A numerical example shows that the total barrier distance increases as the barrier gets closer to the facility, whereas the maximum barrier distance increases as the barrier becomes greater in size.

2 - ALGORITMIC VARIATIONS FOR WEIGHTED p-MEDIAN PROBLEM

Vladimir Medvid

We propose two different algorithms for a facility location problem, which is well-known as a a weighted p-median problem. This is a combinatorial optimization problem well-known to be NP-hard. The goal of the problem is to select locations of p facilities to serve n demand points so as to minimize the total travel between the facilities and the demand points. This is a combinatorial optimization problem known as an NP-hard problem. The first of the proposed algorithms is a classical deterministic exchanged algorithm and the second is a genetic algorithm. Genetic algorithms are heuristic search methods that are designed to solve some optimization problems by the use of mimicking the evolution process. New solutions are produced from old solutions in ways that are reminiscent of the interaction of genes. Genetic algorithms have been applied successfully to problems with very complex objective functions. Our genetic algorithm is presented in some modification ways to find the best solution as far as possible.The algorithm generates a good solution quickly. Computational tests were realized on five different tasks from 21 vertices to 100 vertices and from p-median from p=3 to p=6. The tests were performed 100 times on every task. There were created some modifications of these tasks for a proposed genetic algorithm.The best solution generated by this algorithm is within 0.6% of the optimum for 80% of the tasks. The other 20 % of the tasks is within 1.6 % of the optimum. Time of realization is within 5.9 sec.

■ FA-12

Friday, 8:30-10:00 - HS 33

Transport in the health care sector

Stream: Logistics and Transportation
Chair: *Patrick Hirsch*

1 - Scheduling of urban home health care services during daily business and in times of disasters

Klaus-Dieter Rest, Patrick Hirsch

Home Health Care (HHC) services allow old and frail people a self-determined living in their familiar environment, but still to receive professional help. They are already of vital importance for today's society and due to the current demographic and social developments a significant increase in demand is expected. What is more, people relying on medical supply or those with limited mobility usually need consistent care. Thus, HHC service providers will be faced with two challenges: an increased organizational effort due to the rising demand and the need for an anticipatory risk management. Even though optimization of HHC services is a quick evolving research area, previous research combining optimization and risk management limits itself to rural regions. The presented work specifically addresses the peculiarities of urban regions. Thus, nurses are able to choose between different transport modes (public transport, car, bike, and walking), and for public transport, time-dependent travel times and multimodality are assumed. In times of disasters, operators have to adapt quickly to changing conditions. Therefore, in order to achieve short computation times, Tabu Search based metaheuristics have been implemented. The algorithms have been tested with real-world data from the Austrian Red Cross in Vienna for two operational scenarios, supporting daily business and scheduling in times of disasters. Results show that significant reductions of travel and waiting times can be obtained, such that more time remains for serving the clients. Through sensitivity analysis the effects of certain disasters (e.g., blackout, pandemics, and heat waves) are visualized and the operational limits during such events are shown.

2 - Continuity between planning periods in the home health care problem

Daniela Lüers, Leena Suhl

Home health care is a growing sector in the public health system. In contrast to other health care institutions, clients receiving services stay at their own homes. Hence, the home care providers face a complex routing and scheduling task to plan the services. For application in practice skill requirements and legal labor regulations must be considered. Most publications in literature consider a static planning horizon, e.g. a week. However, as the solution to this problem may be inefficient or even infeasible for a subsequent planning period, a new optimization is inevitable at the end of each period. In home health care, apart from economic objectives, the satisfaction of client and nurse is a decisive factor in market competition. Variations between planning periods may lead to dissatisfaction because clients and nurses have to adapt to the new schedule with every period. Therefore, the consideration of continuity by avoiding extensive changes is essential. To approach this issue, we consider the home health care routing and scheduling problem in a rolling planning horizon. Our solution method determines the routes and shift assignments of the nurses while preserving the continuity between planning periods. We present our heuristic solution approach and an analysis of the numerical results. Since there are many possibilities to quantify continuity, we further compare different measures and show their influence on the solution quality.

3 - Sustainability criteria for home care staff mobility

Jana Voegl, Patrick Hirsch

Transport is a major driver of climate change and other negative effects. At the same time demographic change increases the need for home care (HC) services. HC staff visits clients in their homes to perform different services and thereby increases traffic. At the moment, several mobility concepts are used by HC staff. In addition, there are concepts proposed in literature which are not in practice yet. Different problem definitions have to be extended to optimize the scheduling of HC services. We give an overview of possible mobility concepts for HC staff and their underlying logistical problems. Moreover, we present sustainability criteria to optimize existing and develop new mobility concepts in HC in a real-world context. This was done in a first stage through desk research were existing criteria in related fields were evaluated. The second stage was the conduction of qualitative expert interviews with dispatchers of HC staff in three Austrian provinces, including urban as well as rural areas. In total 15 experts were interviewed. The outcomes of the content analysis of the interview transcripts build the foundation for the catalogue of sustainability criteria, containing over 150 criteria to consider when developing and optimizing mobility concepts in HC. These criteria were assigned to one or more dimensions of sustainability (economic, ecologic, social). The results indicate the importance of these sustainability criteria for existing and new mobility concepts of HC providers. The implementation of them in decision support systems leads to new challenges. Furthermore, it is necessary to develop new tailored solution procedures for upcoming mobility concepts in HC.

■ FA-13

Friday, 8:30-10:00 - HS 41

Inventory Control (c)

Stream: Supply Chain Management
Chair: *Marc Reimann*

1 - A Multi-Objective Differential Evolution Algorithm to Determine Inventory Replenishment Parameters in a Supply Chain

Mualla Gonca Yunusoglu, Hasan Selim

In this study, a three echelon supply chain system consisting of a customer, a manufacturer and a number of suppliers is dealt with. The manufacturer assembles the materials supplied by its suppliers to obtain the final product. The manufacturer receives customer orders weekly and updates its production plan accordingly. To maintain its material inventory, it employs a periodic order-up-to policy. As the customer orders cannot be backordered, products are delivered to customer by a premium freight in case of a delivery delay risk. Similarly, the manufacturer requests a premium freight from its supplier in case of a material stock-out risk. However, since the premium freights are generally delivered by airway, they incur very high costs to the manufacturer. Therefore, the manufacturer avoids from premium freights as far as possible. As one can infer, the manufacturer seeks for an effective inventory management minimizing both total cost and premium freights. In this context, a multi-objective differential evolution algorithm is proposed to optimize inventory replenishment parameters. The objective functions of the proposed algorithm are total cost, the ratio of total material premium freights to total material orders and the ratio of total final product premium freights to total customer orders. The results of the proposed algorithm are found to be superior in comparison with the current performance of the real system.

2 - Multi-Item Two-Echelon Spare Parts Inventory Control Problem with Batch Ordering in the Central Warehouse under Compound Poisson Demand

Z. Pelin Bayindir, Engin Topan

We consider a multi-item two-echelon spare part inventory system in which the central warehouse operates under an (nQ,R) policy and the local warehouses implement order-up-to S policy, each facing a compound Poisson demand. The objective is to find the policy parameters minimizing expected systemwide inventory holding and fixed ordering costs subject to an aggregate mean response time constraint at each warehouse. In this paper, we propose four alternative approximations for the steady state performance of the system; and extend a heuristic and a lower bound proposed under Poisson demand assumption to the compound Poisson setting. In a computational study, we show that the performances of the approximations, the heuristic, and the lower bound are quite satisfactory; and the relative cost saving of setting an aggregate service level rather than individually for each part is quite high.

3 - Simulated annealing for optimization of a two-stage inventory system with transshipments

Andreas Serin, Bernd Hillebrand

A two-level inventory system under a periodic review with lateral transshipments is considered. By this means, the supply chain is enabled to reduce inventories while maintaining fill rates. The supply chain is composed of the external manufacturer, the central warehouse and three identical retail outlets. The aim is to optimize the order-up-to levels under a fill rate constraint. Warehouse shipments as well as transshipment flows are determined dynamically, but the order-up-to levels and the allocation policies are fixed in advance. We combine a simulation with a barycentric interpolation at the Chebyshev points and degree reduction techniques to construct low-degree polynomial tensor product surfaces for the objective function and the constraint. The approximate optimization problem is solved by simulated annealing.

■ FA-14

Friday, 8:30-10:00 - HS 42

Applied Network Optimization (c)

Stream: Graphs and Networks

Chair: *Roberto Montemanni*

1 - Solving Evacuation Problems in Polynomial Space - Earliest Arrival Flows with Multiple Sources

Miriam Schlöter, Martin Skutella

In the last years, the number of evacuations for example in areas endangered by natural disasters has increased. Thus, a better evacuation planning before the emergency occurs is of great interest. The core of evacuation planning is captured by earliest arrival flows. Given a network N with capacities and transit times on the arcs, a subset of source nodes with supplies and a sink node, an earliest arrival flow is a dynamic flow in N such that the total amount of flow that has arrived at the sink is maximal for all points in time. It is a classical result that earliest arrival flows always exist in the single source case while the existence of earliest arrival flows in networks with multiple sources has been shown more recently in the early 2000s. In the single source case earliest arrival flows can be computed in PSpace using the successive shortest path algorithm. In networks with multiple sources it gets more complicated. In 2006 Nadine Baumann and Martin Skutella developed an algorithm to compute earliest arrival flows in networks with multiple sources which is polynomial in the input plus output size. Their algorithm consists of two parts: At first the earliest arrival pattern is computed and after that using the breakpoints of the pattern the actual earliest arrival flow is derived. While the first part of the algorithm only works on the original network, the second part requires expanding the network such that in the wost case it gets exponentially large. In the first part of the algorithm the times at which the sources run empty in an earliest arrival flow are computed. Mainly making use of these times, we present an algorithm to compute earliest arrival flows in networks with multiple sources which only requires polynomial extensions of the original network.

2 - Fast Prize-collecting Steiner tree heuristics for genomics application: a comparison

Roberto Montemanni, Murodzhon Akhmedov, Ivo Kwee

Cancer initiation and progression is caused by the accumulation of multiple aberrations in different genes. Recent developments in high-throughput technologies such as microarrays and next generation sequencers substantially increased the amount of genomics data available. Methods based on Prize-collecting Steiner Tree Problem (PCSTP) can be used on these data to analyze the function of genes. The PCSTP is broadly studied problem in combinatorial optimization literature. It has been used to model several real world problems related to utility networks. More recently, researchers have used the PCSTP to study biological networks. In particular, the PCSTP is applied to gene-gene interaction networks, where nodes correspond to genes and arcs represent the correlation between genes. The PCSTP potentially captures the portion of graphs where genetic aberrations and mutations are mostly present. Biological networks are typically very large in size. This can create a considerable challenge for the available PCSTP methods. Heuristic methods that efficiently scale up to large network instances have therefore been created. Namely, a heuristic method based on Minimum Spanning Tree and an algorithm based on heuristic clustering followed by an exact solution phase of the different clusters, are considered in this work. We provide a detailed performance comparison of these two methods by extensively testing them on different types of large biological networks. Statistics are reported for the methods, including running times and optimality gaps of solutions, when available.

3 - Network Design with Consolidation Facilities for an Air Cargo Company

Guvenc Sahin, Görkem Yençak, Birol Yuceoglu

Air cargo carriers consolidate the freight in order to avoid extra handling effort and cost of handling during transfers. However, transfer stations at the airport may either be limited with their consolidation capability or not have the facilities and the equipment required for consolidation. There is a clear trade-off between the consolidation costs and savings due to consolidation. It is not, therefore, easy to determine which cargo should be consolidated and where. It requires a system-wide consideration of all cargo routings throughout the network. We develop a network representation of the air cargo consolidation problem. First, we study a version of the problem to maximize the savings given the consolidation capacities at the transfer stations. We formulate the problem as a set-covering problem and solve it using a column generation algorithm. Then, we study a network design problem to determine the stations to be equipped with consolidation capability and their facilities. We solve this problem with a heuristic method which uses the column generation algorithm as a subprocedure. We test our solution methods using real data from an air cargo company with 290 transfer stations and 33000 origin-destination pairs.

■ FA-15

Friday, 8:30-10:00 - HS 45

General topics in decision support

Stream: Simulation and Decision Support
Chair: *Kei Takahashi*

1 - Exploring suitability of Combinatorial Auction mechanism for Government securities in India
Anup Sen, Rohit Bhirud, Amit Kumar Sahoo

The Government Securities market is the backbone of the fixed income securities markets of both the developed and developing economies. In India, Reserve Bank of India (RBI) bonds are available to the investors as instruments (items) of auctions. The auction process is similar to standard single item auction where one item at a time is auctioned in sequence or in parallel. However, this current bond auction process has its limitations. Under-subscription of securities is resulting in huge devolvement, which is affecting the revenues of Reserve Bank of India (RBI). This is caused either due to rejection of bids by RBI (due to high yield demand) or due to lack of bids at the cut-off level. This empirical study attempts to suggest Combinatorial Auction (CA) mechanism for RBI bonds to increase the money raised and to make the bonds more attractive for the investors. In CA, multiple items are auctioned together and the bidders can submit bids on bundles of items. The seller determines the set of winning bids that maximizes the revenue. An integer programming formulation may be used to solve this Winner Determination problem. The purpose of CA is to remove the inefficiencies in the current auction process of RBI and bring benefits to both the bidders and the seller. A bidder in CA may bid for bundle of items if the value of the bundle is at least the sum of values of individual items. This auction method has the potential to improve the revenue of RBI. Spectrum auctions are popular applications of CA. We have attempted to find out scenarios in which the investors would like to go for a combination of bonds rather than individual bonds. We have performed simulation using past auction data to compare the revenues generated in both forms of auctions.

2 - How to achieve conversion: modelling individual behavior in multiple online advertising with psychological effects
Kai Sakou, Kei Takahashi

In this paper, we develop a model for determining attribution in multiple online advertising. There are many types of advertising in online marketing, for example display and direct e-mail. In practice, advertising managers tend to allocate much amount of the advertising budget to what is directly connected to consumers' conversion. However, consumers usually follow some psychological processeswith interaction with advertising, for example AIDMA. There are types of advertising that cannot increase many conversions but arouse consumers' awareness widely. Then we should consider consumers' psychological processes and characteristics of advertising when we allocate advertising budget in online marketing. Therefore, we can observe interesting psychological effects, forgetting and pooling effects in the individual dynamics of psychological process of advertising. Forgetting effect is the phenomenon that consumers forget a target issue because of the lack of contacting to the advertisement. Pooling effect is remaining previous effects of advertising that consumers have already contacted with. We construct the model of psychological process of advertising in disaggregate level with the hidden Markov model (HMM). In this model, there are three latent classes that are dormancy, awareness, and consideration. A state of dormancy is a phase that consumers are not aware of a product. That of awareness is being aware of the product and consideration is being interested or desiring to get it. The forgetting and pooling effects have impact on the transition probability. We obtain a disaggregate data from a campaign of Laser-Assisted In-Situ Keratomileusis by using Google Analytics. We distinguish consumers individually based on cookies.

■ FA-16

Friday, 8:30-10:00 - HS 46

Policy Evaluation using Data Envelopment Analysis

Stream: Policy Modelling and Public Sector OR
Chair: *Mikulas Luptacik*

1 - Data Envelopment Analysis for Measuring of Economic Growth in Terms of Welfare Beyond GDP
Eduard Nezinský, Martin Labaj, Mikulas Luptacik

Recent discussions on the definition of growth in terms of welfare beyond GDP suggest that it is of urgent need to develop new approaches for measuring the economic performance of the firms and national economies. The new concepts should take into account simultaneously economic as well as social and environmental goals. We first discuss several approaches to productivity measures. Then we extend the Data Envelopment Analysis models for environment to measure the so called eco-efficiency and for social indicators to take into account the social performance. For an lustration, we perform the analysis of 30 European countries in the year 2010. In the last section we discuss the possibilities of inter-temporal analysis of proposed models and of their use in ex-ante evaluation of different policy scenarios.

2 - Determining drivers of eco-efficiency: decomposition method
Eduard Nezinský

There has been a lively discussion about measures of social welfare beyond GDP induced by Stiglitz Report (Stiglitz et al., 2009) which can be viewed as a summation of the earlier efforts to deal with those challenges. Environmental indicators constitute one important dimension to be taken into account in assessing the welfare along with the economic and social indicators. Employing non-parametrical approach, the Data Envelopment Analysis SBM model is extended for environment to measure the so called eco-efficiency. Resulting scores and benchmarks are used to decompose eco-productivity into factors attributable to changes in efficiency, technology, extensive factors of production, and emissions. Results suggest that in European countries in the span 2000 — 2010, an environment-saving rather than input-saving technology change has been taking place.

■ FA-17

Friday, 8:30-10:00 - HS 47

Lotsizing (c)

Stream: Supply Chain Management
Chair: *Stefan Helber*

1 - A quasi-fixed Cyclic Production Scheme for the Synchronized and Integrated Two-Stage Lot Sizing and Scheduling Problem with Stochastic Demand
Philipp Zeise, Dirk Briskorn

We present an approach to generate a production scheme for a filling and packing process at a Canadian brewery. In each stage multiple production units are available while each filling unit may feed more than one packing unit at the same time. Bottles (intermediates) that are filled in the first stage must be immediately packed into crates in the second stage, i.e., no inventory is available between both stages. However, crates that are palletized can be stored. Most intermediate and final products can be handled on more than one unit of the corresponding stage. The scheme consists of an allocation of products to units and a periodic production sequence, called a cycle, for each unit. Thus, four decisions have to be made: First, all products have to be allocated to a unit in each stage. Second, it is decided how often a product is processed per cycle. Third, the production sequence in the cycle has to be determined. Finally, for a given lot sizing strategy the time provided for each lot has to be specified. Our approach is able to consider sequence-dependent setup times, minimum lot sizes, maintenance of production units and uncertain demand for final products that is satisfied from stock or backlogged. We evaluate our approach by using two alternative lot sizing strategies conducting computational experiments based on practical data.

2 - Benders Decomposition Applied to Cooperative Lot-Sizing
Andreas Elias, Alf Kimms

A lot-sizing problem in the context of purchasing alliances is considered. We focus on a supply chain which consists of several retailers and multiple suppliers. The retailers are free to cooperate in order to benefit from quantity discounts. In case of a cooperation, transshipments are possible, that is, movement of a product from one retailer to another. A mixed integer programming problem is introduced to cope with the optimization problem of material flows. Our goal is to minimize the total cost of the system. A Benders decomposition approach and modified Benders decomposition approaches to speed-up the algorithm's convergence are applied to find solutions to this problem. The performances of the different solution methods and problem formulations are examined in a computational study.

3 - Dynamic multi-product lot-sizing problem under uncertainty

Svenja Lagershausen, Stefan Helber

We present a stochastic single-level, multi-product dynamic lot-sizing problem subject to a production capacity constraint. The production schedule is determined such that the expected costs are minimized. The costs considered are set up and inventory holding costs as usual and additionally backlog costs and costs for overtime. The backlog is limited using a $delta$-service-level constraint. The expected backlog and physical inventory functions subject to the cumulated production quantity lead to a non-linear model that is approximated by a linearization approach.

■ FA-18

Friday, 8:30-10:00 - HS 48

(c) Climate and Environmental Issues

Stream: Energy and Environment
Chair: *David Bunch*

1 - The influencing factors on carbon leakage rates of unilateral climate policy - a meta-analysis

Marlene Sayer

The European Union has set climate targets but failed to establish global CO2 emission standards, which makes unilateral climate policies the only instrument for emission reductions in the upcoming years. A major argument in the debate against unilateral climate policies is the carbon leakage effect, the amount of increase in carbon emissions outside of those countries that reduce their emissions, which has been analyzed in different studies. Since there are many uncertainties about carbon leakage it is of interest to compare the different results of those studies concerning the height of the carbon leakage rate as well as its influence factors. Thus it is useful to perform a meta-analysis. It consists of 39 of those studies and uses a regression model which employs parameters like the size of the countries abating as well as Armington or supply elasticities of fossil fuels. The purpose of this is to estimate the rate of carbon leakage. The results imply that the predicted carbon leakage rates differ substantially among those studies. Further results indicate that an extension of the EU ETS (EU 11% of global CO2 emissions) on EU and China (39% of global CO2 emissions) would reduce the leakage rates in the model by about 8%. An extension to Annex 1 and China (70% of global CO2 emissions) would almost solve the leakage problem. A reduction of about 18% could be achieved in the model while the average leakage rate of 39 studies is about 20%. Those factors have already been widely discussed in the literature. However, a whole new aspect is represented by the significance of the elasticity of supply of fossil fuels, which leads the climate discussion further to supply side policies.

2 - Environmental economic consideration of building renovations

Susanne Lind-Braucher, Robert Hermann

Living quarters built in the 70s no longer meet the current standard of living. One possibility to change this is to thermally rehabilitate them. Another option would be to create new residential areas and upgrade in terms of variability. This is a project which covers the extensive thermal and technical renovation including the revaluation of residential areas designed in the 70's. By building a thermal buffer zone a wider living area is created. The new facade serves as a carrier for hybrid modules that generate electricity using photovoltaic cells which if necessary are cooled by integrated solar thermal collectors in order to increase efficiency and to protect the buffer zone from overheating. The excessive heat is caused by geothermal ground probes. The new shell is applied in a modular design to accomplish a gradual restoration of the building. It also offers an optimization of the building geometry and supports changes to the floor plans. The ground floor area will be rebuilt as part of the mobility concept to an E-LOBBY mobility centre for E-Car sharing. The PV of the facade, the charging of the E-Cars and the public power supply are coordinated in a Smart Grid solution. By using innovative hybrid modules both heat and electrical energy is generated. This can replace fossil fuels and can therefore reduce the CO2 emissions. By using a modified cost-effectiveness analysis, the influences and effects on social, environmental and economic indicators can be measured and evaluated. Furthermore optimally coordinated financing and funding models are developed for the current and future tenants. The robustness of the results will be measured by sensitivity analysis.

3 - COCHIN-TIMES: Integration of Vehicle Consumer Choice in TIMES Model and its Implications for Climate Policy Analysis

David Bunch

A major ongoing concern of those who work with energy-related models for policy analysis for climate change (whether they be CGE or E3 type models) is that the models are missing important factors related to how consumers would actually behave under alternative future scenarios involving new fuel technologies and policy instruments. Top-down models have a much broader scope but less detail, relying on highly aggregated economic indicators. 'Bottom up' models that focus on the energy sector (such as TIMES/MARKAL) are often considered to be highly detailed, employing large databases on energy technologies (including assumed future technologies) with details on efficiency characteristics and costs. However, even these models are primary concerned with 'feasibility' of future scenarios, focusing on 'minimization of social costs.' They lack the ability to address realistic consumer response to scenarios. We have developed approaches to extend these models by integrating behavioral elements from vehicle choice models into the TIMES/MARKAL framework, allowing researchers to leverage existing tools and databases.

■ FA-19

Friday, 8:30-10:00 - HS 50

Data Envelopment Analysis in Energy Economics

Stream: Energy and Environment
Chair: *Bernhard Mahlberg*

1 - Carbon-decreasing Developments Among New Competitors: Gas- and Coal-Fired Power Plants in the US Electricity Sector

Heike Wetzel

Over the last decade, the electrical power sector in the U.S. has been influenced by two major trends. On the supply side plummeting gas prices induced by the so-called shale gas revolution have created incentives for power producers to increase gas usage or even switched investments in new capacity from coal to gas. Whereas the effects of increased gas usage seem straightforward for technology-specific gas plants, we observe that in the U.S. combined coal and gas-fired plants often coexist locally and may facilitate the potential fuel switch from coal to gas. Additionally, regulatory standards for CO2 emissions, both on the national and supranational level, have been tightened in order to trigger less carbon-intensive energy production. This paper analyzes the CO2 emission performance of U.S. fossil fuel power plants on the state level. We model a production technology that includes both desirable and undesirable outputs and calculate a global Malmquist CO2 performance index. The results indicate a significant variation in the CO2-sensitve productivity development between the states and a productivity increase on average.

2 - The Direct Costs and Benefits of US Electric Utility Divestitures

Thomas Triebs

Production and agency theories cannot predict the overall cost effect of vertical separation in network industries. Also, the existing empirical evidence for the divestiture of US electric utilities is ambiguous and incomplete. Previous studies do not model inefficiency explicitly and do not include all parts of the supply chain. We study the net benefit of a sample of US electric utility divestitures including all stages of the supply chain. Our estimate of the effect of divestiture is based on non-parametric estimates of firm-level efficiency using Data Envelopment Analysis. We find a negative but relatively small net benefit. After the divestitures net benefit is trending upwards. Early losses from separation are likely to be offset by gains from restructuring and learning later on.

3 - Analyzing Efficiency of biogas plants in Austria using Data Envelopment Analysis

Andreas Eder, Bernhard Mahlberg

Against the background of the difficult economic situation of many biogas plants in Austria, an improvement of competitiveness by streamlining technical processes is indispensable for survival of the whole industry. Comparing the plants and identifying those who are operating efficiently is an important instrument for this purpose. Since the operation of a biogas plant is complex and influenced by many parameters, multi-criteria analysis has to be applied. In this paper different approaches of the data envelopment analysis (DEA) are combined for assessing efficiency of Austrian biogas plants. The models applied take into account the heterogeneity of plants with respect to technology, non-discretionary inputs and the impact of the environment on efficiency. That way, achievable potentials for improvements of efficiency through process optimizations are estimated.

■ FA-22

Friday, 8:30-10:00 - ÜR Germanistik 3

Revenue Management (c)

Stream: Accounting and Revenue Management
Chair: *Johannes Kolb*

1 - Least squares approximate policy iteration for choice-based revenue management

Sebastian Koch

We consider the revenue management problem of capacity control under customer choice behavior. An exact solution of the underlying stochastic dynamic program is difficult due to the multi-dimensional state space, and approximate dynamic programming (ADP) techniques have to be used. The key idea of ADP is to encode the multi-dimensional state space by a small number of features, leading to a parametric approximation of the dynamic program's value function. In general, two classes of ADP techniques for learning value function approximations exist: mathematical programing and simulation. So far, the scientific literature on capacity control largely focuses on the first class. Among corresponding approaches are the well-known dynamic programming decomposition and the linear programming approach for ADP. In this talk, we present a least squares approximate policy iteration approach which belongs to the second class. Thereby, we suggest several value function approximations which are linear as well as non-linear in the parameters and estimate the parameters via least squares regression. We perform a number of computational experiments to investigate the performance of our approach. The results indicate that simulation-based ADP is a viable alternative for choice-based revenue management.

2 - A DLP formulation considering intertemporal customer behavior

Korel Celepsoy, Johannes Kolb

In the field of customer relationship management, the customer lifetime value — often defined as the present value of all future profits generated from a customer — is a vastly investigated metric which serves as an important decision-making criterion. The incorporation of the expected customer lifetime value into revenue management systems is therefore identified as an existent challenge in the relevant literature — however, there are hardly any revenue management methodologies that comprise such a long-term perspective. Even though a service provider's current pricing and availability decisions may affect the customers' purchase behavior in future periods, these implications are ignored. The up-to-date optimization approaches in capacity control are almost exclusively transaction-based, i.e. solely short-term attainable revenue is maximized. In this presentation, we show how intertemporal customer behavior can be considered in a revenue management context. Therefore, we aggregate the expected revenue and capacity consumption of individual customers derived from the stationary distribution of an infinite Markov chain approach in the well-known deterministic linear programming (DLP) model. The resulting intertemporal choice DLP generates a long-term optimal customer portfolio. We present our results in a numerical illustration.

3 - Capacity control with macro periods

Maximilian Herz, Sebastian Koch, Johannes Kolb

In revenue management environments, problems are usually formulated as dynamic programs. Thereby, time is sufficiently discretized into micro periods such that, in each period, the seller selects the products to offer first, and then at most one customer arrives purchasing a product from the offer set. The micro period view may not be suitable in practice, because companies are often able to decide on the offered products only on specific points of time during the booking horizon. In this talk, we assume that — in addition to the standard assumptions of revenue management's capacity control problem — the same offer set of products is sold in several consecutive micro periods. In doing so, we divide the booking horizon into so-called macro periods, in each of which we aggregate the stochastic demand of several micro periods. Based on this assumption, we first consider a single macro period and derive the one-period distributions of total demand and revenue. Then, we formulate and analyze the corresponding stochastic dynamic program of capacity control. In numerical experiments, we illustrate the impact of the macro period approach for different demand scenarios.

■ FA-23

Friday, 8:30-10:00 - ÜR Germanistik 4

Theory of Integer Programming (c)

Stream: Integer Programming
Chair: *Oliver Stein*

1 - Vector space decomposition for linear programming

Marco Lübbecke, Jean-Bertrand Gauthier, Jacques Desrosiers

We describe a vector space decomposition framework for linear programming guided by dual feasibility. It can be seen as a generalized pivoting rule. Potentially improving directions are obtained via optimizing (part of the) dual variables. From a primal perspective, one selects a convex combination of variables entering the basis. Variants include the primal simplex algorithm, the minimum mean cycle-canceling algorithm, and the improved primal simplex algorithm. Some variants entirely avoid degenerate pivots.

2 - The bound function approach for solving nonlinear mixed-integer problems

Sönke Behrends, Anita Schöbel

We consider mixed-integer nonlinear minimization problems (MINLP): Given a polynomial objective function, find its minimum subject to polynomial (and integrality) constraints. This problem is not solvable by an algorithm without further assumptions. To make it tractable in certain cases, we introduce bound functions: Given a feasible solution to the MINLP, we compute a bound on the norm of all feasible solutions that are as least as good as the current solution. The computation of the best bound is a semi-algebraic problem - which can be approximated by a hierarchy of sos programs. As a consequence, provided the hierarchy of sos programs is eventually feasible, this turns possibly infinite integer problems into finite ones - making the problems accessible to branch and bound - and turns possibly unbounded continuous problems into bounded ones. Our approach is rather general: On the one hand, regarding the objective, we do not require positive semidefinitness of its leading form - nor coercivity or convexity of the objective itself - and on the other hand, regarding the constraints, we do not require convexity or connectivity (relaxing integrality) nor boundedness of the feasible set. We give necessary and sufficient conditions for a feasible hierarchy. Further, we present computational experiments on random instances that relate our ideas to results from the literature and show that significantly better bounds can be generated by sos programming.

3 - Error bounds for nonlinear granular optimization problems
Oliver Stein

We study a-priori and a-posteriori error bounds for optimality and feasibility of a point generated as the rounding of an optimal point of the relaxation of a mixed integer convex optimization problem. Treating the mesh size of integer vectors as a parameter allows us to study the effect of different 'granularities' in the discrete variables on the error bounds. Our analysis mainly bases on the construction of a so-called grid relaxation retract. Relations to proximity results and the integer rounding property in the linear case are highlighted.

■ FA-24

Friday, 8:30-10:00 - ÜR Germanistik 5

Energy & Renewables (c)

Stream: Analytics
Chair: *Alexander Schuller*
Chair: *Philipp Stroehle*
Chair: *Christoph Flath*

1 - Price-based Composition and Coordination of Demand Response Groups
Nikolai Stein, Christoph Flath

The major part of existing research focuses either on the demand responses caused by exogenous price signals or on the optimal response of suppliers to exogenous demand. The goal of this work is to consider both perspectives at the same time and develop a data driven approach to investigate the impact of customers' flexibility on the benefits of nonlinear pricing.

For this purpose a simple mixed-integer program to determine the optimal structure of a time of use tariff (TOU) is applied. Within this model utility-maximizing customers choose between different TOU offers and a traditional linear price scheme. Customers enrolling with the TOU offer will later shift their demand in-line with their flexibility endowment.

We evaluate the multiple interdependences between generation assets, customer flexibility endowments and pricing decision by means of numerical experiments based on empirical load and generation data.

2 - Impact of User Dependent Charging Strategies on Electric Vehicle Battery Degradation
Jennifer Schoch, Johannes Gärttner, Alexander Schuller

The market share of battery electric vehicles (BEV) today is rather low, even though BEVs offer the potential to significantly reduce greenhouse gas emissions and fossil fuel consumption. Slow adoption of BEVs is mainly caused by the high cost of the battery accompanied by uncertainty about battery aging. Furthermore, recharging takes a lot more time for BEVs compared to conventional vehicles and the availability of public charging stations outside of urban centers is another impediment. Initial field studies about the behavior of BEV users indicate the presence of the range anxiety phenomenon, which leads to frequent recharging and high states of charge for the battery. Although battery aging is a complex process, not yet understood in all detail, most Li-ion chemistries show pronounced aging around higher states of charge, indicating that such frequent recharging may not be optimal. Considering every day user mobility needs as well as charging opportunities we determine the optimal charging strategy that minimizes battery degradation for a given battery technology. This allows the provision of individual feedback to the driver about the optimal charging strategy in order to extend battery lifetime and to benefit from the maximum available range. The understanding of the individual optimal charging strategy is of crucial importance for OEMs in order to better understand usage-related battery aging, allowing for prediction of battery end of life and the design of customer incentives for battery friendly behavior.

3 - The Science of Data-Driven Prediction
Ralph Grothmann, Hans Georg Zimmermann

The science of (data-driven) prediction is a race between the increasing complexity of the real world and our accelerating ability to mathematically represent it by means of information-technology-related capabilities, such as neural network models. From a mathematical point of view, neural networks allow the construction of models, which are able to handle high-dimensional problems along with a high degree of nonlinearity. Our philosophy is beyond purely data-driven modeling: The application of neural networks should be based on a deep understanding of the underlying mathematics, first principles on dynamical systems as well as prior (economic) domain knowledge. The talk will introduce basic feedforward neural networks for non-linear regression tasks and time-delay recurrent neural networks for modeling dynamical systems. Examples from real-world real-world industrial applications will be given that outline the merits of such a modeling approach. Among others we will deal with the modeling of e.g. the energy supply from renewable sources, energy load forecasting as well as the forecasting of commodity prices and the identification of features responsible for component failures.

■ FA-27

Friday, 8:30-10:00 - SR Geschichte 2

Portfolio Optimization II (c)

Stream: Financial Modelling
Chair: *Fabio Bellini*

1 - Tracking the 1/N Portfolio
Oliver Strub, Norbert Trautmann

Various stock portfolio selection models are known from the literature that help finding an optimal portfolio in terms of risk and return. However, none of these models seems to consistently outperform the 1/N portfolio, which is composed of all N stocks of a specific investment universe with equal investment amounts. Hence, the 1/N portfolio is a reasonable investment strategy. But, buying all the N stocks can lead to high transaction costs, especially in illiquid markets. Asset managers who want to replicate the returns of some stock index often face the same problem. To avoid excessive transaction costs, they only buy a subset of the index constituents. Index tracking, which is the problem of finding the best of all feasible subsets, can be tackled using mixed-binary convex optimization models. These models aim to find the subset that would have most precisely replicated the index in the past.

The 1/N portfolio can be interpreted as a special index with equally weighted constituents. In this talk, we propose a novel index-tracking technique to replicate the 1/N portfolio. In contrast to the models from the literature, we explicitly use the information about the actual index weights, i.e. 1/N, as input to the mixed-binary linear and quadratic optimization models we formulated. Our computational results indicate that we can closely mimic the 1/N portfolio with significantly fewer stocks.

2 - Portfolio Optimization with Expectiles
Fabio Bellini, Christian Colombo, Mustafa Pinar

The expectiles have been introduced in the statistical literature by Newey and Powell (1987) as the minimizers of an asymmetric quadratic loss function. Expectiles are coherent risk measures in the sense of Artzner et al. (1999), and it has been shown in a series of recent papers that they are actually the only coherent risk measures which can be defined by means of an expected loss minimization, a propriety that is called elicitability. In this work we study mean-expectiles optimal portfolios applying the techniques and results of Ruszczynski and Shapiro (2006) and Rockafellar, Uryasev and Zabarankin (2006). We investigate numerically optimal portfolios and compare them with other mean-risk approaches and with other related approaches based on gain-loss ratios and piecewise linear utilities.

■ FA-30

Friday, 8:30-10:00 - Visitor Center

Stochastic Programming in Energy and Environment (i)

Stream: Stochastic Optimization
Chair: *Steffen Rebennack*

1 - Groebner Bases and Nomination Validation in Gas Networks with Random Load

Sabrina Nitsche, Rüdiger Schultz

In steady state gas networks, Kirchhoff's Laws lead to systems of polynomial equations whose solutions can be computed with the help of Groebner Bases. In the talk we show how to use this approach for determining explicitly the dependence of gas flows on varying, yet stochastic load profiles.

2 - Risk Calculation of Pesticide Residues in Fish Diet

Judith Klein, Christian Schlechtriem, Rüdiger Schultz

In the last few years plant commodities have become more and more important for fish diets. Within the increased use of crops agricultural pesticide residues were found in fish products. Thus a risk also for human consumption exist. Representative two very import aquaculture fish species rainbow trout and common carp are considered. In the talk a possible risk disclosure based on methods of linear programming and stochastic optimization is presented.

3 - A Framework for Stochastic Optimization with Distributional Ambiguity

Steffen Rebennack

We propose an optimization and modeling framework for stochastic optimization under uncertainty. The distributional ambiguity is captured by considering an entire family of distributions, instead of a single one as commonly used in stochastic optimization. We develop a new method to optimally combine all available estimation methods through a combinatorial optimization problem. This yields an optimal restriction of the family of distributions up to a chosen confidence level. By defining an estimator in the interior of the resulting confidence region, we are able to yield an optimization problem which solves the stochastic optimization problem under uncertainty up to a (known) constant for all elements of the family of distributions. The error constant depends on the chosen confidence level, the distances between the estimator and the members of the family of distributions, and the maximum objective function value. The error constant is small for a sufficiently large i.i.d. sample size and we show that the error constant converges to zero for the asymptotic case. We briefly discuss its application for the stochastic unit commitment problem with uncertain wind generation.

■ FA-31

Friday, 8:30-10:00 - Marietta Blau Saal

Performance Measurement in Health Care

Stream: Health and Disaster Aid

Chair: *Christine Burggraf*

1 - Shifting risks from the payor to the provider: a financial problem for swiss drg?

Philippe Widmer

Due to rising health care costs, Swiss politicians have switched to a prospective 'treatment per patient case' payment system (Swiss DRG) to curb the costs. Following the ideas of the U.S., Austrian, and German system, the swap of financial risk from the payor to the provider is expected to increase incentives for cost efficiency. This paper focuses on the financial consequences of this swap. As it turns out, as long as providers are not compensated with a fair price for financial risk, incentives not only motivate for cost efficiency gains. This is mainly due to the fact that lacking treatment standardization fosters risk selection rather than efficiency gains. University hospitals and child care hospitals, which can not optimize at the same level as regional hospitals, have to bear the financial consequences.

2 - The interplay between regulation and efficiency: Evidence from the Austrian inpatient hospital sector

Margit Sommersguter-Reichmann, Adolf Stepan

Austrian health policy aims at maintaining and even expanding high quality health care. To achieve these objectives, the Austrian health care system has seen many regulatory interventions during the last decades. The transition from an input-oriented planning of the health care system to an integrated master plan, the so-called OESG, is considered as being a very important regulatory initiative. Given the fact that the OESG contains input and output target values, which are, at least to a certain extent, based on actual performance, efficiency evaluation can be used to support the regulatory authorities to guarantee that a maximum of health outcomes is obtained with a minimum of resources. From a regulatory perspective, efficiency studies that simultaneously reveal input and output improvement potentials can therefore be promising. Therefore, we applied a non-oriented non-radial super efficiency measure to identify any improvement potential in inputs and outputs for the inpatient sector of Austrian publicly financed acute care hospitals covering a time period of four years. In order to overcome the sensitivity of DEA results to outlier data and measurement problems, a bootstrap algorithm was used to derive bias-corrected efficiency estimates. We found increasing average efficiency between 2009 and 2012, ranging from 86% in 2009 to 91% in 2012, and considerable differences in improvement potentials for the relevant inputs and outputs used to assess hospital efficiency. A second stage regression revealed a significant interaction effect between care level and ownership, significant efficiency differences across supply zones, a significantly negative impact of market concentration and a significantly positive relationship between physician experience and efficiency.

3 - Nutrition related chronic diseases and the optimal demand for dietary quality

Christine Burggraf, Ramona Teuber, Thomas Glauben

Unbalanced and excessive eating patterns increase the prevalence of chronic diseases worldwide und suggest the need for more elaborated demand models. Therefore, we aim at enhancing Grossman's intertemporal health investment model in order to appropriately consider critical aspects of dietary quality. Based on our newly developed dietary health investment model, individuals dynamically control for health investments by healthy nutrient intakes but also for the intake of tasty yet risky nutrients such as saturated fats. Thereby, individuals consider the respective motions of their health and wealth stocks. After the derivation of demand functions for healthy and risky nutrients, a simulation of the dietary health investment model based on the German National Nutrition Survey II is presented to illustrate the model's empirical application. The implications of our derived demand functions for healthy and risky nutrients as well as our estimation results reflect general findings of previous empirical studies but also provide important new insights. For example, in line with our dietary health investment model, our estimation results show that, inter alia, healthy nutrient demand significantly increases with decreasing health states, increasing nutritional knowledge, and lower rates of time preference. Further, our time path illustrations of vitamin C and fat consumption allow tentative hypotheses about the impact of nutrition policies. Our dietary health investment model and the respective simulation model provide a reasonable basis for future empirical work on dietary behavior. It may thus contribute to set up more effective nutrition policies by a growing understanding of the responsible causal mechanisms behind the increasing prevalence of chronic diseases.

Friday, 10:30-11:15

■ FB-04

Friday, 10:30-11:15 - HS 21

Semi-plenary: Ruiz Garcia

Stream: Semi plenaries I
Chair: *Norbert Trautmann*

1 - Scheduling with simple Iterated Greedy Algorithms
Ruben Ruiz

Nowadays scheduling problems are mainly solved with modern metaheuristics. These methods are capable of producing close to optimal solutions for instances of realistic size in a matter of minutes. Metaheuristics have matured and evolved with hundreds of papers being published every year with applications to most domains. Most regrettably, some of these methods are complex in the sense that they have many parameters that affect performance and hence need careful calibration. Furthermore, many times published results are hard to reproduce due to specific speed-ups being used or complicated software constructs. These complex methods are difficult to transfer to industries in the case of scheduling problems. Another important concern is the recently recognized "tsunami' of novel metaheuristics that mimic the most bizarre natural or human processes, as for example intelligent water drops, harmony search, firefly algorithms and the like. See K. Sörensen "Metaheuristics—The Metaphor exposed' (2015), ITOR 22(1):3-18. In this presentation, we will introduce Iterated Greedy (IG) algorithms. These methods are inherently simple with very few parameters. They are easy to code and results are easy to reproduce. We will show that for all tested problems so far they show state-of-the-art performance despite their simplicity. As a result, we will defend the choice of simpler, yet good performing approaches over complicated metaphor-based algorithms. We will explain the foundations of the IG, the simple destruction-reconstruction loop and we will comment on the advantages and drawbacks of the IG. We will show comparisons with other methods from the literature, with special emphasis on scheduling problems and more precisely on flowshop scheduling and parallel machine settings.

■ FB-13

Friday, 10:30-11:15 - HS 41

Semi-plenary: Minner

Stream: Semi plenaries II
Chair: *Karl Doerner*

1 - Data-driven inventory management — recent advances and research challenges
Stefan Minner

In inventory management, demand forecasting and stock optimization are typically conducted sequentially. The data-driven approach suggests integrating both problems by optimizing inventory decisions based on historical data using mixed-integer programming. Thereby, forecast errors are penalized with their operational consequences. Further, the availability of large amounts of detailed data on a customer basis allows for using enhanced demand models in inventory theory. The presentation reviews existing approaches for optimizing target inventory functions and safety stocks for several standard inventory problems including perishable products, dual sourcing, multi-echelon inventory systems, and identifying inventory replenishment patterns. Different exact and heuristics solution approaches to solve the integrated data-driven inventory problems will be presented. Practical applications from the retail sector illustrate the capability over traditional sequential approaches.

■ FB-17

Friday, 10:30-11:15 - HS 47

Semi-plenary: Möller

Stream: Semi plenaries IV
Chair: *Andreas Fink*

1 - Visual data science – Advancing science through visual reasoning
Torsten Möller

Modern science is driven by computers (computational science) and data (data-driven science). While visual analysis has always been an integral part of science, in the context of computational science and data-driven science it has gained new importance. In this talk I will demonstrate novel approaches in visualization to support the process of modeling and simulations. Especially, I will report on some of the latest approaches and challenges in modeling and reasoning with uncertainty. Visual tools for ensemble analysis, sensitivity analysis, and the cognitive challenges during decision making build the basis of an emerging field of visual data science which is becoming an essential ingredient of computational thinking.

■ FB-19

Friday, 10:30-11:15 - HS 50

Semi-plenary: Wozabal

Stream: Semi plenaries III
Chair: *Marco Laumanns*

1 - Dampening the Curse of Dimensionality: Decomposition Methods for Markov Decision Processes
David Wozabal

Large stochastic optimization problems are typically hard to solve. The computational complexity is driven by the number of decision stages and the size of the problems in each stage. We review different approaches to stochastic optimization and present an approach to solve Markov Decision Processes. The approach differs from classical solution methods in two ways: First, it uses scenario lattices instead of a scenario trees to represent uncertainty and thereby significantly reduces the complexity of the problem in the number of stages. Secondly, we use a dynamic programming framework based on decomposition that does not require the discretization of the whole state space and thereby allows for a large number of decision variables in the problem formulation. In combination, these two design choices make large stochastic programming problems with many stages computationally tractable. We demonstrate theoretical properties of the method and show results from realistic problem instances of stochastic optimization problems in the field of energy planning.

Friday, 11:30-13:00

■ FC-02

Friday, 11:30-13:00 - HS 7

Novel Approaches in Scheduling (i)

Stream: Scheduling and Project Management
Chair: *Ulrich Pferschy*

1 - Variability Aspects in Scheduling Systems
Kathrin Benkel, Kurt Jörnsten, Rainer Leisten

The influence of variability is often addressed in queuing theory, e.g. flow variability. In job scheduling, it can be shown that minimization of makespan and flowtime yields more variable inter-departure times of jobs (Leisten/Rajendran (2015)). Therefore the link between approaches of (stochastic) queuing theory and (static-deterministic) job scheduling approaches is subject of current research. We start with an 'ideal' scheduling problem where all jobs have the same processing times on all machines, i.e. there is no processing time variability. As a consequence, no time, capacity or inventory buffers are required. Instead, a real-world system requires an efficient (non-zero) mix of these buffers to balance the influence of non-uniformity. In the scheduling context, inventory buffers are interpreted as waiting time of jobs whereas capacity buffers are seen as idle time of machines. The focus here is to observe the effects of non-uniform processing times on performance measures in a scheduling system, i.e. makespan, flowtime, waiting/idle time. As a reference system, a permutation flow shop is used to illustrate the influence of variability of processing times. Experimentally, non-uniform processing times are smoothed so that the total processing times of jobs and/or machines converge to the same average value. To achieve this, two different modification approaches are analyzed. The first model uses the Kullback-Leibler-Divergence for a logarithmic objective function, the second model uses the statistical least-square-method for a quadratic objective function. Total uniformity cannot be achieved by these approaches, but the behavior of performance measures and variability can be observed.

2 - Personnel Planning with Structured Qualifications
Ulrich Pferschy, Tobias Kreiter, Joachim Schauer

We consider a real-world personnel planning problem encountered at Bühnen Graz, a holding company of all public theaters and most event locations in Graz. For each day of the planning horizon several events are given, each of them with a long list of tasks. Each task has to be fulfilled by a member of the technical staff with a suitable qualification. The resulting personnel scheduling problem is quite different from classical shift assignment problems, such as nurse scheduling or bus driver scheduling. Besides the usual legal regulations and union rules concerning e.g. working time, breaks, days off and weekends, our planning scenario has very different tasks to be executed on each working day, namely different in duration, required skill and intensity.

The necessary duties have to be fulfilled by a highly heterogenous workforce. Each worker has a different set of skills with no strict hierarchical order. Moreover, it is possible for one worker to fulfill several tasks at the same time, but this ability depends again on the particular task, the required intensity and on the individual worker. Thus, we have a highly complicated competence portfolio for each worker.

We develop an Integer Linear Programming model describing the full planning problem. To model the complicated covering of several tasks by individual workers we employ a worker-dependent and a task-dependent conflict matrix. The model was implemented in PuLP and executed with open-source and commercial solvers. Since the number of workers and tasks remains moderate we manage to reach almost optimal solutions within 15 minutes of computation time.

3 - Job Shop Scheduling with Full Lot Streaming
John J. Kanet, Christian Gahm

In the current state-of-the-art in manufacturing much attention is paid to overarching approaches like JIT and Lean. Primarily aiming at the reduction of manufacturing planning and execution complexity, leveling of capacity loads, and reduction of WIP-inventories, a central goal one often hears is the reduction of setup times to reduce lot sizes —in the best case, to realize a "one piece flow'. The current prevalent approach for one piece flow is through implementation of control procedures like KANBAN or CONWIP and not in a shop's planning and scheduling procedures. The purpose of this analysis is to investigate how integrating one piece flow into the planning and scheduling of production can be accomplished via lot streaming. We argue that job shop scheduling with full lot streaming can compensate well-known drawbacks of MRP —i.e., unlimited capacity and fixed planned lead times— and simultaneously attain the benefits expected by a one piece flow. We study a general job shop whose jobs represent lots of product items with the lot size the same for each of the job's operations. Thereby, we permit overlapping of operations but prohibit interruption of operation processing, calling this "full lot streaming'. Instead of lot splitting, we assure a feasible overlapping of operations by minimal time lags (based on the transfer batch size) between the start times of two consecutive operations. With this approach, a transfer batch size equal to one leads to a one piece flow and provides a type of lower bound on the minimum flow time (inventory) necessary to produce a given product demand. For evaluation, we developed several solution methods and compare the one piece flow approach to different transfer batch sizes and to the traditional MRP concept.

■ FC-04

Friday, 11:30-13:00 - HS 21

Robust optimization and applications (c)

Stream: Discrete Optimization
Chair: *Matthias Garbs*

1 - Pre-Tactical Planning of Runway Utilization using Robust and Stochastic Optimization
Manu Kapolke, Andreas Heidt, Frauke Liers, Alexander Martin

Efficient planning of runways is one of the main challenges in Air Traffic Management. In the pre-tactical planning phase we assume to be several hours, or at least 30 minutes, prior to actual arrival times. We develop a specific optimization approach for this planning phase that reduces complexity by omitting unnecessary information. Instead of determining arrival times to the minute in this phase yet, we assign several aircraft to the same time window of a given size. The exact orders within those time windows can be decided later in tactical planning. Mathematically, this leads to a b-matching problem on a bipartite graph with side constraints. In reality, uncertainty and inaccuracy almost always lead to deviations from the actual schedule. In order to handle these uncertainties and decrease the amount of necessary replannings, we present several robust optimization approaches. Namely, since a strict robust approach can be very conservative, we develop optimization models using the concept of recoverable robustness to reduce that conservatism. Further, we present stochastic optimization approaches (single-stage and two-stage models), which incorporate uncertainties using information about the underlying probability distribution, and discuss possible solution methods.

2 - Light and Recoverable Robustness for Runway Schedules in Air Traffic Management
Andreas Heidt, Hartmut Helmke, Manu Kapolke, Frauke Liers, Alexander Martin

In Air Traffic Management (ATM), the runway is the main element that combines airside and groundside. In order to achieve efficient plans, we develop and solve a time-discretized mathematical optimization model. The underlying structure is that of an assignment problem with side constraints. For every time interval, it is computed whether an aircraft is scheduled and if so, which one is. Furthermore, security distances are respected. In reality, we face disturbances and uncertainties in the aircraft flight times that usually lead to deviations from the actual plan or schedule. Using robust optimization, we protect the model against uncertainties in the input data in order to avoid expensive or even infeasible solutions for the disturbed problem. We focus on a strict robust approach as well as on more advanced concepts, such as light and recoverable robustness. These optimization models are incorporated within a simulation procedure. The different concepts are evaluated within the simulation for a planning horizon for up to two hours before landing. Using random initial data for each aircraft and for the uncertainties in the earliest and latest landing or departure times, the robust models are evaluated and compared to each other. The comparison is done with respect to stability of a plan, the number of necessary rescheduling and the number of served aircraft. Furthermore, the results are evaluated considering the quality of the solutions and computational runtime. In presence of uncertainty, the computations yield promising results for improved schedules.

3 - Uncertain bottleneck problems in the cascade utilization of biomass

Matthias Garbs, Jutta Geldermann

Robust optimization has become more important in Operations Research, as uncertainties in decision problems are increasingly taken into account. Two established concepts of robust optimization are min-max robustness and min-max regret robustness. It has already been shown with regard to these concepts that it is possible to reduce uncertain bottleneck problems to simple bottleneck problems. Bottleneck problems in this sense are combinatorial problems where the objective function value is determined by the highest (or lowest) cost value of any element in a feasible solution. In addition to these statements, further statements are made about uncertain bottleneck problem and min-max regret robustness, as well as min-max robustness of multi-criteria bottleneck problems. The statements about the min-max robustness of multi-criteria bottleneck problems are based on known results for the min-max robustness of multi-objective optimization problems. The known and newly found statements are applied to a uncertain bottleneck problem in the cascade utilization of biomass.

■ FC-05

Friday, 11:30-13:00 - HS 23

Cutting and Packing

Stream: Production and Operations Management
Chair: *Günther Raidl*

1 - Logic-based Benders Decomposition for the 3-staged Strip Packing Problem

Johannes Maschler, Günther Raidl

Logic-based Benders Decomposition (LBBD) is a technique for tackling large combinatorial optimization problems having a certain structure by decomposing them into smaller master and related subproblems. In contrast to classic Benders Decomposition the subproblems in LBBD are not restricted to linear programs. LBBD has already been applied with great success on various problems including the strip packing problem. We propose a new LBBD-approach for the 3-staged Strip Packing Problem (3SSPP), in which two-dimensional rectangular items have to be arranged onto a rectangular strip of fixed width, such that the items can be obtained by three stages of guillotine cuts while the required strip height is to be minimized. In the first stage the strip is cut horizontally into levels, in the second stage the levels are vertically subdivided into stacks, and cutting the stacks horizontally results in the items. The restriction to three stages of guillotine cuts is common in industry due to limitations in the manufacturing process. Our LBBD master problem assigns items to levels and within each level for all items of the same width the number of stacks to be used is determined. The actual partitioning of items into stacks is done in the subproblems, which are related to multiprocessor scheduling problems. For a LBBD to be efficient, it is essential that the Benders cuts generated from the subproblems are as general as possible. We apply two techniques. The subproblem is solved multiple times with a decreasing number of items in order to find a smallest set of items that still requires the same height as the original set. Although a Benders cut is generated for a set of items on a certain level, in general it can be applied on all levels with isomorphic sets of items.

2 - A Scalable Heuristic for the Two-Dimensional K-Staged Cutting Stock Problem

Frederico Dusberger, Günther Raidl

This work focuses on the two-dimensional K-staged cutting stock problem with variable sheet size in which we are given a set of rectangular element types with corresponding demands and a set of stock sheet types of certain quantities and associated cost factors. The objective is to find a set of cutting patterns, i.e., an arrangement of the specified elements on the stock sheets without overlap using only up to k stages of guillotine cuts, s.t. the weighted number of used sheets is minimal. In particular, we are dealing with large-scale instances from industry in which the number of different element and sheet types is moderate but the demands of the element types are rather high.

In our heuristic approach we employ a cutting tree data structure that stores multiple congruent sheets and subpatterns by referencing at each node only one respective child node and storing an additional quantity. Based on this data structure we can efficiently exploit symmetries already during solution construction using a congruency-aware sheet construction heuristic that is able to insert multiple instances of a given element type efficiently at once by simultaneously altering multiple congruent subpatterns.

This heuristic is embedded in a beam-search framework which sequentially generates a complete solution sheet by sheet considering several most promising alternatives at each step. This whole procedure is further iterated in the context of a value-correction scheme acting as a guided diversification for producing a series of promising solutions from which the best one is finally returned. Preliminary experiments on large-scale instances from the cutting industry show that the approach yields solutions of high quality in short time and demonstrate its scalability.

3 - Robotic Cell Scheduling under Uncertainty

Daniel Tonke

Existing literature on robotic cells in semiconductor manufacturing usually considers deterministic activity times for all processes. However, in real-time operations of robotic cells there are different sources of stochasticity, for example wafer alignment processes or variances in processing times. Using deterministic schedules in a stochastic environment will often times lead to deadlocks or violations of wafer delay constraints and will therefore make a schedule which is generated on the assumption of deterministic processing times infeasible. Thus, this talk considers the real-time scheduling of robotic cells in semiconductor manufacturing with stochastic processing times and robot task times. We aim at deriving makespan-optimal sequences when activity times are subjected to stochastic variance. For this reason, we develop a hierarchic approach for schedule generation and schedule execution which allows that wafer delay constraints are ensured and high wafer throughput is maintained. Furthermore, a novel scheduling technique is developed which allows to reduce the number of processing steps which have to be considered to the number of bottleneck steps in the robotic cell.

■ FC-06

Friday, 11:30-13:00 - HS 24

Remanufacturing II

Stream: Production and Operations Management
Chair: *Dirk Sackmann*

1 - Remanufacturing as a Competitive Strategy

Subrata Mitra

Remanufacturing is a product recovery option that upgrades the quality of returns to "as-good-as-new' conditions. Remanufactured products cost less, and are sold with the same or better warranty as for new products. In this paper, we consider a duopoly environment with two manufacturers in direct competition selling their respective new products on the primary market. Specifically, we address the question: In case one manufacturer decides to remanufacture and sell remanufactured products on the price-sensitive secondary market, will it get a competitive advantage over the other manufacturer? We develop single- and two-period models, and show that under the stated assumptions, remanufacturing is almost always more profitable than when there is no remanufacturing. Although remanufacturing may cannibalize new product sales, the combined profitability and market share of the (re)manufacturer on account of new and remanufactured product sales improve over new product sales only. For the competitor, we get mixed results. In some situations, its profitability improves; in some others, it worsens. We also conduct sensitivity analyses with respect to the substitution parameters, price-sensitivity of the secondary market, rate of return of used products (cores), relative market shares of the manufacturers, and relative sizes of the primary and secondary markets. We conclude the paper with managerial implications and directions for future research.

2 - Neighborhoods in re-entrant permutation flow shop scheduling problems

Richard Hinze, Dirk Sackmann

The re-entrant flow shop is characterized by an identical machine sequence for each job and an identical job sequence for each machine. A multiple processing of each job on at least one machine is necessary. The problem is relevant, for example, in semiconductor manufacturing, paint shops and LCD panel production. This article examines the effect of different neighborhoods on the solution quality and computation time in a variable neighborhood search (VNS) for the mentioned

problem. The different neighborhoods are created by applying swap and insertion moves inside a block and between different blocks of the job sequence in the current solution. The test criterion is the makespan of a schedule.

■ FC-09

Friday, 11:30-13:00 - HS 30

Noncooperative Games (c)

Stream: Game Theory
Chair: *Josef Hofbauer*

1 - Nash equilibria in a Downsian competition with costs

Mark Van Lokeren

We consider a one-dimensional model of spatial competition where firms are competing to sell a product to customers in a given market. The market is represented by the unit interval and customers are continuously distributed throughout the market according to a density function which is strictly positive. Each firm seeks to maximise its market share by choosing an optimal location in the market. Downsian competition between the firms is modelled as a non-cooperative game with the unit interval as the common strategy set. However, if a firm changes its location, it incurs a cost. We determine the existence and the value of the Nash equilibrium strategies of the firms. We discuss both the symmetric case (where the costs are the same for all firms) and the asymmetric case (where the costs vary among firms).

2 - Analyzing Complex Infinitely Repeated Games with Methods from Evolutionary Game Theory

Matthias Feldotto, Alexander Skopalik

In this talk we will present an approach to analyze complex infinitely repeated games with methods from evolutionary game theory. Therefore, we use techniques from both fields, repeated/stochastic games and evolutionary game theory, together with simulations. We present our current work in this area and we want to discuss further approaches for the future.

Especially for the analysis of global markets with thousands of participants and complex strategic behavior where the impact of a participant's strategy is not directly traceable we need new techniques to gain insights on the development and dependencies of the different market participants.

In our case, we consider a global market of composed services. Many providers offer simple services which are dynamically and flexibly combined to more complex and individual service compositions and offered to the service requesters. To support the market of services and to improve the quality of the services we introduce a reputation system. We are interested in the strategic behavior of the market participants and the impact of the reputation system on them. As we receive only a single reputation value for a service composition and cannot observe the decisions of the participants, providers as well as composers, the impact of the different strategies are not directly traceable and we need new methods to analyze them.

We work on new complexity and dependency statements in the intersection between the field of stochastic games on the one side and evolutionary game theory on the other side. In the talk we give an overview on current results and the on-going work in this topic. We present first results from simulations and give an outlook on planned empirical and theoretical research in this wide area.

■ FC-11

Friday, 11:30-13:00 - HS 32

Transportation Networks and Locations (c)

Stream: Logistics and Transportation
Chair: *Teresa Melo*

1 - Hub location problems with thresholds on flows

H.a. Eiselt, Armin Lüer-Villagra, Vladimir Marianov

For the firm, the main advantage of hubs is that customer flow between hubs can be accommodated more cheaply than between hubs and spokes. While this is entirely justified, solutions can occur, in which the flow on a hub-to-hub arc that does not justify a discount. In order to overcome this problem, we could remove the discounts from all connections, whose flow does not justify a discount, re-solve the problem, and iterate in this manner. Alternatively, we could complicate the problem somewhat and introduce two connections between each hub-to-hub pair: one without a discount, and one with it. The connection without the discount can be used, until its flow reaches a threshold, which justifies the discount. The connection with the discount is only available, if the flow on a connection equals at least the value of the threshold. Computational tests were performed on the CAB data set, which includes 25 U.S. cities. It is apparent that the iterative approach, while attractive, as it uses existing programs and simply shuttles between scenarios with slightly different parameters, does not perform well. The second approach with its addition choice variables performs reasonably well, even though computation times for 50% discounts and 5 hubs are up to ten hours.

2 - A new approach for a location routing problem with pick-up and delivery including the home delivery services for food products

Christian Franz, Rainer Leisten

Still, customers in western countries mostly continue to shop their daily life products by going to supermarkets and other stores. However, the online grocery sales market is growing quickly in many countries. For example the UK has a particularly vibrant market, with internet grocery sales comprising 4.5 percent of total grocery sales in 2010. In other countries with similar characteristics growth has been slower; 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. The reasons for this are diverse. Among others, price sensibility with respect to food products, a high density of supermarkets and a low confidence in food online services appear. 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 delivery cars of the delivery service company. The different stores and the costumers 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.

3 - Multi-period capacitated facility location under delayed demand satisfaction

Teresa Melo, Isabel Correia

We address the problem of re-designing a network of facilities over a multi-period planning horizon. This entails establishing new facilities at a finite set of potential sites and selecting their capacity levels from a set of available discrete sizes. In addition, capacity contraction is also a viable option through closing one or several existing facilities over the time horizon. We assume that customers are sensitive to delivery lead times. Accordingly, two customer segments are considered. The first segment comprises customers that require timely demand satisfaction while customers accepting delayed deliveries make up the second segment. Each customer belonging to the latter segment specifies a preferred and a maximum delivery time. Additional costs are incurred to each unit of demand that is not satisfied on time. We propose two alternative mixed-integer linear programming models to re-design the network so as to minimize the total cost. The latter includes fixed costs for facility siting and operation as well as fixed costs for capacity acquisition and contraction. In addition, variable processing and distribution costs along with penalty costs for delayed demand satisfaction are also considered. A distinctive feature of our models is that different time scales for strategic (i.e. location) and tactical (i.e. distribution) decisions are considered. We also extend the mathematical models to the case in which each customer in the second segment prefers to receive a single shipment even if it arrives with some delay. In other words, partial deliveries are not allowed. A computational study compares the solvability of the proposed models using a general-purpose

solver and investigates the impact of delivery lead time restrictions on the network structure and cost.

■ FC-12

Friday, 11:30-13:00 - HS 33

Relocation and Repositioning Problems in Maritime Transport (c)

Stream: Logistics and Transportation
Chair: *Daniel Mueller*

1 - A Biased Random-Key Genetic Algorithm for the Container Pre-Marshalling Problem

Kevin Tierney, André Hottung

Container terminals around the world perform pre-marshalling to reorder containers they are storing such that they can be efficiently sent onward during periods of peak activity. Due to the wealth of options for re-sorting containers, even small pre-marshalling problems are difficult for state-of-the-art techniques to solve. In this paper, we introduce a biased random-key genetic algorithm with several novel heuristics for solving the container pre-marshalling problem. Our approach builds off of previous approaches in the literature as well as introduces new heuristics for constructing pre-marshalling sequences. We test our approach on standard benchmarks, where it solves pre-marshalling problems to near optimality in just seconds. We further investigate why our approach works well and the types of instances suited to particular heuristics. Our results allow for the creation of decision support systems to assist container terminal operators to pre-marshall containers, which helps terminals increase their efficiency.

2 - Tabu Search Based Heuristic Approaches for the Dynamic Container Relocation Problem

Osman Karpuzoğlu, Mehmet Hakan Akyüz, Temel Öncan

The container relocation problem (CRP) is concerned with clearing out single yard-bay which contains a fixed number of containers each following a given pickup order so as to minimize the total number of relocations made during their retrieval process. In this work, we consider an extension of the CRP to the case where containers are both received and retrieved at a single yard-bay called Dynamic Container Relocation Problem (DCRP). The arrival and departure sequences of containers are assumed to be known in advance. Tabu search based heuristic approaches are proposed to solve the DCRP. Computational experiments are performed on an extensive set of randomly generated test instances. Our results show that the proposed algorithms are very efficient and yield better outcomes than previous heuristic methods.

3 - Data Visualization and Decision Support for the Fleet Repositioning Problem

Daniel Mueller, Kevin Tierney

Maritime transport is responsible for the transportation of about 9.6 billion tons of goods each year on almost 6000 vessels, which equals roughly 80% of the global trade volume and over 70% of the global trade value (UNCTAD Review of Maritime Transport 2014). In order to stay competitive and adjust to market trends, liner carriers move vessels between routes in their networks several times a year in a process called fleet repositioning. There are currently no decision support systems to allow repositioning coordinators to take advantage of recent algorithmic advances in creating repositioning plans. Furthermore, no study has addressed how to visualize repositioning plans and liner shipping services in an accessible manner. Displaying information such as cargo flows and interactions between vessels is a difficult task due to the interactions of container demands and long time scales. To this end, we propose a web-based decision support system designed specifically for the fleet repositioning problem that uses an extended version of the state-of-the-art simulated annealing solution approach. Our approach allows user interaction like evaluating different vessels or omitting specific ports in a repositioning. Using our system, repositioning coordinators can receive rapid feedback for different strategic settings and scenarios. Liner carriers can therefore save money through better fleet utilization and cargo throughput, as well as reduce their environmental impact thanks to less fuel usage.

■ FC-14

Friday, 11:30-13:00 - HS 42

Cliques and Independent sets (c)

Stream: Graphs and Networks
Chair: *Timo Gschwind*

1 - On Critical Independent Sets in Bipartite Graphs

Eugen Mandrescu, Vadim Levit

Let G be a simple graph, having V as a vertex set. A subset S of V is: (a) independent, if no two vertices of S are adjacent; (b) critical, if the difference between the size of S and the size of its neighborhood is maximum (Zhang, SIAM J. Discrete Math., 1990). This difference considered as a set function is supermodular (Levit, Mandrescu, SIAM J. Discrete Math., 2012). Each critical independent set is included in some maximum independent set (Butenko, Trukhanov, Oper. Res. Letters, 2007). While finding a maximum independent set is NP-hard, the maximum critical independent set problem is tractable (Larson, Bull. Inst. Comb. & Appl., 2007). Let core(G) denote the intersection of all maximum independent sets, corona(G) be the union of all maximum independent sets, ker(G) be the intersection of all critical independent sets, and diadem(G) be the union of all maximum critical independent sets. It is known that: every graph G has a unique minimal independent critical set, namely, ker(G), which is a subset of core(G) (Levit, Mandrescu, SIAM J. Discrete Math., 2012), while the equality of these two sets holds for bipartite graphs (Levit, Mandrescu, Ann. of Comb., 2013). Recall that G is a König-Egerváry graph if the size of a maximum matching equals the cardinality of a minimum vertex cover of G. König-Egerváry graphs are exactly the graphs where every maximum independent set is also critical (Larson, Europ. J. Comb., 2011; Levit, Mandrescu, Graphs & Comb., 2012). It is well known that every bipartite graph is a König-Egerváry graph. In this talk, we pay attention to the fact that diadem(G) and corona(G) coincide for König-Egerváry graphs. In addition, we present various relations between core(G), corona(G), ker(G), and diadem(G) with emphasis on bipartite graphs.

2 - Partitioning and Covering a Graph with Relaxed Cliques

Timo Gschwind, Fabio Furini, Stefan Irnich, Roberto Wolfler-Calvo

Relationships between objects can be modeled with graphs, where nodes represent the different objects and edges express the relationship. Social network analysis is an example where clusters, e.g., formed by members of a community, are studied using cliques and clique relaxations. A clique is a complete subgraph, i.e., all nodes are adjacent. Several clique relaxations have been defined either in terms of distance (s-clique), degree (s-plex, k-core), diameter (s-club), density (s-defective clique, -quasi-clique), or connectivity (k-block, s-bundle). The majority of the literature deals with identifying such subgraphs of maximum cardinality or weight. In this presentation, we consider the problem of covering or partitioning a graph with relaxed cliques. Unlike for cliques, covering and partitioning are properly different problems for several types of clique relaxations because subsets of these relaxed cliques are not necessarily relaxed cliques of the same type again. We present an exact solution framework to the relaxed clique partitioning and covering problems based on column generation. Herein, the subproblems consist of finding relaxed cliques of maximum weight. Different strategies for their solution are considered. The most interesting part of the branch-and-price is the branching scheme. We derive branching rules that together guarantee integer solutions. Such branching rules are different and non-trivial for both cases (partitioning and covering) because a good rule should at the same time be compatible with the subproblem's structure and solution approach, create a small number of branches, and generally improve the bound in all resulting problems.

■ FC-17

Friday, 11:30-13:00 - HS 47

Games and Applications (c)

Stream: Game Theory
Chair: *Gustavo Bergantinos*

1 - A Stackelberg Equilibria in Leader-Follower Hub Location and Pricing Problem
Dimitrije Čvokić, Yury Kochetov, Alexander Plyasunov

Hub Location Problem is one of the thriving research areas in Location Theory with many practical applications. Here, we propose a novel model, called the Leader-Follower Hub Location and Pricing Problem, where two competitors, called a Leader and a Follower, are sequentially creating their hub and spoke networks and setting prices. Both competitors are trying to maximize their profits, rather than market share. Profit itself comes from the revenues based on the captured flows, subtracting fixed and variable costs. Customers choose which company and route to patronize by price. Logit model is used as a discrete choice model, which is essentially a rule that determines what fraction of flow is captured by each competitor. We showed that there is unique Stackelberg equilibrium in terms of pricing, for both types of the Follower, altruistic and selfish. Also, we examined a case where players are playing Bertrand alike pricing game for already given hub and spoke networks. We showed that there is unique finite pricing Nash equilibrium for this case as well. Besides existence and uniqueness, transcendental equations for finding both pricing equilibria are provided.

2 - Loss allocation in energy transmission networks
Gustavo Bergantinos, Julio González-Díaz, Ángel Manuel González Rueda, María P. Fernández de Córdoba

In this paper we study a cost allocation problem that is inherent to most energy networks: the allocation of losses. In particular, we study how to allocate gas losses between haulers in gas transmission networks. We discuss four allocation rules, two of them have already been in place in real networks and the rest are defined for the first time in this paper. We then present a comparative analysis of the different rules by studying their behavior with respect to a set of principles set forth by the European Union. This analysis also includes axiomatic characterizations of two of the rules. Finally, as an illustration, we apply them to the Spanish gas transmission network.

■ FC-18

Friday, 11:30-13:00 - HS 48

(c) Renewables

Stream: Energy and Environment
Chair: *Irena Milstein*

1 - An Algorithm for Renewable Energy Trading with a Fleet of Plug-In Electric Vehicles
Nicole Taheri, Robert Entriken, Yinyu Ye

Renewable energy, such as wind or solar power, is a variable source of electricity that does not necessarily increase and decrease with the demand. Energy storage devices can be used to offset the differences between the demand and renewable energy supply, by storing excess energy to be used when it is needed. The batteries of plug-in electric vehicles (PEVs) can be used as such energy storage devices, because PEVs can have flexible charging schedules and are capable of transmitting electricity back to the grid. Trading renewable energy with PEVs has the potential to benefit both the PEV owners and the electric utility; PEVs can offset the variability of renewable energy, and renewable energy can be less expensive for PEV owners than nonrenewable energy from the grid. In this paper, we use predictions of the electricity supply and driving patterns to create a dynamic algorithm for trading renewable energy with a fleet of PEVs.

Our dynamic algorithm uses information from a static linear programming (LP) model of renewable energy trading with a PEV fleet from a similar previous day. Using the LP solution, energy trading schedules are assigned to PEVs as they connect to the grid, with a rolling horizon, and using the most up-to-date predictions of the future energy supply and price. We give empirical results based on real data, including electricity and gasoline pricing, electricity supply and demand, vehicle characteristics, and driving behaviors

2 - Optimized market-oriented operation of renewable energy sources combined with energy storage
Michael Hassler, Jochen Gönsch

Over the last decade, the penetration of decentralized renewable energy sources (RES) has increased considerably and RES occupy a significant part of the total capacity of the energy distribution system. In the long run, RES are supposed to replace the majority of large conventional power stations. However, due to the volatile nature of energy production from RES, this raises the issue of power grid stability. The use of energy storage systems provides one means to cushion the impact that the increasingly volatile production has on the power grid. In order to show how energy storage could help facilitate the integration of RES, we regard a combination of RES with energy storage. We present a model for deriving optimal commitments on the intraday market and present numerical results obtained by an efficient approximation algorithm based on approximate dynamic programming showing the practical applicability of our approach.

3 - Optimal Generation Mix in the Present of Renewable Technologies
Irena Milstein, Asher Tishler

This paper develops a two-stage analytical model of endogenous investments and operations in a competitive (oligopoly) electricity market with two generation technologies. We consider two types of generating technologies: (1) "regular', fossil-using, technologies such as combined cycle gas turbines (CCGT); and (2) weather-dependent renewable technologies in the form of photovoltaic cells (PV). In the first stage of the model, when only the probability distribution functions of future daily electricity demands and weather conditions are known, profit-seeking producers maximize their expected profits by determining the capacity to be constructed from each technology. In the second stage, once daily demands and weather conditions become known, each producer selects the daily production levels of each technology subject to its capacity availability (the available capacity of the renewable technology depends on capacity construction in the first stage of the model, on time of day and on the weather). This paper demonstrates that integrating renewable energy such as photovoltaic technology into the electricity market may indeed lead to higher electricity prices. We show that higher price volatility, not higher production costs, is the culprit, as it bestows market power on fossil-using electricity producers, and more so the lower the costs of PV capacity (due to PV technology improvements, say) and the greater the number of PV-using producers in the market. We also show that the choice of market structure (the number of generation technologies that can be constructed by each producer) may significantly affect price volatility, the average electricity price, industry profits, and welfare.

■ FC-19

Friday, 11:30-13:00 - HS 50

(c) Fossil Fuels

Stream: Energy and Environment
Chair: *Raimund Kovacevic*

1 - MODAL GasLab - Optimization Approaches of Real World Problems in the Gas Transport Industry
Felix Simon, Inken Gamrath, Kai Hennig, Thorsten Koch, Janina Körper, Ralf Lenz

The MODAL GasLab (Mathematical Optimization and Data Analysis Laboratories) brings state-of-the-art mathematical optimization methods into practice in the gas transport industry. For example, critical flow and pressure situations in gas networks might interrupt the gas supply of system-relevant gas power stations. To prevent this, a new contract has been designed to guarantee their gas supply by predefined entries. Here, we present a model formulation as well as first heuristic solution approaches based on game theory.

2 - Practical Application of a Worldwide Gas Market Model at Stadtwerke München
Maik Günther

Natural gas is worldwide an important energy source. Its relatively low specific CO2 emissions make it interesting. On the other hand, security of supply is currently discussed in Europe.

Stadtwerke München (SWM) is invested at all stages of the value chain of natural gas. It ranges from exploration and production over distribution to downstream. SWM also owns gas fired power plants and heating plants. Thus, it is important for SWM to have a good knowledge of the gas market. Especially about gas prices of the next 30 years. But also the knowledge of the price sensitivity at modified parameters like gas demand, indigenous production or geopolitical situations is

an important competitive advantage. Against this background, SWM implemented the worldwide gas market model WEGA in 2013.

WEGA is a mathematical model with linear programming. The model optimizes daily gas flows to cover the demand of each country/trading point as cheap as possible. Results are gas prices and gas flows. Europe is modeled in a particularly detailed way. WEGA takes into account pipelines, interconnections, storages, LNG liquefaction and regasification terminals, gas fields and contracts. Due to the large number of data, business intelligence software is integrated in the graphical user interface of WEGA.

The following questions can be answered with WEGA: What would be the impact of a European moratorium on fracking? Indigenous production goes down in Europe. Where does the gas come from in the future? What is the effect on gas prices if average temperatures become colder or warmer in the future? This contribution gives answers to these questions. Furthermore, the gas market model WEGA and its application at SWM will be explained.

■ FC-22

Friday, 11:30-13:00 - ÜR Germanistik 3

Pricing Management (c)

Stream: Accounting and Revenue Management
Chair: *Claudius Steinhardt*

1 - When Does Better Quality Imply More Advertising?

Régis Chenavaz

Is a product of better quality more heavily advertised? To this classical question, the two main views on advertising, namely the informative view (Stigler 1961, Telser 1964) and the persuasive view (Marshall 1890, Chamberlin 1933), provide elements supporting contradictory answers.

First, based on the informative view, Nelson (1974) replies yes: When the consumer can verify the objective characteristics of a product, misleading advertising is unlikely. In this situation, a firm may advertise a product of better quality more, constituting a positive advertising-quality relationship.

Second, based on the persuasive view, Comanor and Wilson (1979) respond no: If advertising can increase preferences for products of the same objective characteristics, advertising may achieve subjective product differentiation. In this case, a firm may compensate lower quality with higher advertising, creating a negative advertising-quality relationship. Empirical studies summarized by Bagwell (2007) present conflicting evidence in support of these opposing viewpoints.

Yet, how can both views be correct, and how can the controversy be resolved? Presumably by recognizing that the problem is not unidimensional but multidimensional. Under some conditions, one view may apply, whereas under other conditions, the alternative view may be appropriate. Following this contingency approach, Tellis and Fornell (1988) propose a conjecture yielding both positive and negative relationships. But theoretical studies fail to prove any common explanation of such opposing relationships (see the surveys of Bagwell (2007), and Huang (2012)). This paper fills the gap by formally deriving both positive and negative advertising-quality relationships from demand- and supply-sides effects.

2 - What can we learn from Price volatility of Revenue-Managed Goods? Evidence from the airline industry

Benny Mantin, Eran Rubin

The airline industry provides one of the most profound examples for the embracement of Information Technology (IT) to maximize revenue. With Revenue Management (RM) systems, airline carriers implement practices such as real-time capacity allocations and demand forecast updates, which are manifested through frequent updates to prices of airline tickets. While the underlying mechanism of RM systems is practically the same across carriers and routes, different routes exhibit profoundly different volatility levels. This give rise to interesting research questions as the frequently changing prices may alter the dynamics between sellers (airlines) and their consumers (passengers). With increased volatility, will consumers purchase at higher prices, or, resonating strategic behavior, purchase at lower prices? Further, does the increased volatility of posted prices correspond to a similar increase in the dispersion of the transacted fares? Importantly, what are the implications of price volatility on sales levels and revenue? Using data collected on US domestic aviation markets, we find that markets with higher levels of price volatility are associated with higher levels of transacted fares and lower aircrafts' fill rates. We further quantify sources of price volatility.

3 - Optimal product line pricing in the presence of budget-constrained consumers

Claudius Steinhardt, Stefan Mayer

Product line pricing is defined as a seller's task to select prices for his products such that his total revenue is maximised. We consider a setting where consumers' purchase decisions are based on the "max surplus'-rule and subject to individual budget constraints. In addition, products are limited in capacity, such that the consumers' choice set may vary over time, resulting in dynamic substitution effects. We propose mathematical models for the seller's decision problem that incorporate each consumer's knapsack problem both exactly and heuristically and present methods for their solution.

■ FC-23

Friday, 11:30-13:00 - ÜR Germanistik 4

Applications of Integer Programming (c)

Stream: Integer Programming
Chair: *Armin Fügenschuh*

1 - Solving A Challenging Timetabling Problem at Engineering Faculty of Necmettin Erbakan University

Kemal Alaykiran

Necmettin Erbakan University is a new but fast developed one. Although the university and its engineering faculty was established in 2010; by the year 2015 the faculty has fourteen departments with about 1500 graduate and undergraduate students. Until the main campus construction is finalized, the faculty has to use a temporary building which cannot satisfy all educational needs of the departments as a result of this rapid development and increase in the number of students. Due to these realities, the timetabling of classes at the faculty is a crucial problem to be analyzed and solved for maximizing the utilization of classes and laboratories and also dealing with problems which are expected to be experienced in the future. In this study, a mathematical model is developed in order to solve this challenging timetabling problem considering different constraints, cases and scenarios.

2 - Mathematical Optimization of a Magnetic Ruler Layout With Rotated Pole Boundaries

Marzena Fügenschuh, Armin Fügenschuh, Marina Ludszuweit, Aleksandar Mojsic, Joanna Sokół

Rulers for measuring systems are either based on incremental or absolute measuring methods. Incremental methods need to initialize a measurement cycle at a reference point. From there, the position is computed by counting increments of a periodic graduation. Absolute methods do not need reference points, since the position can be read directly from the ruler. In the state of the art approach the absolute position on the ruler is encoded using two incremental tracks with different graduation. To use only one track for position encoding in absolute measuring a pattern of trapezoidal magnetic areas is considered instead of the common rectangular ones. We present a mixed-integer programming model for an optimal placement of the trapezoidal magnetic areas to obtain the longest possible ruler under constraints conditioned by production techniques, physical limits as well as mathematical approximation of the magnetic field.

■ FC-24

Friday, 11:30-13:00 - ÜR Germanistik 5

Failure Analysis (c)

Stream: Analytics
Chair: *Felix Richter*

1 - Data Quality Confidence Bounds
Ralf Gitzel, Simone Turrin, Sylvia Maczey

Product manufacturers and equipment maintenance organizations alike desire to understand the typical failure behavior of their machinery. One common approach is to perform a RAMS (Reliability, Availability, Maintainability, and Safety) analysis. A core element of RAMS is the statistical analysis of equipment failure data. While there are many established methods based on the parameter estimation of probability distribution functions, little thought is given today on the impact of data quality issues on those estimations. This is especially problematic as such issues are quite commonplace in industrial data. In this paper, we propose the calculation of "confidence bounds' based on data quality. Our approach is based on a set of rules which model the impact of data quality issues such as missing data, inaccurate data, obviously wrong entries, bias and implausible data on the data set. Based on different scenarios, it becomes possible to establish upper and lower bounds for the parameters of the failure distribution function. We explain the process of confidence bounds calculation as well as their use with real data.

2 - Automatic Root Cause Analysis by Integrating Heterogeneous Data Sources
Felix Richter, Tetiana Zinchenko, Dirk Christian Mattfeld

Failures that occur while using a product, e.g. complex products like vehicles, result in customer dissatisfaction and increasing aftersales costs for the company. Thus, detecting the root cause of failures in a fast and accurate way is necessary to deal with these problems. Current failure detection has two main challenges: 1) efficient use of data sources and 2) overcome the time-delay between failure occurrence and diagnosis.

We propose a concept for automated root cause analysis, which integrates heterogeneous data sources and works in near real-time. Such sources are a) vehicle data, transmitted online to a backend and b) customer service data comprising all historical diagnosed failures of a vehicle fleet and the performed repair actions. This approach focusses on the equalization of the different granularity of the data sources, by abstracting them in a unified representation.

The vehicle behavior is recorded by raw signal aggregations. These aggregations can be seen as data models depicting a respective time period. At discrete moments in time these models are transmitted to a backend in order to build a history of the vehicle behavior. Each workshop session is used to link the historic vehicle behavior to the customer service data. The result is a root cause database. An automatic root cause analysis can be carried out by comparing the data collected for an ego-vehicle with the root cause database. On the other hand, the customer service data can be analyzed by an occurred failure code and filtered by comparing the vehicle behavior. The most valid root cause is detected by weighting the patterns described above.

This approach is validated with a real-world data set obtained from vehicle endurance test data and customer service data.

■ FC-31

Friday, 11:30-13:00 - Marietta Blau Saal

Health Care Process Management

Stream: Health and Disaster Aid
Chair: *Margit Sommersguter-Reichmann*

1 - Physician shift scheduling with flexible shift extensions
Andreas Fügener, Jens Brunner

Scheduling physicians is a relevant topic in hospitals. Heterogeneous demand and 24/7 service make the problem challenging. Approaches in the literature use flexible shift patterns to match demand with scarce resources. In these approaches, demand is usually assumed to be deterministic. However, surgery durations and emergency arrivals both contain uncertainty leading to massive staff overtime. We introduce stochastic demand for physicians using a scenario-based approach. To incorporate this in scheduling, we allow flexible shift extensions, where physicians are possibly assigned to some overtime. Thus, we ensure matching supply with demand and at the same time we increase predictability of working hours. We propose a mixed-integer model and a column generation heuristic to solve our problem, and provide experimental data from a German university hospital.

2 - Time-dependent ambulance deployment and shift scheduling of crews
Lara Wiesche

For patients requesting emergency medical services in a life-threatening emergency, the probability of survival is strongly related to the rapidness of assistance. A particular difficulty for planners is to allocate limited resources whilst managing increasing demand for services. Empirical studies have shown temporal and spatial variations of emergency demand as well as variations of intraday travel times during the course of a day and therefore a varying number of required ambulances. The provision of sufficient staff resources for these emergency vehicles has a great impact on the initial treatment of patient and thus on the quality of emergency services. Data-driven empirically required ambulance location planning as well as the allocation of staff for these vehicles are simultaneously optimized in the proposed approach to support emergency medical service decision makers. According to the identified problem structure, an integer linear programming model is established. An exemplary case study based on real-world data demonstrates how this approach can be used within the emergency medical service planning process. By performing What-if analyses and shift schedule variations, the decision makers will get improved insights and thus determine an ideal ambulance staff schedule.

3 - Quick-Response Methods for Handling Patient Demand Fluctuations in a Hospital
Jan Schoenfelder, Kurt Bretthauer, Daniel Wright

Hospitals continue to face the challenge of providing high quality patient care in an environment of rising healthcare costs and limited resources. In response, a great deal of attention has been given to advance planning decisions in healthcare operations management, such as nurse staffing, bed mix, surgical scheduling, and patient flow. However, less attention has been given to quick-response methods that have the ability to improve hospital performance by anticipating or responding to often times significant fluctuation in patient demand. Therefore, in this paper, we present a model that combines hospitals' initial nurse staffing level decisions with two classes of quick-response decisions: (i) adjustments to the number of cross-trained nurses working the current shift in each unit and (ii) transfers of patients between units and off-unit admissions. Based on data collected from three hospitals, we derive insights into the level of benefit that can be gained from employing the aforementioned quick-response methods. Furthermore, we find that our proposed foresight policy provided an average 5.9% cost improvement from better informed decision making, which we determine to be highly dependent on bed and nurse capacity utilization.

4 - Stochastic Next-Day OR Scheduling Heuristics
Enis Kayis, Taghi Khaniyev, Refik Gullu

We consider the daily scheduling problem of a single operating room (OR) with uncertain surgery durations. Our aim is to find the optimum sequence and scheduled starting times of the surgeries to minimize weighted sum of expected patient waiting times and OR idle times. Though several sample average approximation models are offered in the literature, our analytical approach provides insights for the practitioners that do not have access to these advanced models or detailed EHR they require. We first consider finding the optimum durations to assign to each surgery for a given sequence. We provide analytical results on the form of objective function such as the joint convexity of objective function, recursive formulation of objective function, insights about the characteristics of optimum decision variables and an explicit expression of objective function for exponentially distributed surgery durations. Finding optimal solutions is limited to some small-size problems. To solve larger problems, we resort to heuristics. For the scheduling problem, we consider three heuristics each motivated by practice and analytical solutions of approximate models: an expected value based heuristic, a heuristic based on decomposition of surgeries (Myopic heuristic) and a heuristic based on the assumption that the OR is never kept idle (Veteran's heuristic). We compare these heuristics with each other and the optimal solution. For the sequencing part of the problem, based on analytical observations of smaller scale problems, we propose ordering surgeries with respect to stochastically increasing durations, which is frequently used in practice. Our results reveal that the sequencing rule proposed coupled with the Veteran's heuristic yield the best outcome under some assumptions.

Friday, 14:00-15:30

■ FD-01

Friday, 14:00-15:30 - AUDIMAX

Plenary (Scott) and Closing

Stream: Plenaries
Chair: *Georg Pflug*

1 - Bayes and Big Data: The Consensus Monte Carlo Algorithm
Steven Scott

A useful definition of "big data" is data that is too big to comfortably process on a single machine, either because of processor, memory, or disk bottlenecks. Graphics processing units can alleviate the processor bottleneck, but memory or disk bottlenecks can only be eliminated by splitting data across multiple machines. Communication between large numbers of machines is expensive (regardless of the amount of data being communicated), so there is a need for algorithms that perform distributed approximate Bayesian analyses with minimal communication. Consensus Monte Carlo operates by running a separate Monte Carlo algorithm on each machine, and then averaging individual Monte Carlo draws across machines. Depending on the model, the resulting draws can be nearly indistinguishable from the draws that would have been obtained by running a single machine algorithm for a very long time. Examples of consensus Monte Carlo are shown for simple models where single-machine solutions are available, for large single-layer hierarchical models, and for Bayesian additive regression trees (BART).

Accounting and Revenue Management

Robert Klein
University of Augsburg
robert.klein@wiwi.uni-augsburg.de

Peter Letmathe
RWTH Aachen University
Peter.Letmathe@rwth-aachen.de

Michaela Schaffhauser-Linzatti
University of Vienna
michaela.linzatti@univie.ac.at
Track(s): 22 24

Analytics

Marcus Hudec
University of Vienna
marcus.hudec@univie.ac.at

Jochen Gönsch
University of Augsburg
jochen.goensch@wiwi.uni-augsburg.de

Thomas Setzer
KIT
thsetzer@gmail.com
Track(s): 24

Bioinformatics

Matthias Dehmer
UMIT
matthias.dehmer@umit.at

Andreas Futschik
Johannes Kepler Univ.
andreas.futschik@jku.at

Rolf Krause
Faculty of Informatics, Università della Svizzera Italiana, Lugano
rolf.krause@usi.ch
Track(s): 25

Computational and Experimental Economics

René Fahr
University of Paderborn
rene.fahr@wiwi.upb.de

Ulrike Leopold-Wildburger
Karl-Franzens-University
ulrike.leopold@uni-graz.at
Track(s): 8

Continuous Optimization

Radu Ioan Bot
University of Vienna
radu.bot@univie.ac.at
Track(s): 26

Control Theory

Gustav Feichtinger
Vienna University of Technology
gustav@eos.tuwien.ac.at

Dmitry Ivanov
Berlin School of Economics and Law
divanov@hwr-berlin.de

Vladimir Veliov
Vienna University of Technology
veliov@tuwien.ac.at

Thomas Weber
EPFL
thomas.weber@epfl.ch
Track(s): 28

Discrete Optimization

Eranda Cela
TU Graz
cela@opt.math.tu-graz.ac.at

Bettina Klinz
TU Graz
klinz@opt.math.tu-graz.ac.at

Marco Lübbecke
RWTH Aachen University
marco.luebbecke@rwth-aachen.de
Track(s): 4 7

Energy and Environment

Roland Scholz
Fraunhofer
roland.scholz@isc.fraunhofer.de

Raimund Kovacevic
Vienna University of Technology
raimund.kovacevic@tuwien.ac.at

Christoph Weber
Universität Essen
Christoph_Weber@uni-duisburg-essen.de

Franz Wirl
Uiversity of Vienna
franz.wirl@univie.ac.at
Track(s): 16 18 19

Financial Modelling

Michael H. Breitner
Institut für Wirtschaftsinformatik
breitner@iwi.uni-hannover.de

Erich Walter Farkas
University of Zurich
walter.farkas@bf.uzh.ch

David Wozabal
Technische Universität München
david.wozabal@tum.de
Track(s): 27

Forecasting

Alessio Benavoli
USI Università della Svizzera italiana
alessio.benavoli@supsi.ch

Sven F. Crone
Lancaster University Management School
s.crone@lancaster.ac.uk

Wolfgang Scherrer
Technische Universitaet Wien
Wolfgang.Scherrer@tuwien.ac.at
Track(s): 8

Game Theory

Tobias Harks
Maastricht University
t.harks@maastrichtuniversity.nl

Josef Hofbauer
University of Vienna
josef.hofbauer@univie.ac.at

Karl Schmedders
University of Zurich
karl.schmedders@business.uzh.ch
Track(s): 9 17

Graphs and Networks

Sven Krumke
University of Kaiserslautern
krumke@mathematik.uni-kl.de

Ivana Ljubic
ESSEC Business School of Paris
ivana.ljubic@univie.ac.at

Roberto Montemanni
SUPSI - University of Applied Sciences of Southern Switzerland
roberto@idsia.ch

Jörg Rambau
LS Wirtschaftsmathematik
joerg.rambau@uni-bayreuth.de
Track(s): 14 16

Health and Disaster Aid

Marion Rauner
University of Vienna
marion.rauner@univie.ac.at

Gerald Reiner
Universitaet Klagenfurt
gerald.reiner@aau.at

Katja Schimmelpfeng
Universität Hohenheim
katja.schimmelpfeng@uni-hohenheim.de

Margit Sommersguter-Reichmann
University of Graz
margit.sommersguter@uni-graz.at
Track(s): 31

Integer Programming

Michael Juenger
Universitaet zu Koeln
mjuenger@informatik.uni-koeln.de

Franz Rendl
Alpen Adria Universität Klagenfurt
franz.rendl@aau.at
Track(s): 23

Logistics and Transportation

Karl Doerner
University of Vienna
karl.doerner@univie.ac.at

Luca Maria Gambardella
IDSIA
luca@idsia.ch

Herbert Kopfer
University of Bremen
kopfer@uni-bremen.de
Track(s): 7 10 11 12

Metaheuristics

Andreas Fink
Helmut-Schmidt-University
andreas.fink@hsu-hamburg.de

Luca Maria Gambardella
IDSIA
luca@idsia.ch

Günther Raidl
Vienna University of Technology
raidl@ads.tuwien.ac.at
Track(s): 6

Multiple Criteria Decision Making

Martin Josef Geiger
Helmut-Schmidt-University
m.j.geiger@hsu-hh.de

Marco Laumanns
IBM Research
mlm@zurich.ibm.com

Rudolf Vetschera
University of Vienna
rudolf.vetschera@univie.ac.at
Track(s): 29

Neural Networks and Fuzzy Systems

Dan Ciresan
USI-SUPSI
dan@idsia.ch

Martin Kuehrer
fin4cast
martin.kuehrer@iovis.at
Track(s): 25

OR for Security

Andrea Seidl
Vienna University of Technology
andrea.seidl@tuwien.ac.at

Stefan Wolfgang Pickl
UBw München COMTESSA
stefan.pickl@unibw.de

Stefan Wrzaczek
University of Vienna
stefan.wrzaczek@tuwien.ac.at
Track(s): 28

OR Software, Modelling Languages

Ronald Hochreiter
WU Vienna University of Economics and Business
ronald.hochreiter@wu.ac.at

Jacint Szabo
IBM Research Lab, Zurich
jsz@zurich.ibm.com
Track(s): 31

Plenaries

Track(s): 1

Policy Modelling and Public Sector OR

Doris Behrens
Cardiff University
BehrensD1@cardiff.ac.uk

Gernot Tragler
Vienna University of Technology
gernot.tragler@tuwien.ac.at
Track(s): 16

Prize awards

Track(s): 3 17

Production and Operations Management

Richard Hartl
University of Vienna
richard.hartl@univie.ac.at

Rainer Kolisch
Technische Universitaet Muenchen
rainer.kolisch@wi.tum.de

Norbert Trautmann
University of Bern
norbert.trautmann@pqm.unibe.ch
Track(s): 5 6

Scheduling and Project Management

Walter Gutjahr
University of Vienna
walter.gutjahr@univie.ac.at

Erwin Pesch
University of Siegen
erwin.pesch@uni-siegen.de

Ulrich Pferschy
University of Graz
pferschy@uni-graz.at

Norbert Trautmann
University of Bern
norbert.trautmann@pqm.unibe.ch
Track(s): 2 3

Semi plenaries I

Track(s): 4

Semi plenaries II

Track(s): 13

Semi plenaries III

Track(s): 19

Semi plenaries IV

Track(s): 17

Simulation and Decision Support

Rizzoli Andrea
IDSIA
andrea@idsia.ch

Fatima Dargam
SimTech Simulation Technology
F.Dargam@SimTechnology.com

Heinrich Kuhn
Catholic University of Eichstaett-Ingolstadt
heinrich.kuhn@ku-eichstaett.de

Track(s): 15

Stochastic Models

Dmitry Efrosinin
Johannes Kepler University Linz
dmitry.efrosinin@jku.at

Karl Frauendorfer
University of St. Gallen
karl.frauendorfer@unisg.ch

Achim Koberstein
European University Viadrina
koberstein@europa-uni.de

Michael Manitz
University of Duisburg/Essen
michael.manitz@uni-due.de

Michael Schürle
University of St. Gallen
michael.schuerle@unisg.ch

Track(s): 30

Stochastic Optimization

Daniel Kuhn
EPFL
daniel.kuhn@epfl.ch

Georg Pflug
University of Vienna
georg.pflug@univie.ac.at

Rüdiger Schultz
University of Duisburg-Essen
ruediger.schultz@uni-due.de

Track(s): 20 21 30

Supply Chain Management

Herbert Meyr
University of Hohenheim
H.Meyr@uni-hohenheim.de

Marc Reimann
Universität Graz
marc.reimann@uni-graz.at

Stephan Wagner
Swiss Federal Institute of Technology Zurich (ETH Zurich)
stwagner@ethz.ch

Track(s): 13 17

Session Chair Index

nico.strasdat@tu-dresden.de
Department of Mathematics, Technische Universität Dresden, Dresden, Germany

Stroehle, Philipp FA-24
philipp.stroehle@kit.edu
Business Engineering and Management, Karlsruhe Institute of Technology, Karlsruhe, Baden-Wuerttemberg, Germany

Suhl, Leena WB-05, TD-17
suhl@upb.de
Dept. Business Information Systems, University of Paderborn, Paderborn, Germany

Takahashi, Kei FA-15
k-taka@ism.ac.jp
The Institute of Statisitical Mathematics, Tachikawa-shi, Tokyo, Japan

Tempelmeier, Horst WE-06
tempelmeier@wiso.uni-koeln.de
Supply Chain Management and Production, University of Cologne, Cologne, Germany

Thäter, Markus TC-28
markus.thaeter@uni-bayreuth.de
Department of Mathematics, University of Bayreuth, Bayreuth, Bayern, Germany

Topaloglu, Seyda FA-03
seyda.topaloglu@deu.edu.tr
Industrial Engineering, Dokuz Eylul University, Izmir, Turkey

Tragler, Gernot WD-17
gernot.tragler@tuwien.ac.at
OR and Control Systems, Vienna University of Technology, Vienna, Austria

Trautmann, Norbert WC-02, FB-04
norbert.trautmann@pqm.unibe.ch
Department of Business Administration, University of Bern, Bern, BE, Switzerland

Tricoire, Fabien WB-29
fabien.tricoire@univie.ac.at
Department of Business Administration, University of Vienna, Vienna, Austria

Trockel, Jan TB-13
jan.trockel@fernuni-hagen.de
FernUniversität in Hagen, Fakultät für Wirtschaftswissenschaft, Lehrstuhl für Betriebswirtschaftslehre, insb. Produktions- und Investitionstheorie, Hagen, Germany

Ulmer, Marlin Wolf WC-07, WE-07
m.ulmer@tu-braunschweig.de
Decision Support Group, Technische Universität Braunschweig, Braunschweig, Germany

van den Heever, Susara WE-31
svdheever@fr.ibm.com
IBM, France

van Stee, Rob TC-09
rob.vanstee@leicester.ac.uk
Leicester, Leicester, United Kingdom

Vespucci, Maria Teresa WB-19
maria-teresa.vespucci@unibg.it
Department of Management, Economics and Quantitative Methods, University of Bergamo, Bergamo, Italy

Vetschera, Rudolf TB-29
rudolf.vetschera@univie.ac.at
Dept. of Business Administration, University of Vienna, Vienna, Austria

Vogel, Jannik TA-20
j.vogel@bwl.uni-mannheim.de
Chair of Production Management, Universität Mannheim, Mannheim, Baden-Württemberg, Germany

Vogel, Silvia TA-29
Silvia.Vogel@tu-ilmenau.de
Mathematics and Natural Sciences, Ilmenau University of Technology, Ilmenau, Thuringia, Germany

Wachowicz, Tomasz TC-29
tomasz.wachowicz@ue.katowice.pl
Operations Research, University of Economics in Katowice, Poland

Wagner, Stephan WC-17
stwagner@ethz.ch
Department of Management, Technology, and Economics, Swiss Federal Institute of Technology Zurich (ETH Zurich), Zurich, Switzerland

Wakolbinger, Tina TA-13
tina.wakolbinger@wu.ac.at
WU (Vienna University of Economics and Business), Vienna, Austria

Wäscher, Gerhard WA-01
gerhard.waescher@ovgu.de
Fakultät für Wirtschaftswissenschaft, Otto-von-Guericke Universität Magdeburg, Magdeburg, Germany

Weber, Gerhard-Wilhelm WC-16
gweber@metu.edu.tr
Institute of Applied Mathematics, Middle East Technical University, Ankara, Turkey

Weber, Marc-Andre WE-17
marc-andre.weber@uni-due.de
Faculty of Engineering, University of Duisburg-Essen, Duisburg, Germany

Weissensteiner, Alex TC-27
alex.weissensteiner@unibz.it
Free University of Bolzano, Italy

Werners, Brigitte WC-31
or@rub.de
Faculty of Management and Economics, Ruhr University Bochum, Bochum, Germany

Wiesemann, Wolfram WB-21
ww@imperial.ac.uk
Imperial College London, United Kingdom

Winkler, Michael TB-23
winkler@gurobi.com
Gurobi GmbH, Germany

Wirl, Franz WC-18
franz.wirl@univie.ac.at
Uiversity of Vienna, Vienna, Austria

Witt, Jonas TA-23
jonas.witt@rwth-aachen.de
Operations Research, RWTH Aachen University, Germany

Author Index

dimitheo@aegean.gr
Mathematics, University of the Aegean, Karlovassi, Samos, Greece

Doan, Xuan Vinh WB-09
Xuan.Doan@wbs.ac.uk
Warwick Business School, The University of Warwick, Coventry, West Midlands, United Kingdom

Dobos, Imre FA-06
imre.dobos@uni-corvinus.hu
Logistics and Supply Chain Management, Corvinus University of Budapest, Budapest, Hungary

Doerner, Karl TA-02, WB-10
karl.doerner@univie.ac.at
Department of Business Studies, University of Vienna, Vienna, Vienna, Austria

Dollevoet, Twan TB-11
dollevoet@ese.eur.nl
Econometric Institute, Erasmus University of Rotterdam, Rotterdam, Netherlands

Doppstadt, Christian WE-11
doppstadt@wiwi.uni-frankfurt.de
Logistics and Supply Chain Management, Goethe University Frankfurt, Frankfurt, Germany

Dörmann, Nora WE-30
doermann@wiwi.uni-frankfurt.de
Economics, Goethe University, Frankfurt am Main, Germany

Dovbischuk, Irina WE-12
dovbischuk@uni-bremen.de
Economics, University of Bremen, Bremen, Bremen, Germany

Döyen, Alper TB-31
alperdoyen@selcuk.edu.tr
Industrial Engineering, Selçuk University, Konya, Turkey

Dragan, Irinel TA-17
dragan@uta.edu
Mathematics, University of Texas, Arlington, Texas, United States

Drees, Maximilian WE-09
maxdrees@mail.upb.de
Heinz-Nixdorf Institute, Germany

Drexl, Michael FA-04
michael_drexl@t-online.de
., Germany

Dris, Djamal WB-29
drisdjamal@yahoo.fr
Commercial Sciences, Bejaia University, Bejaia, Algeria

Drozdowski, Maciej WC-08
Maciej.Drozdowski@cs.put.poznan.pl
Institute of Computing Science, Poznan University of Technology, Poznan, Poland

Dudaklı, Nurhan WE-10
nurhan.dudakli@deu.edu.tr
Industrial Engineering, The Graduate School of Natural and Applied Sciences, İzmir, Turkey

Duer, Mirjam TB-26, WC-26
duer@uni-trier.de
Mathematics, University of Trier, Trier, Germany

Duetting, Paul WC-09
p.d.duetting@lse.ac.uk
Mathematics, London School of Economics, London, United Kingdom

Dupacova, Jitka WB-20
dupacova@karlin.mff.cuni.cz
Probability and Math. Statistics, Charles Univ, Faculty of Math. and Physics, Prague, Czech Republic

Dusberger, Frederico FC-05
dusberger@ac.tuwien.ac.at
Institute of Computer Graphics and Algorithms, Vienna Unviersity of Technology, Vienna, Austria

Dyskin, Alexander TA-22
Alexander.Dyskin@rolandberger.com
RWTH Aachen, Germany

Eder, Andreas FA-19
Eder@iwi.ac.at
Institute for Industrial Research, Vienna, Vienna, Austria

Ederer, Thorsten TA-03, WC-29
ederer@mathematik.tu-darmstadt.de
Chair of Fluid Systems, Technische Universität Darmstadt, Darmstadt, Hessen, Germany

Edman, Christine TB-26
edman@uni-trier.de
University of Trier, Germany

Efrosinin, Dmitry WE-05
dmitry.efrosinin@jku.at
Johannes Kepler University Linz, Austria

Ehmke, Jan Fabian WB-11, TC-15
janfabian.ehmke@fu-berlin.de
Business Information Systems, Freie Universität Berlin, Berlin, Germany

Ehtamo, Harri TB-15
harri.ehtamo@aalto.fi
Department of Mathematics and Systems Analysis, Aalto University, School of Science, Espoo, Finland

Eichfelder, Gabriele TA-29
Gabriele.Eichfelder@tu-ilmenau.de
Institute of Mathematics, Technische Universität Ilmenau, Ilmenau, Germany

Eichhorn, Andreas TA-27
Andreas.Eichhorn@gmx.net
Portfolio Management, VERBUND Trading GmbH, Vienna, Austria

Eilers, Dennis WB-08
eilers@iwi.uni-hannover.de
Leibniz Universität Hannover, Hannover, Germany

Eiselt, H.a. FC-11
haeiselt@unb.ca
University of New Brunswick, Fredericton, NB, Canada

Ekenberg, Love TA-29
ekenberg@iiasa.ac.at
International Institute of Applied Systems Analysis (IIASA), Laxenburg, -, Austria

Ekici, Ali WB-31
ali.ekici@ozyegin.edu.tr

arno.karrer@aau.at
Controlling and Strategic Management, University of Klagenfurt, Klagenfurt, Austria

Kasperski, Adam TB-04
adam.kasperski@pwr.wroc.pl
Wroclaw University of Technology, Department of Operations Research, Wroclaw, Poland

Kassa, Rabah WB-29
rabah_kassa2002@yahoo.fr
mathematique, Universite Bejaia algerie, bejaia, Algeria

Kato, Satoshi TA-12
s.kato-bir.8386@toki.waseda.jp
Industrial and Management Systems Engineering, Waseda University, Tokyo, Japan

Katoh, Naoki WE-04
naoki.katoh@gmail.com
Department of Informatics, Kwansei gakuin University, Sanda, Hyogo, Japan

Kauermann, Goeran TA-22
goeran.kauermann@lmu.de
LMU Munich, Germany

Kaya, Murat TB-17
mkaya@sabanciuniv.edu
Faculty of Engineering and Natural Sciences, Sabanci University, Istanbul, Turkey

Kayis, Enis FC-31
enis.kayis@ozyegin.edu.tr
Industrial Engineering Department, Ozyegin University, Istanbul, International, Turkey

Kazempour, S. Jalal WB-16
seykaz@elektro.dtu.dk
Department of Electrical Engineering, Technical University of Denmark, Denmark

Kellenbrink, Carolin WB-02
carolin.kellenbrink@prod.uni-hannover.de
Institut für Produktionswirtschaft, Universität Hannover, Hannover, Germany

Kerstens, Kristiaan WC-06
k.kerstens@ieseg.fr
IESEG School of Management, Cnrs-lem (umr 9221), Lille, France

Kesselheim, Thomas WC-09
thomas.kesselheim@mpi-inf.mpg.de
Max-Planck-Institut fuer Informatik, Germany

Khaniyev, Taghi FC-31
tagikhaniyev@gmail.com
Department of Management Sciences, University of Waterloo, Canada

Khmelev, Alexey TB-10
avhmel@gmail.com
Novosibirsk State University, Novosibirsk, Russian Federation

Kiesel, Rudiger TC-19
Ruediger.Kiesel@uni-due.de
Chair for Energy Trading and Finance, University Duisburg Essen, Duisburg, Germany

Kimms, Alf FA-17, TC-17, WE-28, TB-31
alf.kimms@uni-due.de
Mercator School of Management, University of Duisburg-Essen, Duisburg, Germany

Kirchner, Sarah WC-02, TA-14
kirchner@or.rwth-aachen.de
Operations Research, RWTH Aachen, Aachen, Germany

Kirschstein, Thomas WE-11
thomas.kirschstein@wiwi.uni-halle.de
Chair of Production & Logistics, Martin-Luther-University Halle-Wittenberg, Halle/Saale, – Bitte auswählen (nur für USA / Kan. / Aus.), Germany

Kirste, Michael WB-30
kirste@wiso.uni-koeln.de
Supply Chain Management and Production, University of Cologne, Germany

Kleiman, Elena TC-09
elena.kleiman@gmail.com
The Technion, Haifa, Israel

Klein, Judith FA-30
Judith.Klein@uni-due.de
Department of Mathematics, University Duisburg-Essen, Essen, North Rhine-Westphalia, Germany

Klein, Robert TC-24
robert.klein@wiwi.uni-augsburg.de
Chair of Analytics & Optimization, University of Augsburg, Augsburg, Germany

Kliewer, Natalia TB-10, WB-11
natalia.kliewer@fu-berlin.de
Information Systems, Freie Universitaet Berlin, Berlin, Germany

Klimm, Max TB-09
klimm@math.tu-berlin.de
Institut für Mathematik, Technische Universität Berlin, Berlin, Germany

Klocker, Benedikt TC-10
benedikt.klocker@yahoo.com
Institute of Computer Graphics and Algorithms, Vienna University of Technology, Vienna, Austria

Kloos, Konstantin TC-13
konstantin.kloos@uni-wuerzburg.de
Chair of Logistics and Quantitative Methods, Julius-Maximilans-Universität Würzburg, 97070, Germany

Knust, Sigrid TC-03, TB-07
sigrid@informatik.uni-osnabrueck.de
Institute of Computer Science, University of Osnabrück, Osnabrück, Germany

Koch, André TB-07
andre.koch@tuhh.de
Institute for Operations Research and Information Systems, Hamburg University of Technology (TUHH), Hamburg, Hamburg, Germany

Koch, Sebastian FA-22
sebastian.koch@wiwi.uni-augsburg.de
Department of Analytics & Optimization, University of Augsburg, Augsburg, Germany

Koch, Thorsten FC-19
koch@zib.de
Optimization, Zuze Institue Berlin, Berlin, Germany

Lehrstuhl für Produktion und Supply Chain Management, Technische Universität München, München, Bayern, Germany

Popovic, Drazen WE-10
d.popovic@sf.bg.ac.rs
Logistics Department, University of Belgrade, Faculty of Transport and Traffic Engineering, Belgrade, Serbia

Poss, Michael WB-21
michael.poss@lirmm.fr
Cnrs, Lirmm, France

Pöttgen, Philipp TA-03, WC-29
philipp.poettgen@fst.tu-darmstadt.de
Chair of Fluid Systems, Technische Universität Darmstadt, Germany

Poulsen, Rolf TC-27
rolf@math.ku.dk
Applied Math. and Statistics, University of Copenhagen, Copenhagen, Denmark

Prandtstetter, Matthias TC-10
matthias.prandtstetter@ait.ac.at
Mobility Department, Dynamic Transportation Systems, AIT Austrian Institute of Technology GmbH, Vienna, Austria

Prause, Gunnar WC-12
gunnar.prause@ttu.ee
Department of Business Administration, Tallinn University of Technology, Tallinn, Estonia

Preis, Henning TC-11
henning.preis@tu-dresden.de
Faculty of Traffic and Transportation Sciences, Institute for Logistics and Aviation, Technical University of Dresden, Germany

Prekopa, Andras TD-04, WE-20
prekopa@rutcor.rutgers.edu
RUTCOR, Rutgers University, Piscataway, New Jersey, United States

Puchert, Christian TA-06
puchert@or.rwth-aachen.de
Operations Research, RWTH Aachen University, Aachen, Germany

Puchinger, Jakob WE-07
Jakob.Puchinger@ait.ac.at
AIT, Vienna, Austria

Puchinger, Jakob WC-11
jpuchinger@gmail.com
Mobility, AIT Austrian Institute of Technology GmbH, Wien, Österreich, Austria

Puigjaner, Luis TB-13
luis.puigjaner@upc.edu
Chemical Engineering, Universitat Politècnica de Catalunya, Barcelona, Spain

Pulaj, Jonad TB-14
pulaj@zib.de
Optimization, Zuse Institute Berlin, Berlin, Germany

Purshouse, Robin WE-29
r.purshouse@sheffield.ac.uk
University of Sheffield, United Kingdom

Qu, Zheng WB-26
zheng.qu@ed.ac.uk
University of Edinburgh, China

Raghavan, T. E. S. TA-17
ter@uic.edu
University of Illinois at Chicago, Chicago, United States

Raidl, Günther FC-05, TC-10
raidl@ads.tuwien.ac.at
Institute for Computer Graphics and Algorithms, Vienna University of Technology, Vienna, Austria

Raith, Andrea WC-14
a.raith@auckland.ac.nz
Engineering Science, The University of Auckland, Auckland, New Zealand

Rambau, Jörg WC-04
joerg.rambau@uni-bayreuth.de
Fakultät für Mathematik, Physik und Informatik, LS Wirtschaftsmathematik, Bayreuth, Bayern, Germany

Ramik, Jaroslav TA-25
ramik@opf.slu.cz
Dept. of Math. Methods in Economics, Silesian University, School of Business, Karvina, Czech Republic

Rangaraj, Narayan TB-12, TA-23
narayan.rangaraj@iitb.ac.in
Industrial Engineering and Operations Research, Indian Institute of Technology, Mumbai, India

Rasol Roveicy, Mohamad Reza WB-06
rasoli@live.co.uk
Department of Computer Hardware Engineering , Central Tehran Branch, Islamic Azad University , Tehran , Iran, Tehran, Tehran, Iran, Islamic Republic Of

Rauner, Marion TB-22, TB-31
marion.rauner@univie.ac.at
Dept. Innovation and Technology Management, University of Vienna, Vienna, Austria

Rebennack, Steffen FA-30
srebenna@mines.edu
Economics and Business, Colorado School of Mines, Golden, CO, United States

Recht, Peter WE-16
peter.recht@tu-dortmund.de
OR und Wirtschaftsinformatik, TU Dortmund, Dortmund, Germany

Reiner, Gerald TB-31
gerald.reiner@aau.at
Universitaet Klagenfurt, Klagenfurt, Austria

Reisser, Matthias TB-24
matthias_reisser@hotmail.com
Karlsruhe Institute of Technology, Germany

Rest, Klaus-Dieter FA-12
klausdieter.rest@boku.ac.at
Institute of Production and Logistics, University of Natural Resources and Life Sciences, Vienna, Vienna, Austria

Rethmann, Jochen TB-04, TC-07
jochen.rethmann@hsnr.de
Faculty of Electrical Engineering and Computer Science, Niederrhein University of Applied Sciences, Krefeld, Germany

tim@cs.stanford.edu
Stanford University, Stanford, CA, United States

Roy, Sankar Kumar WC-07
sankroy2006@gmail.com
Applied Mathematics with Oceanology and Computer Programming, Vidyasagar University, Midnapore, West Bengal, India

Rub Nawaz, Raja TB-29
raja.nawaz@pafkiet.edu.pk
Marketing, PAF Karachi Institute of Economics & Technology, Pakistan

Rubin, Eran FC-22
eranr@hit.ac.il
Department of Technology Management, Holon Institute of Technology, Holon, Israel

Rubio-Herrero, Javier TC-05
javier.rubioherrero@rutgers.edu
Management Science and Information Systems, Rutgers University, Piscataway, NJ, United States

Rückel, Bastian TA-18
bastian.rueckel@fau.de
Economics, University of Erlangen-Nuremberg, Nuremberg, Bavaria, Germany

Ruckmann, Jan-J WC-26
Jan-Joachim.Ruckmann@ii.uib.no
Department of Informatics, University of Bergen, Bergen, Norway

Rudi, Andreas TB-19
andreas.rudi@kit.edu
Institute for Industrial Production (IIP), Karlsruhe Institute of Technology (KIT), Karlsruhe, BW, Germany

Rudolph, Günter WE-29
Guenter.Rudolph@tu-dortmund.de
Computer Science, TU Dortmund University, Dortmund, Germany

Ruhnau, Oliver WE-08
oliver.ruhnau@rwth-aachen.de
RWTH Aachen University, Aachen, Germany

Ruiz, Ruben FB-04
rruiz@eio.upv.es
Departamento de Estadistica e Investigación Operativa Aplicadas y Calidad, Universitat Politècnica de València, Valencia, Spain

Rujeerapaiboon, Napat WB-21
napat.rujeerapaiboon@epfl.ch
Risk Analytics and Optimization Chair, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

Rusyaeva, Olga WB-20
olga.rusyaeva@the-klu.org
Kuehne Logistics University, Germany

Ruthmair, Mario WE-14
mario.ruthmair@ait.ac.at
Mobility Department, Austrian Institute of Technology, Vienna, Vienna, Austria

Ruzika, Stefan WC-14, TC-28
ruzika@uni-koblenz.de
Department of Mathematics, University of Koblenz, Koblenz, Germany

Saavedra-Rosas, Jose TA-05
J.Saavedra-Rosas@curtin.edu.au
Department of Mineral and Energy Economics, Curtin University, Perth, Western Australia, Australia

Saboiev, Rizo TB-20
rizosaboiev@gmail.com
Mathematics and Informatics, TU BErgakademie Freiberg, Germany

Sackmann, Dirk FC-06, WB-12
dirk.sackmann@hs-merseburg.de
Merseburg University of Applied Sciences, Merseburg, Germany

Sadeh, Arik TC-08
sadeh@hit.ac.il
Management of Technology, Holon Institute of Technology, Holon, Israel

Saeb, Ali TC-06
ali.saeb@gmail.com
Department of Computer Science, Univ. of Khayyam university, Mashhad, Khorasan, Iran, Islamic Republic Of

Sahin, Guvenc FA-14, TB-17
guvencs@sabanciuniv.edu
Faculty of Engineering and Natural Sciences, Industrial Engineering, Sabanci University, Istanbul, Turkey

Sahling, Florian TA-03, WC-31
sahling@prod.uni-hannover.de
Department of Production Management, Leibniz Universität Hannover, Hannover, Germany

Sahoo, Amit Kumar FA-15
amitk2014@email.iimcal.ac.in
Managerial Information System, IIM Calcutta, Bhubaneswar, Odisha, India

Sakou, Kai FA-15
920scruri@gmail.com
Faculty of Science and Engineering, Waseda University, Shinjuku-ku, Tokyo, Japan

Saliba, Sleman TA-05, WC-16
sleman.saliba@de.abb.com
Power Generation, Abb Ag, Mannheim, Germany

Salo, Ahti WC-19
ahti.salo@aalto.fi
Systems Analysis Laboratory, Aalto University School of Science, Aalto, Finland

Santos, Paulo Sergio Marques WE-26
psergio@ufpi.edu.br
Mathematics, Federal University of Piaui, Teresina, Piauí, Brazil

Santos-Arteaga, Francisco Javier WC-15
FSantosArteaga@unibz.it
Economics, Free University of Bolzano, Bolzano, Bolzano, Italy

Sasse, Lisa TB-31
lisa.sasse@univie.ac.at
University of Vienna, Wien, Austria

Savku, Emel WC-16
esavku@gmail.com
Institute of Applied Mathematics, Financial Mathematics,

Hans_Georg.Zimmermann@siemens.com
Corporate Technology CT RTC BAM, Siemens AG, München, Germany

juergen.zimmermann@tu-clausthal.de
Operations Research, TU Clausthal, Clausthal-Zellerfeld, Germany

u.zimmermann@tu-bs.de
Institute of Mathematical Optimization, TU Braunschweig, Braunschweig, Germany

tetiana.zinchenko@volkswagen.de
Volkswagen AG, Wolfsburg, Germany

nikola.zogovic@pupin.rs
Institute Mihajlo Pupin, University of Belgrade, Belgrade, Serbia

gregor.zoettl@fau.de
VWL, FAU Erlangen-Nuernberg, Nuernberg, Germany

benteng.zou@uni.lu
University of Luxembourg, Luxembourg

martin.zsifkovits@unibw.de
Universität der Bundeswehr München, Neubiberg, Germany

SESSION INDEX

Wednesday, 8:30-10:00

Wednesday, 10:30-12:30

Wednesday, 14:00-15:30

Wednesday, 16:00-16:45

Wednesday, 17:00-18:30

Thursday, 8:30-10:00

Thursday, 10:30-12:30

Thursday, 14:00-15:30

Thursday, 16:00-16:45

Friday, 8:30-10:00

Friday, 10:30-11:15

Friday, 11:30-13:00

Friday, 14:00-15:30